Cape Peninsula University of Technology

EXTENDED ATTRIBUTION RETRAINING IN THE REDUCTION OF MATHEMATICS ANXIETY EXPERIENCED BY FIRST-TIME DESIGN STUDENTS AT A SOUTH AFRICAN UNIVERSITY OF TECHNOLOGY.

by

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DECLARATION

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Signed **Date**

ABSTRACT

Mathematical literacy among the citizenry of a nation is considered indispensable to the economic welfare and global competitiveness of that nation (World Economic Forum, 2013a). In a world governed by technology, quantitative literacy is crucial (Colwell cited by Steen, 2002:8) and becomes a "most important professional and life skill" (Maloney et al., 2012:380). It is also seen as an individual's ability to "manage situations or solve problems in practice" (Frith & Prince, 2006). Lastly, Jansen (2012) believes that sound mathematical literacy leads to an understanding of cause and effect and would guide citizens in their choices of actions.

Yet, the belief that mathematical competence (or even just quantitative literacy) is the privilege of a small group of intellectually predisposed individuals is widely accepted in society, further entrenched by erroneous stereotyping (Eccles et al., 1990; Bonnot & Croizet, 2007; Mangels et al., 2011), as well as inadequate teaching methods in the Mathematics classroom/lecture theatre (Artigue, 1999; NSTF, 2009, 2010; Department of Basic Education, 2014). The consequences of this skewed view of Mathematics, and the emotional stress caused by regular failure at the subject, have resulted in wide-spread maths anxiety and maths avoidance among scholars and students.

This dissertation examines an intervention programme which was designed to alter students' negative perceptions of their intellectual ability to grasp mathematical concepts. Instead of attributing their past failures to internal, stable and uncontrollable causes, such as cognitive inability (Weiner, 1985), they were asked to consider factors which were internal or external, but certainly unstable and controllable, and which played a major role in their disappointing history in Mathematics. The interventions were aimed at bringing about a paradigm shift from a fixed mindset (entity theory) to a growth mindset (increment theory) as researched by Dweck since the 1980s.

The intervention programme was implemented in the Foundation Course of a South African university of technology. It involved four interventions spread over roughly four months of the first semester and was comprised of the following lecture units and activities: a session of free-writing (Elbow, 1973), lectures on the plasticity of the brain (Hebb, 1949; Diamond 2001, Zull, 2002), the three memory systems (Eysenck & Calvo, 1992), a very basic version of Kolb's experiential and reflective learning cycle (Atherton, 2009), and the notion of threshold concepts (Meyer & Land, 2003).

The ultimate objectives of this intervention programme were (a) to retrain the students in their causal attribution, (b) to teach them efficient cognitive strategies so that (c) they would renew their efforts at mastering basic mathematics (and gain academic control in this domain), and (d) to equip them with meta-cognitive skills which would stand them in good stead in their further studies.

This study has taken on a mixed-methods research design: the quantitative data are represented by the assessment results of the diagnostic numeracy test in February of each year, as well as the assessment outcomes of the summative and formal June examination of both years. The qualitative data are garnered from verbal and written feedback both during the two years in question as well as recently during interviews and via cell phone communication. These data are further augmented by private and informal small-group discussions and my personal observations of the classes and individuals during those two years.

The new and extended attribution retraining programme is evaluated by comparing the qualitative with the qualitative data to identify convergence and discrepancies and is then compared to the conventional attribution retraining treatments.

Lastly, recommendations are put forward, as well as suggestions for further development and refinement of the interventions.

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DEDICATION

To all my students (past, present and future) who work tirelessly and cheerfully to uplift their lives through improving their education - often against seemingly insurmountable odds. You make every day and effort worthwhile and meaningful for me; you are the cherries on top of my teaching career.

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GLOSSARY

Terms	Explanation
'conventional'/'standard' attribution retraining (AR) treatment	the AR treatment as it has been administered internationally, mainly in the U.S.A., Canada and Australia, over the past two decades (I have added the 'conventional' to distinguish it from my set of interventions.)
extended attribution retraining intervention programme	the set of attribution retraining interventions devised and implemented in the Foundation Course during Years A and B, and on which this study is based
Foundation Course	an introductory year for selected students who have registered with a particular design programme in the faculty; the course introduces the students to the design programmes offered in the faculty and teaches them the elementary and core principles of design; the students are identified as having potential but lacking certain necessary skills; they are also invited to reflect on whether they chose the right design programme at the outset, or whether they wish to reregister for a different programme
Mathematics versus mathematics	Throughout this dissertation terms referring to subjects (at school or at university) are written with capital letters, whereas the general concept of a body of knowledge in the domain of mathematics (or any other subject) is written with lower case letters.
"maths"	The term "maths" refers to the general and rather vague concept of every mental activity which involves numbers. It encompasses Mathematics as well as mathematics. It is a term used by scholars, students and society alike.
Mathematical Literacy (Maths Literacy)	a subject offered at high school to scholars who feel that 'pure' Mathematics is beyond their grasp or who believe that, for their future careers, they do not need to have 'pure' Mathematics; Maths Literacy aims at rendering young adults quantitatively literate.
'pure' Mathematics	the colloquial term used to distinguish Mathematics from Maths Literacy; 'pure' Mathematics is offered at a higher level to prepare scholars for tertiary studies involving the STEM subjects and careers.
Numeracy	In the Professional Business Practice subject, the component which deals with basic numerical computations is called Numeracy. It entails work and concepts which are taught at school from 7^{th} to 9^{th} Grades.
Professional Business Practice	a subject in the Foundation Course which offers life skills, research and study skills, writing and language skills, numeracy skills and elementary computer skills
pupil	For the sake of differentiating between 'learners' at the various levels of educational institutions, I have chosen to call children at primary school level 'pupils'.
Quantitative literacy	Much has been written about the exact meaning of quantitative literacy. When I use it in this study, I refer to general numerical (or quantitative) abilities and skills which are indispensable in all aspects of life.

scholar	a young person attending high school
student	an adult studying at a university

ABBREVIATIONS

Abbreviations	
AR	attribution retraining
CPUT	Cape Peninsula University of Technology
DUT	Durban University of Technology
NEEDU	National Education, Evaluation and Development Unit
NSC	National Senior Certificate
NSTF	National Science and Technology Forum
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
QL	quantitative literacy
SoTL	Scholarship of Teaching and Learning
STEM	Science, Technology, Engineering and Mathematics
TIMMS	Trends in International Mathematics and Science Study
TUT	Tshwane University of Technology
UCT	University of Cape Town
WMC	working memory capacity

CHAPTER ONE

INTRODUCTION

1.1. Introduction

This dissertation presents a multiple-case study of an adapted and extended attribution retraining programme implemented during two consecutive years (Year A and Year B) in the Foundation Course of the Design Department at a South African university of technology. The programme was aimed at cognitive behavioural readjustment in students with a history of underperformance in Mathematics/ Mathematical Literacy. Their past experiences had resulted in affective and cognitive barriers to the subject and any activities related to it.

Conventional once-off and very brief attribution retraining treatments have rekindled in students motivation, the willingness to employ new study strategies and to persevere in their academic efforts. In contrast, the extended attribution retraining intervention programme under discussion here was implemented over a period of four months, slotted into the syllabus of the Professional Business Practice subject. It aimed at training the students in cognitive and meta-cognitive awareness and skills in order to correct their maladaptive causal attribution.

Having taught Mathematics at high school and Numeracy to Foundation Course students at a university of technology, I became acutely aware of the deep-rooted misgivings and fears which scholars and students harbour concerning everything numerical. The regular reports on South African (and international) scholars' and students' underperformance in maths-related subjects have created in me the wish to contribute to the search for solutions to this phenomenon.

In order to persuade the students to believe that they are cognitively capable of accessing the epistemology of *basic* mathematics/numeracy, I devised an attribution retraining programme consisting of four interventions: (a) introducing the students to the plasticity of their brain, (b) teaching them about their three memory systems and emphasising the information processing mechanism of the working memory, (c) explaining to them a very basic version of Kolb's experiential and reflecting learning cycle, and (d) introducing them to the notion of threshold concepts.

The subsequent improvement in their assessment outcomes (achieved within the space of four months) led me to believe that there was value in the programme I had

implemented. With the purpose of analysing which interventions had been meaningful for the students (and why?), as well as which interventions had not been as accessible to them (and why?), I embarked on the study which I am presenting here.

My analysis of both qualitative and quantitative data collected over the two years brought to light that the first two interventions, which highlighted the brain's learning processes and vast potential, had the most profound effect on the students and initiated a gradual paradigm shift in many of them from a fixed mindset (entity theory) to a growth mindset (increment theory), as conceptualised by Dweck and Leggett (1988). The last two interventions, which aimed at explicitly teaching the students meta-cognitive skills, were less accessible to them. Broadly speaking, the impasse seems to have been threefold: (a) Many students found the concepts too abstract to understand and internalise. (b) Students did not seem to think it important to acquire the meta-cognitive disposition to analyse the underlying causes of positive or negative experiences and outcomes (Weiner's causal attribution). (c) Students found it difficult to identify and isolate barriers to their academic progress - both personal/situational and academic barriers - which rendered the teaching of Kolb's reflective learning cycle less effective. On the other hand, students with a sound self-concept and a sense of academic control, employed these meta-cognitive skills across all their subjects and into the following years of study, and they reported success.

The general improvement in the assessment outcomes of the Numeracy module persuades me to conclude that the intervention programme should be kept and refined. The two interventions regarding meta-cognitive skills should not be excluded, but need close attention and reformulating to make them more accessible to the students. At the same time the unit in the subject which deals with thinking skills and critical thinking should be expanded and highlighted. This may help students identify obstacles which could be overcome by employing the meta-cognitive skills taught.

1.2. Purpose of this study

The **aim of this study** is to understand the cognitive and affective implications of using attribution retraining to support underperforming students in Numeracy. The research involved a reflection on the data generated in the course of teaching Numeracy to students in the Foundation Course of the Design Department at a South African university of technology.

The **practical problem** from which this research arises is the poor performance in Mathematics by students entering a university in South Africa (Scott et al., 2007; National Science and Technology Forum's workshops on STEM Education, 2009 and 2010; Frith & Prince, 2009; Frith, 2010, 2011; Jansen, 2012).

The **intellectual puzzle** that forms the academic problem for this study lies in the extent to which affective factors, such as anxiety and low academic self-confidence, form barriers to successful cognitive development in the field of Mathematics or, in our case, Numeracy.

The **personal rationale** for this study is that throughout my teaching career I have found that the principal barrier to sound competency in Mathematics has not been the cognitive lack of ability of my students, but rather their fear of "maths" and the resultant low sense of self-efficacy which creates an aversion to the subject. Consequently, students avoid applying themselves in the subject and fail.

The **academic rationale** is that understanding the dynamics between the affective and the cognitive domains in teaching Numeracy (or Mathematics) may lead to the development of attribution retraining models that aim to improve the teaching of the subject to underachieving students.

1.2.1. Mathematics education: global background and local context

The importance of assisting students - in our case in a design faculty! - to become mathematically competent must be seen against the global background of economic competitiveness and the local context of a university of technology.

1.2.2. International underachievement of students in Mathematics

The global poor performance of scholars in Mathematics is well documented. UNESCO's (2012:9) report, titled "Challenges in basic mathematics education", states that "both national and international evaluations show that, on completion of basic education, many pupils' mathematics knowledge and competencies fall short of the expected level." The report bases its conclusion on research results obtained by both the Trends in International Mathematics and Science Study (TIMMS) and the Programme for International Student Assessment (PISA).

The PISA 2012 evaluation results proved to be of serious concern to the Organisation for Economic Co-operation and Development (OECD), as well as educationists, politicians and economists. Hurst (2013) reports that "Australia's biggest decline in

the OECD's programme for international student assessment was in the Mathematics section''. The European Union did not fare much better. The 2012 OECD report shows that the European Union was not on par with the OECD's expectations (European Commission: Press Release, 2013). The United Kingdom's Ofsted (Office for Standards in Education) report of early 2012 stated that ''almost 40 000 bright children are failed by poor Maths lessons at school" and "that the scale of underachievement at school was a 'cause of national concern' " (Paton, 2012). The American education system does not perform well either, according to a headline on the *Educators4Excellence* website: 'American Schools vs. the World: Expensive, Unequal, Bad at Math' (Ryan, 2013).

Although many reservations have been expressed regarding the PISA testing methods, there is, nevertheless, serious reason for concern regarding Mathematics. The UNESCO 2012 report (p. 9, 10) makes the following observations which it considers "barriers to quality mathematics education for all":

(a) Even scholars who perform well in Mathematics dislike the subject and do not see its value (identified by TIMMS and PISA research results).

(b) Although mathematics is "omnipresent in today's world" this is not obvious to the broad citizenry of countries, and is thus not considered important beyond the most basic numeracy competencies.

(c) There is a general misconception with respect to mathematics being an "almost exclusively solitary activity" reserved for an elite who have a 'mathematical mind'. [Ashcraft and Moore (2009:200) mention that "negative conversational remarks about math are relatively common in our culture".]

(d) Gender stereotyping portrays girls, in general, as not being as cognitively able to engage with mathematics as are boys, an issue raised by the International Organisation of Women and Mathematics Education, and studied by researchers, such as Steele (1997), Bonnot and Croizet (2006) and Mangels et al. (2011).

1.2.3. The South African situation

In South Africa, the situation is worse. South African students entering tertiary institutions are underprepared in academic literacies in general (Frith & Prince, 2009; Frith, 2010, 2011; Scott, Yeld & Hendry, 2007; Jansen, 2012) and in quantitative literacy in particular (TIMSS, 1999, 2003; Scott et al., 2007; NSTF, 2009, 2010; World Economic Forum rankings, 2013a).

At the 2009 National Science and Technology Forum's workshop on STEM education, Brombacher (NSTF, 2009:11), discussed the results of the National Senior

Certificate (NSC) for the period 2000 – 2005. He reported that more or less 500 000 scholars wrote the Senior Certificate examination every year. Of this cohort approximately 250 000 scholars sat for the Mathematics (Standard Grade) examination, and approximately 40% passed. That represented 21% of each year's entire matric cohort. In Mathematics (Higher Grade), only 5,2% of each year's Senior Certificate candidates passed their examination. Brombacher (NSTF, 2009:15) then discussed the Mathematics and Mathematical Literacy results of the 2009 National Benchmark Test Project: 25% of first-year students were proficient in Maths Literacy, and only 7% of first-year students were proficient enough in Mathematics to study this subject.

The TIMSS researches of 1999 and 2003 established that South Africa performed very poorly, coming last in 2003 out of 50 countries in Grade 8 Mathematics and Science performance. These 50 countries included five other African countries (Scott et al., 2007:34). According to the World Economic Forum rankings, South Africa came last out of 148 nations in its 'quality of Maths and Science education' (World Economic Forum, 2013a:347).

Finally, Scott (2009) draws together all the above findings and concerns, supported by additional and detailed statistics regarding attrition and success rates at South Africa's universities as recorded by Scott et al. (2007).

1.2.4. The importance of being mathematically literate

Mathematical literacy is seen to be a cornerstone of a country's economic performance, as well as of the personal well-being of its population.

Economic performance

Internationally, Mathematics and maths-related subjects are considered to be of pivotal importance in a country's endeavour to become or remain globally competitive. Global competitiveness depends on a country's productivity which, in turn, is driven by its standard of education and training, and the expertise and innovation in its Science-Technology-Engineering-Mathematics (STEM) orientated economic sectors (World Economic Forum, 2013a:4-9). The World Economic Forum's Human Capital Report (2013b:3) suggests that "a nation's human capital endowment – the skills and capacities that reside in people and that are put to productive use – can be a more important determinant of its long-term economic success than virtually any other resource". This is echoed by Maloney et al. (2012:380) and Schmitt (2003:260).

Socio-political benefits

The view, that a nation's economic health and its citizens' ability to thrive in "today's information age" are dependent on "quantitative reasoning capabilities", was expressed by prominent academics and economists at a forum on quantitative literacy held by the National Research Council of the United States of America (Steen, 2002:8). During the forum discussion, Carnevale, Vice President for Public Leadership of the Educational Testing Service, stated that "quantitative literacy is about the democratisation of mathematics". Carnevale called for the "QL movement to focus on egalitarian rather than economic goals."

An identical call is made in South Africa (Frith et al., 2010). In a paper discussing a quantitative literacy course for university students in the Humanities and Law, they state that their concern is for social justice and that they hold "a firm belief that our students should be functional, yet critical, citizens." Frith (2012:3) quotes a definition for quantitative literacy which she and Prince (2006:30) adopted in their Numeracy Centre at the University of Cape Town (UCT):

> "Quantitative literacy is the ability to manage situations or solve problems in practice, and involves responding to quantitative (mathematical and statistical) information that may be presented verbally, visually, in tabular or symbolic form. It requires the activation of enabling knowledge and behaviours and can be observed when it is expressed in the form of a communication, in written, oral or visual mode."

Jansen (2012) concurs with Frith's concerns regarding the development of 'functional, yet critical' citizenship (based on a broad foundation of quantitative literacy) when he places the "chaos in the land, from Marikana to De Doorns," squarely at the feet of a sadly inadequate quantitative literacy among the workforce of South Africa. He maintains that anger and violent behaviour are signs of the absence of logical reasoning, of the ability to foresee accurately enough the consequences of one's destructive actions. Kolata's (1997, in Orrill, 2003:vii) definition of quantitative literacy - "Quantitative literacy, in my view, means knowing how to reason and how to think" - agrees with Jansen's stance. Finally, Johnston (2007:54, in Frith et al. 2010:2) describes being mathematically literate as "a critical awareness that builds bridges between mathematics and the real world".

Personal benefit

The World Economic Forum's Human Capital Report (2013b:3) notes that recently "health has come to be seen as a fundamental component of human capital", and one

aspect of human health, from the point of view of a nation's productivity, is the *cognitive function* of its citizens. The Freudenthal Institute perceives sound mathematical competence as "one of the key human competences through which people can express themselves as human beings and can understand the world around them" (UNESCO, 2012:56).

1.2.5. The barriers to mathematics among design students

However, building these bridges of which Johnston speaks, is not easy for two reasons. In the minds of the public, in general, there is a sharp disconnect between "mathematics and the real world". Here I wish to highlight two of the reasons given by the UNESCO report as they feature prominently in the design context.

Firstly, mathematical competencies are in danger of being relegated to a backseat (UNESCO, 2012:9). Mathematical calculations can be left to sophisticated computer programmes or sub-contracted to professionals – who then use such computer programmes themselves! Moreover, students in design programmes, such as fashion, surface and graphic design, are convinced that numeracy plays no role in their work.

Secondly, UNESCO (2012:10) touches on the deeply embedded 'common sense' in society that being numerically literate is granted to an exclusive group of individuals gifted with a 'mathematical brain'. This perception is prevalent among design students who, in general, have not been selected for their excellent performance in Mathematics/Maths Literacy at school level. Unfortunately, many such students, who feel that they do not belong to the exclusive group gifted with a mathematical intelligence, turn their back on numeracy altogether and consciously or subconsciously resign themselves to the 'fact' that they are – and *will always be*! – failures at "maths".

If one considers the importance of quantitative literacy in all spheres of life - personal, professional, public, political – then no effort should be spared to dislodge the affective and cognitive obstacles that prevent students from accepting that they *can* gain epistemological access to numeracy. In order to attempt such dislodgement, one needs to:

(a) unearth the very roots of these obstacles,

(b) understand the nature of the obstacles and how they block students' willingness to engage with and experience success in Mathematics/Numeracy,

(c) appreciate the effect which negative affective factors have on even otherwise academically self-confident individuals' ability to grasp mathematical concepts and solve mathematical problems, and

(d) then devise interventions which address this apparent intellectual and emotional paralysis by persuading students to make a paradigm shift from *intellectual deficiency* to *intellectual abundance*.

1.2.6. Local context: Numeracy in the Foundation Course of a Faculty of Design

Institutionally, the university at which the present study has been done, has taken note of the poor performance of students in Mathematics and Physics and has put in place a number of interventions, such as the support given by a teaching and development grant.

In the Foundation Course of the Design Department in the Faculty of Informatics and Design, the problem regarding mathematical proficiency is equally serious.

For the past five years, I taught the students in this Foundation Course. Although our students have registered with either Product Design, Fashion Design, Surface Design, Graphic or Jewellery Design, their projects in the Foundation Course introduce them to all the above-mentioned design fields. At the same time the students are taught basic design principles.

Furthermore, they have two theory subjects: Communication Studies (or History of Design) and Professional Business Practice (my subject) the components of which are life skills, basic study and research skills, communication skills, numeracy skills and elementary computer skills.

Ever since I was asked to create a Professional Business Practice subject in 2010, I administered a diagnostic numeracy test at the beginning of each year to gauge the students' basic mathematical competencies and establish the weak areas in which they would need support. Competencies tested were: metric conversions, questions relating to the circumference and area of a circle (in this case a large pizza), the volume of regular prisms (the volume of yellowwood used to manufacture a table) and the area of rectangles (how many metres of wallpaper are needed for a wall with a large window), as well as some basic costing.

Without fail the results of this test have been profoundly disappointing every year. Below is a tabulated summary of the averages obtained for each question in the test in Year A.

Table 1.1.: Average marks (per question) obtained in the diagnostic numeracy test (February of Year A - 53 students)

Competencies tested in each question	**Q.1:** Geometrical shapes & terminology	**Q.2:** Area & circumference of circle (the pizza)	**Q.3:** Volume of rectangular prisms + metric conversions (the yellow-wood table)	**Q.4:** Areas of rectangles, scale drawing (the wallpaper); costing	**TOTAL (mark out of 30)**
Ave. mark in %	**79%**	**32,0%**	**30,6%**	**21,2%**	**40,5%**

The above table of results indicates that the students were familiar with geometric shapes and their several components (Question 1). However, all elementary calculations involving areas and volumes of very basic shapes and forms were very poorly executed.

Students admitted that they did not know or understand the most basic numeracy concepts. Metric conversions were a serious challenge as students were unsure of how many millimetres there are in a centimetre, how many centimetres in a metre or, for that matter, how many metres in a kilometre. Dealing with decimal fractions when doing conversions was a serious problem. Furthermore, they confused a unit^2 with a unit^3, as well as the formulae for the area and circumference of a circle. Lastly, the scripts indicated a complete lack of critical reflection on the answers obtained. The 2013 NSC Diagnostic Report documented identical weaknesses in the scripts of the 2013 Matric students.

1.3. Research question

This study will critically evaluate the quantitative and qualitative data generated over two years (Year A and Year B) while teaching the Numeracy module in my subject in order to gauge and analyse the implications of using an *extended and adapted* attribution retraining programme as a teaching approach to the students' perceived inability to gain epistemological access to numeracy. This programme was offered as a standard and integral part of the Numeracy module and comprised four interventions, which will be discussed in Chapter 3. Interventions 1 and 2 were 'sandwiched' between an initial free-writing exercise and a subsequent analysis of the writing done. Though not interventions in themselves, the free writing and analysis

were meant to add to the effect which these two interventions would have on the students.

The main question driving the study was:

What happened during the two years of presenting an extended and adapted attribution retraining programme, and why did it happen?

This main question can be carved into three sub-questions:

(a) Which interventions were effective? To what degree were they effective, and why?
(b) Which interventions were less effective, and why?
(c) What should be done to render this attribution retraining programme as effective as possible?

1.4. Research Method

The interventions implemented during the extended attribution retraining programme were guided by considerations regarding the students' emotional and intellectual barriers to epistemological access to Numeracy. Many students believe that they are cognitively unable to acquire even very basic mathematical competencies, and the aim of the attribution retraining programme was to convince them of the opposite. The interventions introduced the students to:

(a) the brain's plasticity and neuronal networks (Hebb, 1949; Diamond, 2001; Zull, 2002; Dweck, 2008),
(b) the memory systems, especially the working memory (Ashcraft & Krause, 2004),
(c) Kolb's experiential and reflective learning cycle (Atherton, 2009), and
(d) threshold concepts (Meyer & Land, 2003).

In this dissertation I wish to evaluate the effectiveness of the programme by means of a mixed-methods research design. The quantitative data identify specific trends in the students' engagement with numeracy, and answer the first part of the research question "What happened?", whereas the qualitative data cast light on the second part of the question "Why did it happen?" The important underlying reason for this approach is that I wish to gain insight into the degree and nature of the interrelationship between the students' intellectual move from a fixed mindset to a growth mindset (Dweck & Leggett, 1988) and the resultant 'shift' in their Numeracy assessment outcomes. It is the paradoxical endeavour of taking a closer look at the invisible 'interface' between a student's slow and effortful revision of his or her self-image with regard to "maths" and his or her tentative willingness to engage with the demands and challenges of the subject.

1.4.1. Data collection and processing

Both quantitative and qualitative data were gathered at the time of implementing the extended attribution retaining interventions. Recently, a second set of qualitative data was gathered for additional analysis.

Quantitative data collection

The quantitative data for this study have been drawn from the assessment results generated as a natural consequence of teaching Numeracy as part of the Professional Business Practice subject. At the time of teaching, the students' marks for the subject were entered into a spreadsheet containing the class list. I recorded separately the students' marks for each question in all assignments and summative assessments. This meant that I could single out the results for every type of computation. The results were carefully analysed to ascertain the following :

(a) in which areas did each student show strengths and weaknesses,
(b) which concepts were understood well by the entire class, and which needed remedial attention, and
(c) which students appeared to lack mathematical proficiency altogether?

These data also indicated to what degree the students were making progress in the Numeracy component of the subject.

Qualitative data collection

For my research, qualitative data were drawn from students' written and verbal feedback at the time of teaching them, as well as my own notes, observations and reflections. Further qualitative data were collected recently during interviews conducted with students who were identified as having typical profiles based on the analysis of the quantitative data. These students also completed a final questionnaire. Furthermore, I also had recent and very valuable discussions with a few students via WhatsApp.

Data processing and analysis

In both Years A and B, the quantitative data represent the outcomes of the diagnostic test done in February, as well as those of the summative June examination. All sets of marks for the Numeracy assessments (or Numeracy components of a larger examination) have been graphically summarised in Chapter 4. Of interest is the comparison between

(a) the average percentage achieved by the class for each assessment question,
(b) the shift in the level indicators for the entire class.

This dissertation will adopt a *dominant* method of analysis (Creswell, 2003:184) by focusing on the qualitative data and using the quantitative data only to establish broad trends in the groups of students and to establish whether the quantitative data converge with the qualitative data in the case of individual students. From the qualitative data which accumulated at the time of the interventions, as well as those gathered during recent interviews and written communications, I have endeavoured to ascertain what motivated the students to engage with Numeracy yet again, despite past failures, and whether any of the interventions persuaded them to make a paradigm shift from a fixed mindset to a growth mindset.

1.4.2. Further considerations

My research may be labelled a multiple-case study as, according to Davison (1998:3-7), this entails "examin[ing] a phenomenon in its natural setting". Davison continues by stating that "the boundaries of the phenomenon are not clearly evident at the outset of the research and no experimental control or manipulation is used." Such circumstances for a study require that one keeps certain factors in mind.

(a) Reliability and validity

This study takes cognisance of the advantages and disadvantages inherent in my being a teacher-researcher; of researching a quasi-experimental project, and of having offered the intervention programme over the course of a semester. This latter point meant that no two assessments were similar in content or level of difficulty (in fact, the tasks became ever more complex and advanced as the semester progressed). It was impossible to create, and then replicate, laboratory-style conditions for assessments. I am also aware of the fact that my teaching style and personal convictions and objectives will have played a role in the students' experience of the intervention programme. Consequently, in themselves, the quantitative and qualitative data analysed cannot be considered objective and reliable from a purely scientific point of view. However, I hope to establish to what degree the two types of data validate each other and create a realistic picture of the students' engagement with the interventions in a very "natural setting".

(b) Delimitations and challenges

One's method of teaching any given subject contributes considerably towards the students' ability to gain epistemological access to that subject. Brombacher (NSTF, 2009:15-16) believes that this is especially applicable in the Mathematics teaching

and learning domain. However, engaging with the theoretical framework which informs my actual teaching of the Numeracy syllabus itself, and whether it was effective or not, would be substance for further research. The present research concerns itself exclusively with the set of interventions which, I hoped, would persuade the students to engage with “maths” yet again.

It is also important to keep in mind that in every class one deals with as many sets of personal circumstances and life experiences as there are students in that class. All information transmitted during a lesson is filtered through these individual frames of reference and is, consequently, received and assimilated (or rejected) for a variety of reasons, some of which may be guessed at - or remain hidden below the surface of consciousness.

Finally, time constraints were a constant challenge. The “natural setting” (Davison, 1998:3-7) in which I taught was fraught with distractions, interruptions and the students’ studio-related preoccupations. This certainly compromised the effect which the attribution retraining interventions might otherwise have had.

(c) Ethical considerations

Because the students under discussion were my own students, it is important that I give account of the ethical considerations I entertained. I shall elaborate on these at the end of Chapter 3.

1.5. Conclusion

General mathematical competency is considered indispensible to a nation’s well-being, from its economic advancement to its social cohesion and its citizens’ personal and intellectual development. In the next chapter I shall elaborate on the link between mathematical literacy and the benefits mentioned above. I shall examine the root causes of South African students’ apprehension with respect to “maths”. Next I shall briefly trace the history of attribution retraining, voice my reservations regarding its conventional format, and sketch the theoretical background to the adapted and extended attribution retraining programme which I implemented in the Foundation Course.

CHAPTER TWO

LITERATURE REVIEW

2.1. Purpose of this chapter

Globally, educationists, economists and the informed public have concerned themselves with the underachievement of scholars and young adults in mathematics-related subjects. Consequently, much research has been done and written up regarding the teaching and learning of Mathematics. It is against the background of some of this research that I write up my own research and findings.

The purpose of this literature review is to examine some of the root causes of the affective barriers which many South African students experience when confronted with numeracy tasks, and which then result in cognitive barriers to the epistemological access to numeracy. In order to offer insight into these root causes, I shall review documents and diagnostic reports on the state of Mathematics education in our schools published by the South African Department of Basic Education and other parties interested in the national level of mathematical literacy among the young in South Africa.

I shall then look at attribution retraining which was devised, implemented and analysed by educational psychologists (Weiner, 1985; Hall et al., 2004; Perry, 2009; Haynes et al. 2009; Koles & Boyle, 2013 and many others) in order to help first-year at-risk students improve their academic performance. The existing models of attribution retraining will be reported upon briefly, and reservations will be discussed based on the following:

(a) research done into the brain's plasticity and the role of the neuronal pathways and networks (Hebb, 1949; Rosenzweig & Bennett, 1995; Zull, 2002, 2004a; Schlaug et al., 2005; Diamond, 2001; Kleim & Jones, 2008),

(b) research done into the working memory, its information processing mechanism, its strengths and weaknesses (Hopko et al., 1998; Baddeley & Logie, 1999; Baddeley, 2002; Derakshan & Eysenck, 2009; Raghubar et al., 2010),

(c) research done into maths anxiety and its effect on the working memory (Hembree, 1990; Eysenck & Calvo, 1992; Ashcraft & Krause, 2004; Ashcraft & Moore, 2009; Hoffmann, 2010),

(d) the concept of perceived low or high academic control (Thompson et al., 1993; Perry et al., 2005), and

(e) research into teaching meta-cognitive skills explicitly (Flavell, 1979; Garner & Alexander, 1989; Cornford, 2004; Efklides, 2006; Tanner, 2012; Chick, 2015).

Research into the above issues has led me to the conclusion that, if educators wish to be instrumental in reversing the poor self-concept of students who struggle with Mathematics/Numeracy, they will have to devise interventions which convince their students of their *innate, physiological* cognitive ability to grasp elementary mathematical concepts. Certainly in the South African context, increased effort and new task-related strategies alone have not produced the desired outcomes, as will be discussed under the heading of *Reservations regarding conventional attribution retraining treatments* (# 2.2.4.d.).

A new and extended model of attribution retraining, which embraces the teaching of certain cognitive and meta-cognitive skills and addresses the complexities of the South African educational situation, will be suggested and elaborated upon.

2.2. Mathematics and the economic viability of a country

In order to appreciate the dire situation in which South African education, specifically with regard to Mathematics, finds itself, one needs to view the country's National Senior Certificate (NSC) Mathematics results in the context of the importance which is globally attached to mathematics-based studies and professions.

2.2.1. National Senior Certificate Mathematics results in South Africa

As mentioned in Chapter 1, there is a global concern regarding the fact that many countries' educational systems struggle to produce satisfactory, much less excellent, results in the STEM (Science-Technology-Engineering-Mathematics) subjects. Closer to home, South Africa ranks last out of 148 countries in its mathematics and science education (World Economic Forum, 2013:347).

According to the Department of Basic Education, as reported by Hanna Barry (2014), only 43% of the entire cohort of 2013 full-time National Senior Certificate candidates wrote the Mathematics examination. Of these candidates, 14,4% obtained 40%-49% for the subject, 10,5% obtained 50%-59%, and only 15,6% achieved results of 60% and upwards. This means that only 40,5% of all

candidates who wrote Mathematics, achieved a pass mark of 40% and above. In order to be admitted to any of the STEM subjects, however, aspirant students must achieve at the very least 65% (UCT 2016 Undergraduate Prospectus) or 50%-59% (Level 4) at a university of technology (CPUT, 2014b) in their NSC Mathematics examination – and there is an urgent need for more professionals in the mathematics- and science-related fields in South Africa.

2.2.2. Importance of mathematical competencies in a nation's economy

The importance of a sound foundation in mathematics or, for that matter, general quantitative literacy/numeracy cannot be over-emphasised in a world of economics, digital information, and ever changing technology.

In its report on 'global competitiveness', the World Economic Forum (2013a, 4-9) makes the following statements:

(a) "We define competitiveness as the set of institutions, policies, and factors that determine *the level of productivity* of a country." (my emphasis)

(b) One of the determinants which drive productivity (and, therefore, competitiveness) is *education and training*, as …

(c) … "basic education increases the *efficiency of each individual worker*" (my emphasis).

(d) The report speaks of the 12 pillars of competitiveness, and one of these pillars is innovation. However, "a *strong innovation capacity* (pillar 12) will be very difficult to achieve without *a* healthy, well-educated and trained workforce (pillars 4 and 5)" (my emphasis).

(e) This workforce needs be able to "*perform complex tasks* and *adapt rapidly* to their changing environment and the evolving needs of the production system" (my emphasis).

At the Washington 2001 forum on quantitative literacy, held by the American National Research Council, the following observations were made by experts in the fields of Mathematics and related subjects (Steen, 2002:8):

(a) Mathematics should be taught in order *to develop and strengthen reasoning powers in students* (observation made by De Lange of the Freudenthal Institute in Utrecht and member of the Mathematical, Sciences Education Board).

(b) Denmark was developing a school Mathematics curriculum which would be based on mathematical competencies, such as *reasoning,*

argumentation and communication (comment made by Niss of Roskilde University in Denmark).

(c) Finally, the forum's white paper described quantitative literacy as the "*quantitative reasoning capabilities* required of citizens in today's information age" (Steen, 2002:8). (my emphasis in each case above)

South African educationists agree with the stance adopted at the forum regarding the indispensible benefits of a citizenry that is quantitatively literate. Frith et al. (2010:2) hold as true that "quantitative literacy is the ability to manage situations or solve problems in practice……". Jansen (2012) observes that "it is and should be the concern of democracy t**h**at, without access to the best in mathematics education, we fail to strengthen the foundations of a still fragile society, given the values that are lost in poor maths teaching." Campbell and Prew (2014) argue that only real success in the National Senior Certificate Mathematics and Science examinations will ensure that "South Africa [will] achieve its growth and development goals". These reflections on the importance of mathematical literacy echo the World Economic Forum's observations mentioned above.

Moreover, the Global Competitiveness Report (World Economic Forum, 2013a:8) identifies technological breakthroughs as being at the core of advanced productivity in national economies. As technologies reach the outer limits of what has been designed and created so far, it becomes vitally important that new avenues be opened for new products and services. This means, the report argues, that innovation is the engine which drives the economy of a country, as simply realigning existing knowledge is not sufficient anymore. New ground has to be broken, and for this to be possible, a country needs (in all fields!) designers with vision, creative thinkers, pioneers who have a profound understanding of what is possible and what is not in order to be able to break the mould and afford the country's economy a competitive edge.

2.2.3. The role of universities of technology in the quest for mathematical competency and national productivity

If innovation in technology and technology-related areas depends on quality education, especially in the fields of science and mathematics, and, in turn, guarantees the potential for sustained productivity, then universities of technology have a very important role to play in a country's economic competitiveness. This is borne out by the vision and mission statements of some of South Africa's universities of technology. For instance, the Cape Peninsula

University of Technology aims to be “at the heart of technological education in Africa” (CPUT vision and mission statement, n. d.). The Tshwane University of Technology’s mission is to “creat[e] sustainable economic growth” by “promot[ing] knowledge and technology”, as well as stimulating “innovation and creative thinking” (Tshwane University of Technology, 2012). Durban’s university of technology sums up the key principles of the World Economic Forum’s Global Competitiveness Report in its vision statement: “A preferred university for developing leadership in technology and productive citizenship” (Durban University of Technology, 2015a).

2.2.4. Introduction to educational hurdles, conventional attribution retraining and reservations regarding the latter

It is imperative that every effort should be made to improve the learning experience and success rate of both scholars and students in Mathematics and mathematics-related subjects – starting at school level and continuing into tertiary education. However, education at both school level and tertiary institutions has failed scholars and first-time students alike and predisposed them to underachievement in the STEM subjects.

In this section I shall, therefore, very briefly touch upon the hurdles presented by the educational environment. I shall introduce the conventional attribution retraining treatment and enumerate my reservations regarding its possible application to Mathematics in the South African context. In Section 2.3. I shall analyse in greater detail the teaching and learning of Arithmetic/Mathematics/ Maths Literacy from primary school through high school to tertiary institutions in order to suggest reasons for young adults’ lack of academic self-confidence in Mathematics/Numeracy. In Section 2.4. I shall sketch the history and implementation of conventional attribution retraining and present the theories on which I base my reservations. In Section 2.5. a new and extended attribution retraining programme will be introduced and discussed.

(a) Obstacles to successful Mathematics/Maths Literacy results at South African schools

I shall consider some of the main obstacles to successful National Senior Certificate results in Mathematics/Maths Literacy examinations as diagnosed by the Department of Basic Education in its review of the 2013 National Senior

Certificate outcomes. The discussions held at the National Science and Technology Forums of 2009 and 2010 revolved around similar concerns. The obstacles identified are to be found in primary school and secondary school education, as well as in many teachers' methods of preparing their matriculation candidates for the final examination. However, the 'obstacle course' continues into first-year university.

(b) Obstacles at tertiary level

The admission requirements at universities of technology are particularly low, which forces many students to attempt bridging a very wide gap between secondary and tertiary academic discourses and demands. Students experience novel situations on several fronts and start losing their academic self-confidence. In this period of profound transition, adaptation and reorientation, they run the risk of, at least temporarily, losing their sense of being in control of their situation (Ruthig et al., 2004; Haynes et al., 2008).

(c) Conventional attribution retraining (AR) for at-risk freshmen

I shall review attribution retraining as a "treatment" hitherto "administered" (to use the relevant researchers' terminology) in the United States, Canada and Australia to assist academically at-risk students. In order to understand the rationale which underpins such treatments it is important to summarise the research which led to the introduction of attribution retraining. In particular, I shall focus on Weiner's (1985) three dimensions of causality, his 'levels of aspiration and expectancy' and his concept of the 'attribution-emotion process'. I shall then examine the format of conventional attribution retraining and consider the results obtained.

(d) Reservations regarding conventional attribution retraining

Reservations regarding conventional attribution retraining will be discussed against the background of the South African context. My reservations are also based upon research done into the plasticity of the brain and its neuronal pathways (and networks), the cognitive processes of the working memory, and how negative intrusive thoughts (in our case, maths anxiety) impair the functioning of the working memory by reducing its capacity (WMC). A brief analysis of the intellectual demands made by any engagement with mathematical tasks will highlight the risks of further shrinking the working memory capacity. To compound matters, this reduction in capacity is then worsened by anxious

students' compensation strategies. Finally, I need to highlight the concept of students' 'perceived control' in an academic environment, as this has been shown to be a crucial factor in the success (or failure) of the existing attribution retraining treatments. It has played an equally important role in our students' chances at winning the battle with "maths".

The plasticity of the brain and its neuronal networks

According to Zull (2002:13-29) the brain is an organ designed to learn; it learns continuously. Students are expected to assimilate and apply knowledge with ever greater efficiency. The logical deduction should, therefore, be that it would profit them greatly if they understood how to employ this very complex organ optimally. If, by introducing my students to the world of neuronal pathways and networks, I could convince them of the plasticity of their brain, then I might be able to change their concept of a *fixed* 'intelligence' to that of an 'intelligence' with the potential to *grow* (Hebb, 1949; Diamond, 2001; Hopkins, 2005; Nussbaum & Dweck, 2008).

The working memory, maths anxiety and coping mechanisms

In order for a possibly more effective attribution retraining programme to be developed in the South African context, one needs to understand and appreciate the effect which the obstacles to mathematical competency referred to above have on our students. I shall, therefore, discuss research done into the cognitive processes of the working memory, and then examine research on maths anxiety and its affective impact on these cognitive processes. Students' coping strategies, when confronted with numeracy assignments, will be mentioned, as well as the effect these coping strategies have on the ability of the working memory to deal *efficiently* with such assignments.

The introduction of lectures regarding both the plasticity of the brain, as well as the information processing mechanism of the working memory, would be an example of explicitly teaching cognitive skills.

Perceived control

Much research has been done into the concept of perceived control among students, especially perceived academic control among first-year students who are experiencing a challenging transition period from high school to university (Perry, 2009; Haynes et al., 2008). Having a sense of being in control motivates them to work hard and persevere, even in the face of initial disappointments. A faltering sense of control can be stabilised by changing their mindset from a fixed

mindset to a growth mindset (Dweck & Leggett, 1988). Researchers into attribution retraining treatments have also established that students with a perceived high academic control react positively to such treatments as opposed to those with a perceived low academic control (Perry, 1991, 2003). However, my contention is that many South African students arrive at university with an already internalised sense of low academic control.

The concept of teaching meta-cognitive skills explicitly

Since the 1970s the concept of teaching meta-cognitive skills explicitly has received ever more attention (Flavell, 1979; Garner & Alexander, 1989; Gall, 1990; Cornford, 2004; Efklides, 2006; Tanner, 2012, to name but a few). If the success of conventional attribution retraining treatments is based, in part, on persuading students to use new and better learning strategies, then it would seem that interventions which teach the students such strategies *explicitly,* should be part of such a programme. However, the literature on conventional attribution retraining which I studied for this dissertation does not mention such interventions. In fact, it is stressed that students, *after a brief treatment* (Wilson & Linville, 1982; Hall et al., 2004; Perry et al., 2009) showed academic improvement. For students with a temporary loss of control such a treatment may be sufficient. However, students with a deep-seated and permanent sense of very low academic control may profit greatly from being taught explicitly how to make optimal use of their cognitive capacities.

Consequently, I have included in my interventions Elbow's (1973, 1983) free writing, teaching the students to employ Kolb's (1984) experiential and reflective learning cycle, and the idea of threshold concepts (Meyer & Land, 2003; Meyer et al., 2010). These interventions will be discussed as well.

(e) A different kind of attribution retraining

With the discussion of the above topics I wish to present the rationale which underpins my introduction of an extended programme of attribution retraining interventions that focus on the root causes of the *apparent* cognitive inability to conquer "maths". These interventions would help students make the paradigm shift from believing that their cognitive capacity is a fixed entity (Nussbaum & Dweck's entity theory, 2008:600) to understanding that their cognitive capacity can be expanded at any time (Rosenzweig & Bennett, 1995; Diamond, 2001; Zull, 2004; Kleim & Jones, 2008;). In other words, I wish students to accept and

internalise a growth mindset (Nussbaum & Dweck's incremental theory, 2008:600). This should motivate them to renew their quest for epistemological access to "maths" - the term they use for every task that involves numerical computations.

2.3. A less-than-happy history with "maths"

In Chapter 1, I stated that, in order to appreciate our students' aversion to Mathematics/Numeracy, one needs to have some insight into their past experiences with the subject. According to Brombacher (NSTF, 2009), these experiences go back to the very beginnings of a young person's school career. Consequently, I wish to trace students' engagement with everything mathematical back to their primary school days.

2.3.1. The state of Mathematics/Maths Literacy teaching and learning at South African schools

The proceedings of the 2009 workshop on STEM-education, held by the National Science and Technology Forum (NSTF), reveal serious shortcomings in the national school system. In fact, Brombacher (NSTF, 2009:18) spoke of "the horrors that we see in schools .0... the depravity of what passes for Mathematics in many of the schools in the country." He maintains that good Grade 8 results in Mathematics are reliable predictors of not just good performance in Grade 12 Mathematics but of good results across all subjects in Grade 12. However, to ensure the necessary results in Grade 8 Mathematics, the pupils have to have had an excellent grounding in Arithmetic in their early primary school years (NSTF, 2009:16).

Unfortunately, whether one studies the briefing (2009) to the Parliamentary Monitoring Group of the National Benchmark Tests Project or NEEDU's (National Education Evaluation & Development Unit) 2013 report entitled *National Report 2012: The State of Literacy Teaching and Learning in the Foundation Phase,* the verdict is that teachers in general, and Mathematics teachers in particular, are inadequately prepared to teach their subject. According to the NSTF 2010 proceedings (p. 5), there had been large-scale programmes to equip and support underprepared or unqualified teachers with the relevant knowledge for their subject. However, Brombacher, in his discussion of STEM subjects, maintains that it is not just a matter of relevant knowledge, but also "the knowledge of how

to teach the subject... so that teachers know how children learn a particular subject" (NSTF, 2009:15-16). In the case of Mathematics, Brombacher calls it "mathematical knowledge for teaching" and is convinced that, due to the difficulties teachers experience with teaching Arithmetic, many children "are lost to Mathematics by the time they reach Grade 4. They have no understanding of the fundamental concept of [a] number" (NSTF, 2009:16). Dr Bantwini of the Human Sciences Research Council agreed with Brombacher's conviction that the foundations for mathematical literacy are laid in the very early years of primary school as "there is a considerable body of literature on the cognitive gains between the ages of 3 and 8" (NSTF, 2009:3).

(a) Obstacles at primary school level

The CPUT 2015 admission requirements for a student who wishes to study towards a diploma in primary education state that s/he needs to have obtained a minimum achievement rating of 2 in Mathematics/Maths Literacy in the National Senior Certificate examination (CPUT, 2014a). A rating of 2 equals 30%-39% or an 'elementary achievement', according to the National Curriculum Statement (Department of Basic Education, 2013:36). This means that such a candidate, who will have to teach Arithmetic to his or her pupils, has a personal history of struggling with mathematical concepts.

Hembree (1990:41), as cited by Ashcraft and Moore (2009:201), states that "the college major with the highest level of math anxiety is elementary education." This finding is reflected in Peker's study (2009:342) as well. Peker reports on a substantial body of research done into pre- and in-service teachers' mathematics anxiety, and which concludes that this affect can be attributed to their own experiences as Mathematics scholars/students (2009:336). According to Hoffman (2010:279), Brady and Bowd's (2005) research indicates that "Mathematics teachers pass their anxiety on to their students". Steele (1997) states that a Mathematics teacher's low self-efficacy beliefs will influence a pupil to think that Mathematics is a difficult subject. Thus it stands to reason that many of our students, especially those from disadvantaged schools in townships and rural areas, have had a shaky introduction to Arithmetic, tinted by the misgivings and self-doubts of their teachers. Consequently, they enter secondary school, ill-prepared for and subconsciously already apprehensive about Grade 8 Mathematics.

Furthermore, according to The World Bank's 2012 international statistical data regarding the percentage female teachers at primary school level, South African female primary school teachers make up 79% of the national primary school teaching staff.

In order to appreciate how the above statistic further lowers a primary school pupil's chances at developing a sound foundation in numeracy, one needs to consider the concept of gender stereotyping in the realm of mathematics.

Bonnot and Croizet (2006) have researched the interaction of girls with Mathematics and maths-related studies and career choices. Their research has shown that society has stereotyped girls as having less *cognitive ability* in the realm of numbers than boys. This gender stereotyping has affected girls' self-concept of intellectual capacity (in the Mathematics domain) to the point where international statistics collected by the OECD-PISA report in 2012 showed that boys had a better self-concept with regard to Mathematics than girls (OECD, 2014:18). "Self-knowledge in the math domain and the way it affects performance appears therefore crucial" (Bonnot & Croizet, 2006:858). Girls were found to have internalised this gender stereotyping to such a degree that, despite previous positive experiences in Mathematics, their low self-evaluation still undermined their performance. They anticipated failure because, after all, they were girls, and girls do not perform well in Maths (Eccles et al., 1990; Jacobs, 1991; Steele, 1997; OECD, 2014).

Consequently, it is to be expected that many female primary school teachers, who (a) have had a personal history of disappointments in Mathematics, and who (b) possibly suffer from gender stereotyping, will have had, unwittingly, a negative influence on their pupils' self-image regarding numeracy.

(b) Obstacles at high school level

At high school level, the proximal environment is infused with additional negative elements.

(i) Insecure scholars' problems are compounded by further ineffective teaching (Department of Basic Education, 2014) and the pressure of having to deliver during examinations.

(ii) The Mathematics of high school is not the Arithmetic or Numeracy of primary school. New mathematical concepts are introduced and bewilder the insecure scholar who also needs to deal with new and

unfamiliar surroundings (Haynes et al., 2008; Haynes et al., 2009; Hoffman, 2010:277).

(iii) The competition in the classroom intensifies, and scholars with a low self-efficacy belief lose heart in the face of having to prove themselves and achieve the expected – and necessary! - level of performance (Haynes et al., 2009). Repeated failure breeds a spectrum of negative emotions, such as disappointment, shame, guilt and fear (Weiner, 1985), which leads to despondency and decreases motivation. Such an attitude translates into a decrease in effort and concentration - which, in turn, results in even poorer grades - the downward spiral (Haynes et al., 2008).

(iv) Female high school scholars may possibly fall prey to the gender stereotype threat regarding Mathematics mentioned above. As they are faced with making subject choices which depend on their envisaged career choices, those who would like to become teachers might well opt for primary school training as they need to obtain *only* a level 2 in their National Senior Certificate Mathematics examination. Although this is an assumption on my part it is based on Ashcraft and Moore's (2009:204) findings that "math-anxious individuals avoid elective math course-work, avoid college majors that require math, and avoid career paths that involve math."

(v) Furthermore, a new stereotype threat may have developed. In connection with gender stereotype threats, Bonnot & Croizet (2006:858) speak of socialisation agents which influence our beliefs and attitudes. In South Africa, the socialisation agents regarding self-concept and Mathematics may well be the media and our schools themselves. However, they pose a different kind of stereotype threat.

There are regular reports in newspapers and on the daily news concerning the disarray in our education department and the school system. We hear of disadvantaged schools without adequately trained teachers and without study materials. The national and international statistics which condemn our education system can be read up on the internet. And at the forefront are always the concerns about the poor teaching and learning performances in Mathematics and Science (National Business Initiative, 2009; NSTF, 2009, 2010; NEEDU, 2013). One must assume that this has a negative impact on the academic self-concept of scholars who are aware of the fact that they are products of disadvantaged, and often also dysfunctional, schools. In particular, this situation must sow seeds of self-doubt with respect to mathematics- and science-related subjects because of the general belief that these subjects are more difficult to master than other subjects.

(vi) In addition, schools themselves act as negative socialisation agents when they unwittingly entrench the low self-efficacy beliefs regarding Mathematics in the majority of their scholars (NSTF, 2009; Jansen, 2012). In the past, Mathematics HG (Higher Grade) was considered the subject for the chosen few in the streamed first and second classes of Grades 10, 11 and 12. Scholars who realised that they needed Mathematics, but felt that they would not cope with HG, took Mathematics SG (Standard Grade). In recent years, those who have wanted to take up science- and technology-orientated careers have

chosen 'pure' Mathematics; the rest have taken Mathematical Literacy which is the 'soft option'. Jansen (2012) speaks of the "dramatic migration from Mathematics to Mathematical Literacy". This is welcomed, and even advocated, by principals and provincial education departments alike as it guarantees better results in the final examinations (NSTF, 2009; Jansen, 2012), and thus helps schools and departments save face, and hopefully bolsters their reputation for producing a good Matric pass rate. This is happening predominantly at schools with large numbers of African and Coloured scholars (NSTF, 2010; Jansen, 2012). However, the loser, according to Jansen, is the scholar who sees himself as a second-rate individual because he has opted for, or has been advised to opt for, the 'easier' subject, namely Maths Literacy. Perhaps one should add that the Education Department's rationale for two bands of Mathematics may be considered to have been based on sound educational principles; however, in practice, this streaming of scholars must have a negative effect on the self-efficacy beliefs of those who are relegated to Maths Literacy.

A combination of the above factors creates a kind of societal stereotyping which senior scholars will have internalised by the time they enter university as first-time students – with, at best, a lowered self-concept of competence in the field of Mathematics and, at worst, an inferiority or failure complex regarding Mathematics.

(c) Preparation for the NSC examination

In connection with the 2013 Mathematics and Maths Literacy Papers written during the National Senior Certificate examination, the National Diagnostic Report on the 2013 NSC examination (Department of Basic Education, 2014) repeatedly notes the following shortcomings in the preparation of Grade 12s for this examination:

(i) fundamental concepts/theory not being taught thoroughly enough (pp. 138, 163),

(ii) rote learning through setting regular and "pointless" (p.142) drill exercises to prepare candidates for the final examination – "a stimulus-response method" used as teaching strategy (p. 136). This leads to the following weaknesses:

(iii) Candidates cannot adapt mathematical concepts and formulae to different contexts (pp. 126, 136, 169, 170), develop their own formulae (p. 172), or successfully apply re-arranged formulae (p. 162).

(iv) They give "standard responses to questions" (p. 136) which are un-related to the answers required.

The above critique was echoed during the NSTF workshop of 2009 by Dr Naidoo who stated that students, who had done well in their Mathematics papers because they had worked through many exemplars that prepared them for the final examination, were now struggling at tertiary level (p. 9). Garner and Alexander (1989:149) refer to Brown et al. (1983) when they speak of “strategies [having been] welded to the original instructional setting”.

2.3.2. Obstacles at tertiary level

As if the obstacles of the past were not enough, matriculants entering tertiary institutions are faced with new challenges which threaten their inner balance.

(a) A period of transition

Perry and his fellow researchers, in their discussion of *perceived control* among first-year students, refer to Thompson et al. (1993) who researched the reaction of individuals to changes in life situations. If a person experiences major and simultaneous changes in his or her life situation which are objectively and/or subjectively perceived as unpredictable, then that person may consider himself or herself caught in a *low-control environment* and may develop a “psychological state of being ‘out of control’ “ (Perry et al., 2005:374).

Perry and his colleagues state that having a sense of high academic control is indispensable to a student’s academic success. And yet, gaining a sense of high control is a profound challenge for a first-time student, especially if one considers the first-year hurdles enlisted by Ruthig and her colleagues (2004:712). Haynes et al. (2009:237) label this transition period a ‘developmental transition’ during which students “face an uphill struggle that requires intellectual ability, content knowledge, emotional stamina, unflagging motivation, and unrelenting goal striving” (2009:227).

According to Weiner (1985:549), we instinctively search for the underlying causes of our successes and failures in order to repeat the former and eliminate the latter in the future. We do so especially if we strive to improve the outcomes of our efforts and if we feel that there is much at stake for us to win and not lose. Students are no exception to this rule. Entering university for the first time, they will be preoccupied with themselves, assimilating new experiences and challenges, examining themselves for weaknesses and strengths, comparing themselves to their classmates. Students will instinctively be searching for

attributes within themselves which lead them to success or poor performance (Perry et al., 2005:376).

Haynes et al. (2009), in their review of attribution retraining treatments, discuss in considerable detail the challenges which first-time students experience during the transition period from school to tertiary institutions.

The changes (and challenges) can be grouped into those experienced in the new academic environment, as well as those experienced in the students' personal life situation. Both categories of changes can cause students to develop low-control perceptions which may be temporary (until students have settled in and have proved themselves in the academic discourse) or become permanent and debilitating, "giving rise to a sense of helplessness and hopelessness" (Perry et al., 2005:373).

I shall look at the circumstances which, in the South African context, can lead to a sense of low academic control first, and then mention situational challenges.

(b) Admission requirements

For American students, who have been selected and admitted to tertiary institutions subject to strict academic criteria (Choy, 2002:14-15), the period of transition may entail only temporary unease and disorientation. However, in South Africa the selection criteria have been lowered considerably (especially at universities of technology) in order to offer as many scholastically and socio-economically disadvantaged students as possible the chance of a better future. In the 2015 Handbook of the Faculty of Informatics and Design at the Cape Peninsula University of Technology (CPUT), the following *general* minimum admission requirements have been stipulated for 2015 (p. 23). (See textbox below.)

However, in some programmes of the Faculty of Informatics and Design, additional requirements regarding certain National Senior Certificate subjects and ratings govern the selection process. Students in those programmes are expected to have the following ratings:

Home Language: 4
First Additional Language (English or Afrikaans): 3

Moreover, in a few programmes the Mathematics or Maths Literacy requirements are higher than indicated above as these programmes rely more heavily on mathematical competencies.

These admission criteria are not unique to CPUT. In the Faculty of Arts and Design at the Durban University of Technology, nine out of twelve programmes stipulate as admission criteria a rating 3 for English (home or first additional

A National Senior Certificate (NSC), as certified by Umalusi, with

- *an achievement rating of 3 or better in four recognised NSC 20-credit subjects,*
- *an achievement rating of 2 for Mathematics or 4 for Mathematical Literacy,*
- *an achievement rating of 3 in the required official language at Home Language level,*
- *an achievement rating of 2 in the other required language on at least First Additional Language level.*
- *one of these languages shall be English or Afrikaans.*

Rating

For easy reference, the scale of achievement for the National Curriculum Statement Grades 10 – 12 (General) is given below.

7- Outstanding achievement	*-*	*80% -100%*
6 - Meritorious achievement	*-*	*70% - 79%*
5 - Substantial achievement	*-*	*60% - 69%*
4 - Adequate achievement	*-*	*50% - 59%*
3 - Moderate achievement	*-*	*40% - 49%*
2 - Elementary achievement	*-*	*30% - 39%*
1 - Not achieved	*-*	*0% - 29%*

language) and a 3 for two other subjects which have a credit bearing of 20 (DUT, 2015b). The Nelson Mandela Metropolitan University states the following:

> "minimum statutory NSC requirements for diploma entry: English, Afrikaans or isiXhosa (home language or first additional language) on at least level 3 (40% - 49%). NSC achievement rating of at least a 2 (30% - 39%) for Mathematics or a 3 (40% - 49%) Mathematical Literacy" (NMMU, 2013).

These examples of entry requirements for tertiary institutions of technology lead one to the conclusion that, in theory, students may register in most design programmes having passed only one subject with 'substantial achievement' - their home language. At worst, they have not obtained a 50+% mark in a single National Senior Certificate (NSC) subject. In the Faculty of Informatics and Design at CPUT, the basic requirements translate into the admission of

candidates who have achieved below 50% in at least four of their six NSC subjects.

With the above scenario in mind, it should be easy to appreciate many students' general misgivings as they start to engage with tertiary academic activities.

(c) Perceived low academic self-efficacy

At the outset of a new academic year, most first-year students are, for the first time, given a subject guide and/or a study guide. Some important facts impressed upon them are that the pass mark, from now onwards, is 50%; that deadlines are to be taken seriously; that the work load will increase dramatically; that the tertiary academic discourse is very different to their past secondary school experiences.

Referring to Nicholls and Bandura, Koles and Boyle (2013) speak of four kinds of information which shape a student's self-efficacy perception:

(i) the student's previous experiences with assessment outcomes (Nicholls, 1978, 1990),

(ii) the "vicarious experiences of observing the performance of others" (Nicholls, 1978, 1990) – in our case, other students,

(iii) listening to discussions by fellow students, as well as information given by the lecturers (Bandura, 1982), and

(iv) their own heightened stress levels when confronted with new study materials and tasks (Bandura, 1982).

Furthermore, according to Bandura (1982:123, in Koles & Boyle, 2013), a student's self-efficacy belief influences his or her thoughts *before* and *during* a particular event. If the student doubts whether s/he will be able to rise to an upcoming challenge (assessment tasks and tests), then his or her sense of low self-efficacy becomes unreasonably inflated. The pressure to perform adequately is further intensified by increased competition in a class of strangers (Ruthig et al., 2004:712).

As such students then engage with the assessment task or test, their negative thoughts produce stress which impedes their ability to apply themselves to the challenge with undivided attention. If this finding applies to individual situations, one should be allowed to apply it to the general, novel and intimidating experience of a first-time student at a university, especially in the light of Koles and Boyle's concept of '*perceived environmental requirements*' (2013) which

students will extract from the above four types of information. This concept is echoed by Perry (2003), as cited by Haynes et al. (2009:230).

Furthermore, according to Koles and Boyle (2013), Bandura (1977) established that a student's expectations of how difficult future tasks will be and how much effort s/he needs to exert in order to cope with such tasks (or then the entire 'perceived environmental requirements'), also influence his or her sense of self-efficacy and will play a causal role in the level of his or her performance. Bandura (1977) posits that an individual's sense of self-efficacy is more often than not linked to his or her belief that personal success or failure are governed by internal, stable and uncontrollable causes (such as ability) rather than external, and possibly controllable, causes.

These findings lead one to surmise that, for students with a low self-efficacy perception, the academic odds are stacked very highly against them, partly due to objective factors in a novel academic environment, partly due to their subjective interpretations of this environment.

(d) Situational challenges

Perry and his fellow researchers (2001), as cited by Haynes et al. (2009:237), speak of added stressors, namely "new physical and social setting[s]". Haynes and his colleagues themselves include in this new environment "unpredictable and unfamiliar experiences" which are not limited to academic matters.

Adjusting to and orientating oneself in such a variety of novel circumstances, both the personal and situational ones off campus and those on campus, requires courage, resourcefulness and perseverance (Haynes et al., 2009:227). In turn, this adjustment demands extra working memory capacity and can threaten a first-time student's ability to focus single-mindedly on his or her work.

(e) Perceived control

In the above sections, I have considered briefly only some of the challenges of a South African first-time student; there are many more which would be material for a very necessary further research task. I now wish to return to the concept of high or low academic control.

Students' perceived control plays a decisive role in their ability to adjust to the academic discourse of a tertiary environment. According to Perry and his colleagues (2005:382), students who believe that, in general, they are able to face and overcome obstacles and, in particular, can positively influence the outcomes of their academic efforts, have a greater sense of being 'in control' (perceived high control) than those who come to mistrust their ability to rise to new challenges (perceived low control). The former will be motivated to exert themselves as they believe that success is within their reach (Perry et al., 2005:383). The latter will be less motivated and reduce their efforts to succeed, as they believe that failure is inevitable. They will turn their attention to other spheres in which they feel more 'in control' in order to preserve their sense of self-esteem (Koles & Boyle, 2013).

The seriously debilitating impact, which the academic and situational circumstances described above have on a first-time student with a compromised sense of control, lowers his or her ability to focus on the tasks presented. Hoffman (2010), referring to maths anxiety, states that "diverted attention endemic to high anxious individuals, regardless of ability, strains working memory resources". The same would apply to students who feel overwhelmed and 'out of control' during their transition from a secondary to a tertiary academic environment.

To compound matters, the insecure student tends to resort to obsolete strategies, dating back to school, which are ineffectual, or even counter-productive. Not only that, but such students will often employ coping and compensation strategies which take a serious toll on their working memory capacity. This will come to light when I turn to research done into the cognitive functions of the working memory and students' strategies when confronted with formative and summative assessments in Numeracy.

2.4. Attribution retraining

In Chapter 3, I argue that my research would fall into the category of a multiple case study. The criteria on which I base this categorisation are informed by Davison (1998:3-8) and Yin (2009, in Farquhar, 2012:6). The important point to be made here is that my interventions were a spontaneous reaction to the students' disheartening performance in Numeracy and their firm belief that failure would be inevitable. At the time I was not aware of the standard attribution

retraining treatments administered by other educational researchers. However, the overarching objective of my interventions was the retraining of my students' maladaptive causal beliefs. Since then I have researched existing attribution retraining treatments as administered in other countries. They are considered exceptionally successful by researchers, such as Hall et al. (2004), Haynes et al. (2008, 2009), Koles and Boyle (2013) and Perry (2009). The following section is an analysis of the background to and application of attribution retraining.

Note: I have chosen to label the attribution retaining, as it has been implemented by universities hitherto, 'conventional' or 'standard' attribution retraining treatments to distinguish it from the extended and modified model of attribution retraining which I have developed. Also, researchers and implementers of the conventional attribution retraining speak of "administering" it as "AR treatments" - which is an apt choice of words, as these treatments are, as far as my research has been able to establish, once-off exercises about 30 minutes in duration. I call my retraining an 'intervention programme', as it stretches over a semester and entails several distinct interventions, as well as constant reinforcement of the concepts and skills taught.

2.4.1. Attribution theory

Attribution retraining has been researched for the past 30 years, based on the attribution theory developed by Weiner (1985) and discussed by Perry (2009), Koles and Boyle (2013) and others.

2.4.2. Weiner's attribution theory

Weiner (1985:548) quotes Kelley (1971:22) as follows:

> "The attributor is not simply an attributor, a seeker after knowledge; his latent goal in attaining knowledge is that of effective management of himself and his environment."

Weiner (1985:548) himself continues by saying:

> "Once a cause, or causes, are assigned, effective management may be possible and a prescription or guide for future action can be suggested."

Perry et al. (2005:375-376) note that students will instinctively search for reasons within themselves for why they have adjusted to the tertiary and academic environment successfully - or have fallen short of their own expectations and the institution's requirements. For this reason it is important to explore Weiner's 'dimensions of causality' and attribution theory.

(a) Three dimensions of causality

Weiner's attribution theory (1985) posits that outcomes of an activity, especially if the outcomes are very important and/or negative or even unexpected, lead to a search for underlying reasons. In other words, the person involved will want to attribute the outcomes to certain causes – causal attribution (Perry, 2009; Koles & Boyle, 2013). Weiner (1985:548) refers to White (1959) who developed the principle of mastery, and to Kelley (1971) who stated that the goal of mastery was to acquire that kind of specific knowledge that will enable a person to manage himself and his environment effectively.

Weiner (1985:549) states that adaptation (and, therefore, survival, one should add) are not possible unless one has analysed the causes that underlie a certain outcome. If the outcome is desirable, one wants to be able to repeat it; if the outcome is negative, one wants to know what caused it and how to avoid it in future.

Weiner (1985:551-552) summarises earlier research findings in connection with causal attributions as follows:

(i) The most basic dimension of a cause is whether it is situated within a person or within the environment (Heider, 1958). Weiner calls it the *locus of causality* which is internal or external.

(ii) A second dimension of a cause is whether it is perceived as *stable* or *unstable* (Weiner et al., 1971). Causes may be perceived as being internal to the person and stable (such as ability) or internal and unstable (such as effort), or they may be external and stable (degree of difficulty of a subject) or external and unstable (class atmosphere conducive to meaningful learning).

(iii) The third dimension is that of *controllability* (Weiner, 1979). Does the individual who is reflecting on the outcome of his or her work ascribe the nature of the outcome to factors which are in his or her control or not? In other words, does the person consider future outcomes to be potentially modifiable – or not.

These three dimensions of causality have been confirmed and employed in educational research and practices ever since (Haynes et al., 2008; Koles & Boyle, 2013).

(b) Level of aspiration and expectancy

Weiner (1985:556) speaks of 'level[s] of aspiration' and maintains that an individual's level of aspiration depends on prior experiences of success or failure. If s/he has experienced success in a previous instance, then his or her level of aspiration will rise, especially if the success is attributed to internal, unstable and controllable factors. The opposite occurs if an individual has experienced failure repeatedly. The level of aspiration will drop, especially if the undesirable outcome is ascribed to internal (or external!), stable and uncontrollable factors (such as lack of ability or difficulty of course), and the person will lose motivation, believing that no amount of effort will have a positive impact on future outcomes (Weiner, 1985:557).

Weiner also formulated the 'expectancy principle' according to which "changes in expectancy of success following an outcome are influenced by the perceived stability of the cause of the event" (1985:559). If positive outcomes of previous challenges could be ascribed to unstable and controllable causes, then the individual's expectancy of future successes will increase incrementally - as will his or her level of aspiration (Weiner, 1985:556). Unfortunately, the converse of this principle should be true as well: the more convinced a person is of his or her innate inability to achieve a certain goal, based on previous negative experiences, the less that person will expect future success, and the less s/he will engage in activities to secure future success. His or her level of aspiration will then decline as well. This principle needs to be kept in mind when our students' personal history in connection with Mathematics is considered.

(c) The attribution-emotion process

Weiner (1985:561-564) discusses 'dimension-related emotions'. Although he investigates seven affects generated by various combinations of the dimensions of attributional causes, I shall consider only those which are relevant to our students and this dissertation.

If a student experiences successful outcomes and attributes these to an internal, stable locus (innate ability) and/or an internal, controllable locus (effort,

perseverance) then the resultant affect will be *pride* and *self-esteem.* The student will develop a healthy sense of academic self-efficacy and confidence.

If a student experiences repeated failure, he or she will develop a sense of *shame* if the failure is ascribed to an internal, stable and uncontrollable cause (e.g., lack of ability). At best, such feelings of shame lead to decreased motivation. At worst, however, they can result in stress, anxiety and avoidance behaviour (Ashcraft & Moore, 2009:201). Furthermore, this sense of shame can deepen into a feeling of hopelessness and resignation if future outcomes are anticipated to be as negative as past outcomes (Weiner, 1985; Hall et al., 2004). Such an attitude results in an ever lower sense of self-worth and self-efficacy brought about by a 'maladaptive failure attribution', as Haynes et al. call it (2009:234). 'Maladaptive failure attribution' refers to an individual having attributed his or her failure to the wrong causes, such as lack of ability in the case of Mathematics.

If an outcome is ascribed to an internal, unstable and controllable cause (e.g., lack of effort) the student may experience *guilt* feelings. According to Weiner, it has been documented that feelings of guilt lead to increased motivation and effort as the student understands that future success is within his or her reach.

To sum up, Weiner (1985:566) believes that "expectancy and affect are presumed to determine action" - or, of course, lack thereof in the case of avoidance behaviour, as documented by Ashcraft and Moore (2009:201) with regard to maths anxiety.

I, therefore, contend that, in the case of students' disappointing history with Mathematics/Numeracy, expectancy and affect would influence each other negatively and create a downward spiral. If one does not expect future improvement, one tends to be disheartened and unmotivated. Emotional negativity, in turn, paints future outcomes in a bleak light. This vicious circle plays an important and almost paralysing role in students' attempts at mastering a subject (Haynes et al., 2009:234). In our case, that would be Numeracy.

Consequently, in order to help students break out of the downward spiral of negative expectation and subsequent confirmation, one needs to convince them that they had fallen prey to 'maladaptive failure attribution'.

2.4.3. Attribution retraining treatments

Attribution retraining (teaching students that the root causes for their academic underperformance are often unstable and, therefore, controllable, rather than stable and uncontrollable) plays a pivotal role in academic 'rehabilitation' (may I add: intellectual rehabilitation?) which cannot be underestimated or overemphasised.

The Rationale

Weiner (1985:566) then turns to 'achievement change programs' which he describes as "popular therapeutic treatment[s]" and which endeavour to correct students' maladaptive attributional thinking. He discusses empirical evidence, collected by other investigators in the field, which indicates that, if students can be persuaded to believe that their persistent failure is not due to internal, stable and uncontrollable causes, but to internal, unstable and controllable causes, such as insufficient effort, poor strategy or other non-permanent obstacles, then success is attainable. The realisation that failure is not a fixed given, that improvement is possible because the underlying causes of failure can be eradicated, motivates students to renew their efforts, which leads to a rise in expectancy – even if success is not attained immediately. Dweck (1988, 2005, 2008) speaks of a mind shift from a 'fixed mindset' (which implies a stable, uncontrollable cause, namely a fixed 'intelligence') to a 'growth mindset' (which implies an unstable, controllable cause, namely the ability to expand one's intellectual capacity).

In conclusion then, Haynes et al. (2009, 237-238) argue that attribution retraining treatments aim at:

(i) persuading students to accept and believe that their lack of academic success is not due to internal, stable and uncontrollable causes, but to internal, unstable and controllable causes, such as effort, strategy and perseverance;

(ii) thus affording students a sense of control over future outcomes and, consequently, raising their level of expectancy, which, in turn…

(iii) … should motivate them to exert greater effort, be open to new and more effective strategies, and develop greater perseverance in their studies.

Unfortunately, the last point does not seem applicable to many of our students who certainly have persevered and put in great effort, and who were also willing to engage with new and more effective strategies in Numeracy, but who, in

stress-inducing situations, reverted to old and ineffective strategies. These observations will be discussed when I elaborate on my reservations concerning the established attribution retraining treatments.

2.4.4. Formats of attribution retraining treatments and their outcomes

Haynes and her colleagues (2009) produced a detailed and extensive review of three decades of research into and various experiments with attribution retraining treatments. After I have examined in some detail the first attribution retraining treatment administered by Wilson and Linville (1982) I shall briefly discuss subsequent such treatments with regard to the following three aspects:

- according to which criteria the students were chosen,
- the format of the treatments, and
- the recorded outcomes.

(a) Wilson and Linville's attribution retraining treatment model

Wilson and Linville's (1982) attribution retraining treatment is a prototype of all later such treatments (Haynes et al., 2009). However, the content of these later treatments has progressively focused more on very specific attributional aspects which rendered students vulnerable to failure and attrition.

Wilson and Linville chose freshmen who had been disappointed by their own underperformance at the end of their first semester as they felt they could have done better in their assignments and tests. This implies that the students felt that improvement and success were within their reach (internal, controllable locus).

The students in the experiment were given a pamphlet which told of senior students who had also struggled in their freshman year, but had improved their performance over time and were doing well in their senior year at university. The freshmen were then shown a videotape in which senior students discussed their original academic struggles and disappointments and how, in time and with perseverance, their results had improved. (The videotaped discussions had been scripted to consolidate the content of the pamphlets.) The freshmen were also asked to note down to which unstable causes they attributed their own disappointing academic performance.

The researchers followed the students' progress at university and established that their performance improved to the point where even at the end of their second academic year, fewer students who had been exposed to the treatment

dropped out of university than did among the students who had not received the treatment. Wilson and Linville's conclusion, in Haynes et al. (2009:241) words, was that: "… a brief one-time exposure to the AR videotape treatment could result in dramatic differences to students' actual academic profile up to 2 years later."

(b) Subsequent attribution retraining treatments

Judging by Haynes and her colleagues' review (2009), later treatments followed much the same basic format, as indicated below.

The type of students chosen:

The criteria according to which the students were chosen for attribution retraining treatment were as follows:

(i) students who employed "self-protective external attributions' (Haynes et al., 2009:241, citing Noel et al., 1987:152), such as luck or ineffective lecturers,

(ii) low-control students who fell prey to the belief that they had little or no influence over their new and unfamiliar environment, as well as over their academic outcomes (Perry, 1991; Schulz & Heckhausen, 1999, as cited in Haynes et al., 2009:229),

(iii) students with 'maladaptive failure attributions' (Haynes et al., 2009:234), who had habitually attributed failure to internal, stable and uncontrollable causes (e.g. low ability),

(iv) students with unrealistically optimistic expectations of success (Ruthig et al., 2004; Haynes et al., 2009), and

(v) students who for any of the above reasons, or others, exhibited a very low level of motivation (Haynes et al., 2009:234).

The general format of the treatments offered

Wilson and Linville's model was adopted as more or less the standard format. Attribution retraining was offered in laboratory settings, as well as field settings. The students were chosen according to various combinations of attributional causes or other personality traits which could render them vulnerable to failure. The video-taped material and/or handouts would focus on the combination of causal attributions according to which the students had been chosen. There would always be a control group of non-vulnerable students who would be given the treatment and/or a group of vulnerable students who would not be given the

treatment. The treatments would always be followed by tests either directly after the treatment and/or a week or so later, and then again a few months later.

Attribution retraining treatment outcomes

Studying Haynes et al.'s (2009) review of the history of attribution retraining leads one to conclude that, no matter which format of treatment was administered, students at risk for a variety of reasons, as discussed above, benefited from these treatments in the short- and the long-term. Wilson and Linville's results have been mentioned above. Hall and his colleagues (2006) found that students with a low sense of perceived control improved their marks by 10% in their final grades. Haynes et al. (2009:244) report similar results and note that the treatment achieved improvement in students' *mastery motivation*, the motivation to learn, understand and master content (2008:205).

To sum up, Haynes et al.'s review concludes that "both early and recent AR research provides 3 decades of support for the effectiveness of attribution retraining treatments in higher education settings" (2009:249). Furthermore, Ruthig and her fellow researchers (2004:723) note that students, who had received the treatment, did well in all their subjects and obtained a satisfactory aggregate comprised of an entire year's results across all subjects (the American GPA). Not just that, but the treatments also reduced the number of withdrawals from subjects during the course of an academic year.

At the same time, many researchers discussed in Haynes and her colleagues' review reported that students, who were not at risk for any of the reasons for which attribution retraining is administered, did not show any significant improvement in their grades after having had the treatment.

2.4.5. Reservations regarding conventional attribution retraining treatments

In the literature on attribution retraining studied for the purpose of this dissertation, no mention has been made of the scholastic background from which academically vulnerable students came.

(a) Permanent versus temporary perception of low academic control

With regard to the psychosocial variable of *perceived control* it is important to ask the following question:

Did the freshmen develop a maladaptive sense of control only once they had entered university? Haynes et al. (2009:237) discuss the "shift from high school to college [as] a developmental transition" which, in the face of many new and challenging factors, can create in students "the perception of the college environment as a *low control setting*". This is borne out by the findings of other researchers as well (Perry et al., 2005; Haynes et al., 2008) and would imply that these students had felt in control in their pre-university environment.

In fact, Haynes et al. (2009:228) discuss what Perry and his colleagues (2001) call the 'paradox of failure': in the United States, criteria for admission to university have become ever stricter, and yet, according to Perry et al., "disproportionate numbers of *bright* students" (my emphasis) fail their first year at university or drop out along the way. Haynes et al. (2008:204) concur with this finding when they report that freshmen had to deal with "the consequences of *unexpected* failure" (my emphasis) at the beginning of their first year. Some of these freshmen even admitted that they had managed to obtain A+ results at school with very little effort on their part.

The above observations made by researchers lead one to assume that the sense of low control was a new experience for first-year students, and a brief attribution retraining treatment helped them reclaim control over their new situation. This is further supported by the fact that the video-taped interviews and discussions during the treatments always emphasised the challenges associated with the freshman year. There is no mention of pre-college academic difficulties. However, pre-university academic difficulties are a very real and deep-rooted problem with many South African first-time students.

(b) Mathematics-related perception of low control

One should also consider the scenario in which students arrive at university with a *general* sense of being in control - except for a particular area of weakness. In the case of my research this is the area of basic mathematics in which many

students feel they lack control because of years of disappointment and frustration. Here attribution retraining would have to be tailored to the subject of Numeracy.

(c) Beliefs regarding mathematical ability entrenched in neuronal networks

Research into the plasticity of the brain, which will be discussed below, has established that neuronal networks in the brain are created by experiences, information assimilated, reflections on these, and skills practised. Recurring thought patterns and self-talk also create such networks – either negative ones or positive ones. Therefore, a student with a humiliating history of dealing with Mathematics/Maths Literacy at primary and/or high school – and the resultant sense of failure and academic inadequacy – cannot free his brain from the firmly established negative pathways regarding his lack of competence in the realm of numbers within a few days. A once-off attribution retraining treatment, the duration of which, according to Hall et al. (2004:600), is roughly 30 minutes, cannot 'silence' negative neuronal networks and create positive ones within a brief period of time. In fact, in my classes, I have observed very cynical, if not angry, reactions to my suggestion that competence in basic mathematics is achievable by all, is necessary for a responsible life and career, and can be attained within a few months.

My reservation is hinted at by Dweck (2008:7) as well when she recommends that the entire academic environment of an institution of learning should support and guide students in their effort to make the paradigm shift from a fixed to a growth mindset (on the basis of having been taught about the brain's plasticity) – and thus gain ground in the Maths/Science domains. Dweck records an improvement in the students' results during the first semester and suggests that these students should be monitored beyond the semester examinations to establish whether the effect of the improvement would last. My quantitative data of Year B and a later year indicate a drop in Numeracy assessment outcomes after July as we had no time for further work in this component of my subject. I would like to interpret this as a sign that correcting students maladaptive causal attributions concerning "maths" takes even longer than just four months.

(d) Motivation/effort-enhancement, strategies and perseverance

Finally, Haynes et al. (2009:243) report that attribution retraining treatments focus predominantly on motivating students by impressing upon them that greater effort, better strategies and greater perseverance would lead to better grades. The positive results reported by researchers support this strategy.

However, the majority of my students have encountered and dealt with serious challenges in order to enter university and have, therefore, not lacked motivation, effort or perseverance. Many of them had invested great effort in their Mathematics at school - and had still done poorly. Faced with the fact that, in Professional Business Practice, they yet again had to deal with numbers, they worked just as hard. I was regularly asked for sheets of additional exercises because, I was told, that was how they had managed to pass Mathematics at school. Working hard against all odds should, therefore, also prove that these students did not lack perseverance.

Regarding the adoption of new and more effective strategies I wish to refer to Garner and Alexander (1989). In their paper these two researchers pose the following question (1989:149) “How can we expect to change well-established maladaptive routines with relatively brief instructional programmes?” Although this question pertains to issues around standardised tests, it certainly speaks to my observations of my students. Despite my having taught the students new and more effective methods of calculation, those who suffered from exam stress or had a low sense of self-efficacy, would revert to old and trusted, but ineffective, strategies when under pressure because of time constraints and/or the fear of poor performance. Garner and Alexander give an apt description of ingrained and outdated strategies when, referring to Brown and his colleagues’ (1983) work, they speak of these strategies as having been “welded to the original instructional setting” (1989:149). They would agree that a *brief* treatment cannot possibly have the desired results when administered to students held back by old and ‘trusted’ strategies.

Guided by the considerations mentioned here above, I wish to put forward a set of interventions which, I hope, will go some way towards establishing and refining a new and extended programme of attribution retraining. This would be in keeping with the direction recently taken by international researchers.

2.5. A new form of attribution retraining: a 'cognitive behavioural approach'

Ruthig et al. (2004:727) suggest that "a new form of AR would be more appropriate". Furthermore, although Koles and Boyle (2013) also reported positive outcomes after the standard treatments, they do state that attribution retraining researchers of the 21st century are adopting a cognitive behavioural approach (Toland & Boyle, 2008), or consider a psychotherapeutic cognitive treatment (Haynes, et al., 2008).

Toland and Boyle (2008:288) define cognitive behaviourism as follows:

> "Cognitive behaviourism rests on the assumption that thinking precedes feelings and behaviour. It is the appraisal that a person makes of a situation that leads to emotional and behavioural reactions. These appraisals can be influenced by inappropriate beliefs, cognitive distortions and automatic thoughts. *Changing the thinking will lead to a different response*." (my emphasis)

The attribution retraining interventions implemented in our department over the past five years have done that, namely adopt a cognitive behavioural approach.

Students burdened with a sense of low self-efficacy in mathematics perceive the prospect of having Numeracy classes and assessments as threatening. They would experience strong negative emotions and react in various counterproductive ways (see # 2.5.2.b.iii. below). Their reactions are prompted by the belief that mathematics is for the gifted few ('inappropriate beliefs') – which excludes them! Mathematical concepts are deemed difficult to grasp, which their poor track record has seemingly proved to them, and these concepts can only be mastered by adequate repetition of exercises ('cognitive distortion'). Their negative self-talk would be set in motion like a tape-recording (the 'automatic thoughts').

My intention with the modified and extended intervention programme was to alter the students' maladaptive thinking patterns and thus their responses to the Numeracy module and all it entailed. I included lessons on the neuronal networks of the brain and the cognitive mechanism of the working memory, as well as meta-cognitive skills, to allow our students to reclaim control over their academic life. It is my endeavour to devise a set of attribution retraining interventions which

will hopefully afford first-time students in South Africa, with their particular scholastic and socio-economical background, a smoother and more successful academic transition from school to university in general, and will foster in them the conviction that epistemological access to Mathematics/Numeracy, in particular, is within their reach.

In order to explain the several interventions which, together, make up the attribution retraining programme which I offer our students, I need to digress and discuss, briefly where possible and in very much non-neuroscientific terms,

- the plasticity of the brain,
- the working memory (and its cognitive processes),
- the complexities inherent in mathematical computations,
- maths anxiety and its effect on the working memory.

Teaching the students about the plasticity of the brain and the information processing mechanism of the working memory make up the first two interventions which concentrate on teaching cognitive skills. The interventions regarding Kolb's experiential and reflective learning cycle and Meyer and Land's threshold concepts introduce the students to meta-cognitive skills.

2.5.1. The plasticity of the brain

An in-depth study of the synaptic learning mechanism gathered momentum in the first half of the 20th century (Tokuhama-Espinosa, 2011a). Hebb (1949), one very influential proponent of the link between brain, science and learning, formulated the Hebbian synapse rule: Neurons that fire together, wire together. One example of such 'firing' and 'wiring' together would be if certain emotions were felt regularly in connection with certain experiences. Tokuhama-Espinosa (2011a) goes on to give an example: If a pupil has had regular negative experiences with a subject, such as Mathematics, s/he would develop maths anxiety, which would later be triggered automatically, whenever the scholar (or now student) is confronted with numbers. (Comments from my students: "I was worried and my brain shutt (*sic.*) out." and "I was shocked and had fear.")

Brown, Kairiss, and Keenan (1990:477) summarise Hebb's 'postulate of learning' as follows - here formulated by Stent (1973:62):

> "When an axon of cell A is near enough to excite cell B or repeatedly or consistently takes part in firing it, some growth process or metabolic change

> takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased."

Ever since the 1980s, research into the link between neuroscience and learning has moved into the foreground; so much so that the 1990s were called the Decade of the Brain (Tokuhama-Espinosa, 2011b). Hebb's 'postulate of learning' inspired extensive research into the development of neuronal networks, and his assumption that there is a ''growth process or metabolic change" that takes place in the cells involved in 'firing' has been re-formulated into "memory [that] is associated with use-dependent synaptic modification" (Brown et al. 1990, 475). Rosenzweig and Bennett (1996:61) speak of "use-induced brain plasticity".
Hebb's discussion of the "growth process or metabolic change" in the cells (or: synaptic modification) is summed up in Zull's statement "Learning is physical - we can understand!" in his book *The Art of Changing the Brain* (2002:1). Zull (2004) defines the brain's plasticity as the brain's ability to change its wiring continuously throughout one's life. He speaks of two vital elements which lead to such changes in the brain:

Practice: "Neurons ... possess biochemical pathways that make them grow and reach out to other neurons." If these neurons fire repeatedly, they will connect with each other and form neuronal networks, and the more often the specific activity is repeated, the stronger the neuronal networks become. Zull writes: "These networks are the physical equivalent of knowledge, and the change in the connections that make up the networks is learning" (2004).

Emotion: Regarding emotion, Zull refers to Brembs et al. (2002) who state that, when emotional chemicals are present at the time of specific neural activity, "synapse strength is modified and the responsiveness of neuron networks can be dramatically changed" (Zull's words, 2004).

Finally, Zull (2002:114-122) describes in some detail how neurons may be stimulated to fire more rapidly and consistently (growing stronger neuronal networks) and, conversely, may fire ever less frequently until they, and their networks, grow weak and even 'silent'. Diamond's illustration below depicts such progressive or regressive development in brain cells.

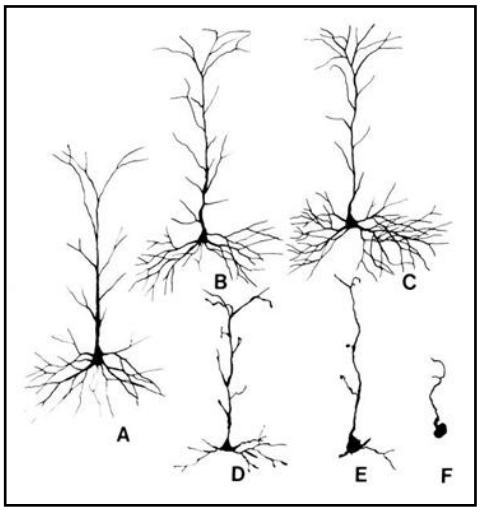


Figure 2.1.: Diamond's illustration of the change in cortical pyramid cells

(Diamond, 2001)

To quote Diamond's caption to the above sketch:

> "Two possible patterns of age-related alterations in cortical pyramidal cells. The normal mature neuron (A) may show regressive dendritic changes characterized by loss of basilar dendritic branches and eventual loss of the entire dendritic tree (D, E, F). Other neurons (B, C) may show progressive increase in dendritic branching. Drawing based on Golgi impregnations."

Although Diamond's illustration refers to *age-related* changes in mature neurons, this illustration is taken from her article on the 'response of the brain to enrichment' (Diamond, 2001). I wish to suggest that this illustration would also reflect Zull's explanation of why neurons may grow stronger or weaker through regular (or ever less regular) 'firing' activities, as touched upon above. Furthermore, Diamond's article discusses neuronal changes in rats, but the discoveries reported upon have long since also been studied, and verified, in humans as well (Rosenzweig & Bennett, 1995:61ff; Schlaug, 2005; Kleim & Jones, 2008).

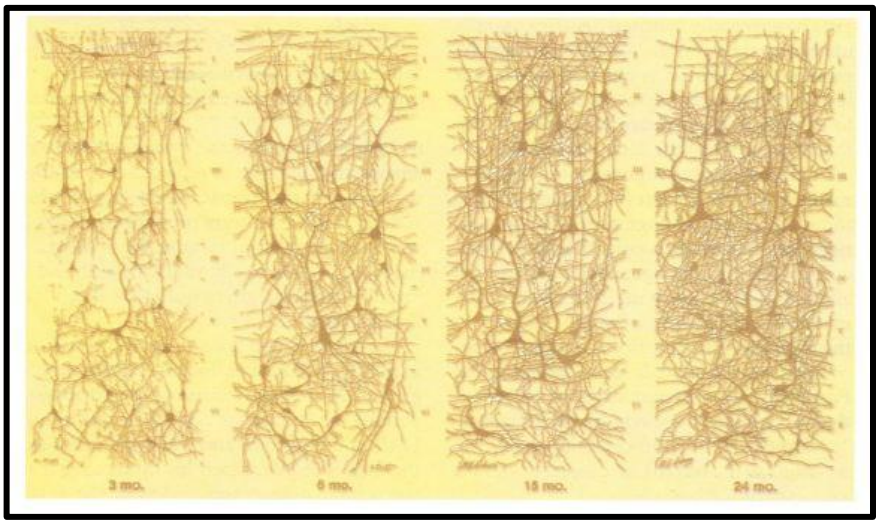


Figure 2.1: Growth and development of neuronal networks in children aged 3 – 24 months

(Zull, 2004b)

The above image (Figure 2.2) shows the development of the brain's ever more complex neuronal networks as a young child learns. The imaging was done at the ages of 3 months, 6 months, 15 months and 24 months. This development of neuronal pathways and networks does not stop as we carry on acquiring knowledge and skills throughout our lives, as indicated by Diamond (Figure 2.1).

As we focus on any intellectual or physical knowledge- or skill-acquiring activity, the dendrites in the cerebral cortex 'sprout' new spines which allows for a multitude of new connections between neurons to be formed, thus growing and strengthening neuronal networks. Figure 2.3. illustrates how, after just five minutes of focusing on a task, dendritic spines start to develop (left image); after 20 minutes they are clearly visible (right image). Furthermore, the more powerful the emotions (positive or negative) which accompany such 'firing and wiring', the stronger and more permanent these networks become (Zull, 2004a).

The above led me to conclude that the brains of first-year students with a personal history of failure in Mathematics must have developed negative neuronal networks regarding their seemingly poor cognitive ability in the realm of mathematics. These neuronal networks would have been strengthened by repeated poor results over the years of primary and/or high school education, and cemented by a range of emotions from disappointment and frustration to guilt, shame, anger and resignation (Weiner, 1985:563). It would take more than

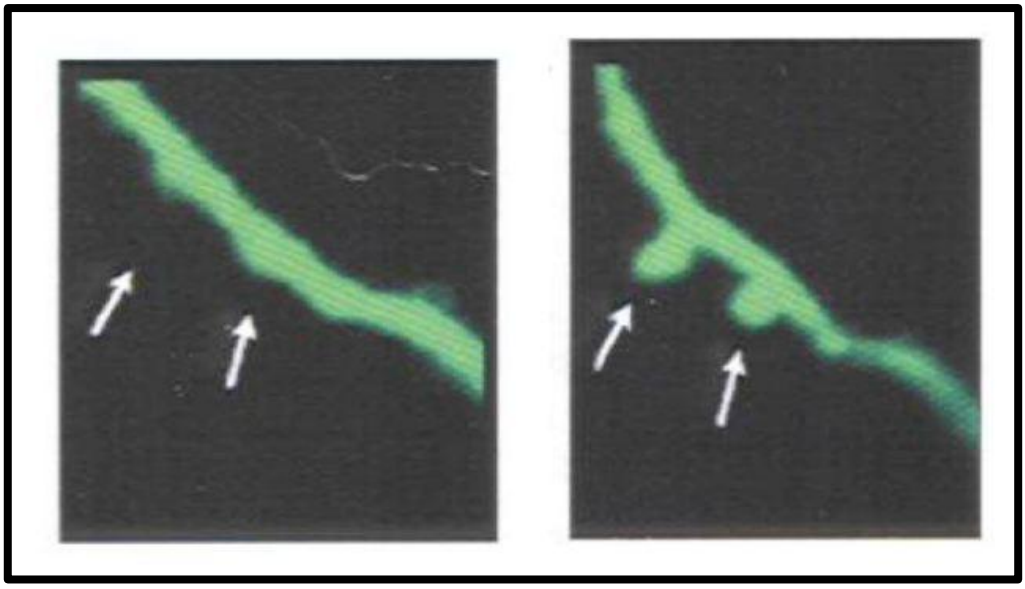


Figure 2.3.: The development of new dendritic spines

(Zull, 2004b)

a 30-minute intervention to change the deep-rooted perception of cognitive inability in Mathematics to one of cognitive ability.

2.5.2. The working memory

In order to appreciate some of the factors which lead to underperformance in Mathematics or Maths Literacy at school level, one needs to understand the cognitive processes of the working memory and how these are influenced – positively or negatively - by the proximal environment of the classroom, as well as conscious or subconscious attitudes and behaviours of scholars themselves. If these cognitive processes can be explained to students in layman's terms, they may, in retrospect, come to realise that it was not an intellectual deficiency on their part, but causes which were partly external (and often uncontrollable), but also very much internal and controllable, which hindered them from achieving *at least satisfactory* results in Mathematics.

The question of why some persons achieve mathematical excellence, and many others do not, does not play a role here, and will, therefore, not be considered. Gardner (1993, 2004) has written extensively on the subject of multiple intelligences. However, for a career in design it is not higher mathematics that is needed, but basic and applied numeracy. It is this basic quantitative literacy which should be - and needs to be - within the reach of every person.

(a) Cognitive processes of the working memory

One needs to understand how the working memory functions to appreciate the negative effect which distractive emotions, behaviour and environments can have on our ability to apply ourselves to a task. In particular, much research has been done over the past three decades into the relationship between the working memory, students' approach to Mathematics and their resultant performance (Hopko et al., 1998a; Kellogg et al., 1999; Ashcraft & Kirk, 2001; Hoffman, 2010; Raghubar et al., 2010).

Raghubar and his colleagues (2010), in their review of studies done to ascertain whether there is a connection between working memory and mathematical processing, and if there is, to understand that connection, have discussed various working memory models. However, the model which this dissertation wishes to describe is Baddeley's multi-component model (Baddeley & Logie, 1999).

Working memory model

According to the multi-component model, the working memory is

> "a limited capacity central executive system that interacts with a set of two passive subsystems used for the temporary storage of different classes of information: the speech-based phonological loop and the visual-spatial sketchpad." (Raghubar et al., 2010:111)

The phonological loop stores verbal information for a short period of time, and the visual-spatial sketchpad stores visual-spatial information temporarily[1]. The central executive is seen as co-ordinating the activities of these subsystems, but also "*devotes some of its resources* to increasing the amount of information that can be held in the two passive subsystems" (Raghubar et al., 2010) (my emphasis).

Raghubar and his colleagues then briefly discuss Engle et al.'s (1999) single-capacity view of the working memory, the single-capacity being the central executive. The "*variations in working memory across individuals reflect the*

[1] Baddeley (2002) has reviewed his and Hitch's (1974) original multi-component working However, for the purpose of this study the finer details are not necessary. However, for the purpose of this study the finer details are not necessary. The general concept of these two sub-systems still holds true.

capacity of the central executive" (my emphasis). Furthermore, Engle and his fellow researchers attribute the following responsibilities to the central executive: "*inhibition of irrelevant information, task switching*, information updating, goal management, and strategic retrieval from long-term memory" (my emphasis) (Engle et al., 1999, in Raghubar et al., 2010:111). In other words, the central executive is primarily responsible for attentional control. Thus, the effectiveness of an individual's working memory, as well as its capacity for holding and manipulating task-relevant information, is more dependent on the effectiveness of the attentional control capacity of the central executive than on the ability to hold a certain amount of information during the performance of a task.

If one overlays this single-capacity model onto the multi-component model, then a very distinct picture of the central executive emerges: it regulates attentional control in that

- it inhibits irrelevant information from claiming attention which should be focused on the present task,
- it draws from the long-term memory, and other sources, information which needs to be at hand for the task,
- it allows attention to be switched from one aspect of the task to another, or even from one task to another secondary task (multi-tasking) if and when this is necessary, and
- it monitors the progress made towards the goal of the primary task.

Figure 2.4 illustrates the multi-component model of the working memory. The choice of background colour in the illustration reflects that of the central executive to indicate the concept of a single-capacity model with the central executive representing that single capacity (Engle et al. 1999).

The effect of distracters on the working memory

According to Derakshan and Eysenck (2009:168),

> "....there is a fundamental distinction between performance effectiveness (quality of performance) and processing efficiency (the relationship between performance effectiveness and use of processing resources), and that anxiety impairs processing efficiency more than performance effectiveness."

Derakshan and Eysenck (2009:169) briefly trace the development of research into the central executive's attentional control which affects the cognitive

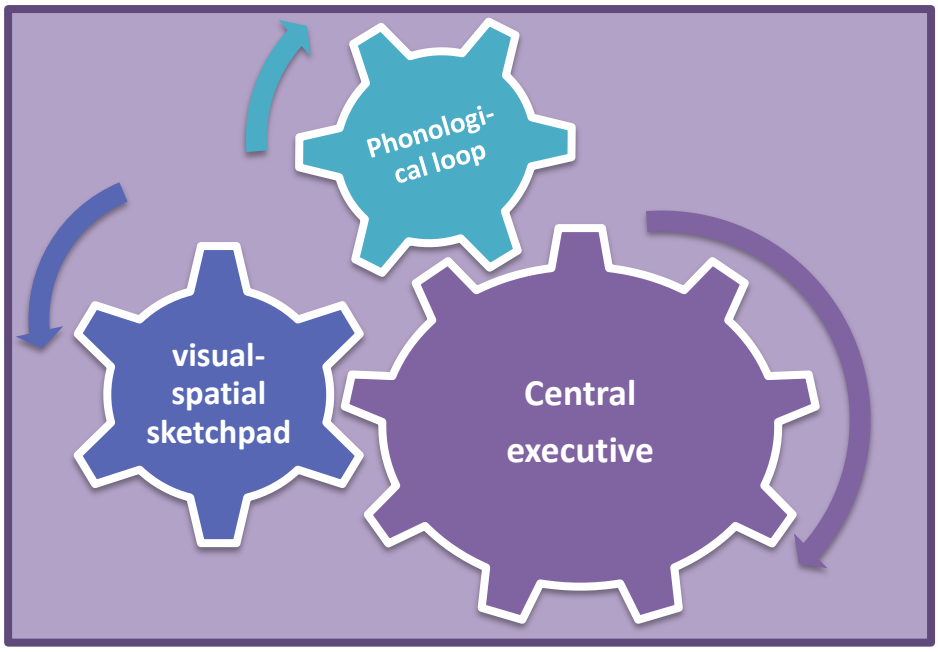


Figure 2.4: Illustration of the multi-component model of the working memory

(Illustration: Rohlwink, 2013)

Derakshan and Eysenck (2009:169) briefly trace the development of research into the central executive's attentional control which affects the cognitive processing ability of the working memory. The research delved into the link between task-irrelevant thoughts, emotions and information (distracters) and the working memory's ability to focus on a given task and produce the desired outcomes. Because the distracters mentioned here lie at the heart of students' difficulties to focus on their Numeracy tasks, I shall briefly elaborate on the research done into distracters and their impact on the central executive's attentional control capacity.

Cognitive interference theory

Derakshan and Eysenck (2009) report that research into the effect which anxiety has on cognitive processes dates back to the 1980s. According to these two researchers (2009:169), Sarason (1988) formulated the *cognitive interference theory*. According to this theory, task-irrelevant thoughts (e.g. apprehension, doubt, memories of past failures) reduce the amount of attention which the anxious person can invest in the task at hand.

Processing efficiency theory

However, according to Derakshan and Eysenck (2009:169), Eysenck and Calvo (1992) established that the cognitive interference theory needed to be refined:

Was it performance effectiveness or processing efficiency that was impaired by intrusive thoughts? Researchers had observed that individuals prone to self-doubt would compensate by using greater processing resources and/or more time in order to achieve the desired outcomes.[2] The assumption was, therefore, made that intrusive thoughts adversely affect processing efficiency more than performance effectiveness (Derakshan & Eysenck, 2009:169). This approach was summarised in Eysenck and Calvo's (1992) *processing efficiency theory*: A student's underperformance in a task was now directly linked to how much time and effort (resources) his/her working memory system needed to perform at the expected or desired level. Consequently, according to Eysenck et al.'s (2005) research, as noted by Derakshan and Eysenck (2009:170), distracters encroach on the available capacity of the central executive.

Attentional control theory

The central executive regulates attentional control as described above. However, according to Yantis (1998), as discussed by Derakshan and Eysenck (2009:170), there are also two separate and opposing attentional systems at work in the central executive:

- a 'top-down goal driven or controlled process', and
- a 'bottom-up stimulus driven process'.

As the above descriptions of these processes indicate, the former refers to the central executive's attention focused on a task because the person is determined to perform as well as is possible. The person applies himself consciously to the task at hand and employs his working memory constructively. The latter process refers to the central executive's reaction to and engagement with non-task specific stimuli (distracters) (Corbetta & Shulman, 2002). These two processes vie with each other and are, under normal circumstances, regulated successfully by the central executive.

However, under adverse conditions (such as negative emotions), the 'bottom-up stimuli-driven process' may disrupt the balance between the two systems and compromise the efficiency of the goal-driven system (Corbetta & Shulman, 2002). Translated into a class- and performance-related context, this means that, if students feel threatened by a situation, such as being expected to perform well in

[2] I have observed such behaviour in my classes and will discuss it under 'Coping and compensation strategies'.

an area in which they have experienced only disappointment, their central executive will be compromised by intrusive and negative 'bottom-up' stimuli which will demand greater attention than the student's 'top-down' goal-driven willingness to do well in the task. Thus the 'top-down' attentional focus needed for efficient cognitive performance is reduced.

Inhibition theory

Hopko and his fellow researchers (1998a:345) discuss an attentional suppression/inhibition mechanism which should minimise the attention paid to distracters (the attention paid to bottom-up stimuli) so that sufficient attention can be directed at the performance of a task (the top-down goal-driven process). Engle et al. (1999) mention this inhibition of irrelevant information (and its negative impact on attentional control capacity) as one of the vital functions of the central executive, as noted above. Hopko et al. (1998a:346) then suggest that the concept of an inhibition theory would most accurately define the problem at the core of the central executive's attentional dilemma.

Furthermore, Derakshan and Eysenck (2009:171) add that distracting stimuli can be external (e.g., noise, discomfort) or internal (e.g., worry, self-doubt); also, that the negative impact of such stimuli is greater if they are threat-related. In fact, according to Derakshan and Eysenck, Bar-Haim et al. (2007) have shown in their research that individuals suffering from trait anxiety are more vulnerable to threat-related stimuli than non-anxious individuals.

Once again, the processing efficiency is considered the domain of the central executive, and anxiety affects its attentional control. In Derakshan and Eysenck's (2009:171) study, a distinction is made between (a) negative attentional control, or inhibition function, which inhibits attention to task-irrelevant stimuli (or distracters), and (b) positive attentional control (shifting function) which focuses on the task-related processes and on smooth switching of attention between and within tasks.

As educators, we, therefore, need to understand that a student's task-performance depends on his or her working memory *capacity*, and the latter is influenced, positively or negatively, by the effectiveness and efficiency of its central executive's attentional control. Furthermore, one needs to keep in mind that the working memory's capacity depends on the amount of *relevant* information which the central executive can hold within its two subsystems. If

some of the capacity is occupied by task-irrelevant data and stimuli (especially threat-related ones), and the attentional control of the central executive (especially its inhibition, as well as shifting/attentional control) is compromised, then the effectiveness and efficiency of the working memory are reduced, and, consequently, the outcomes of a particular task will be less than satisfactory.

Figure 2.5. illustrates how task-irrelevant thoughts and emotions, as well as environmental and personal distracters, can interfere with the central executive's attentional inhibition mechanism and thus reduce the working memory's capacity.

In order to appreciate the effect which maths anxiety has on the effectiveness and efficiency of the working memory's central executive, I need briefly to discuss the inherent difficulties in mathematics.

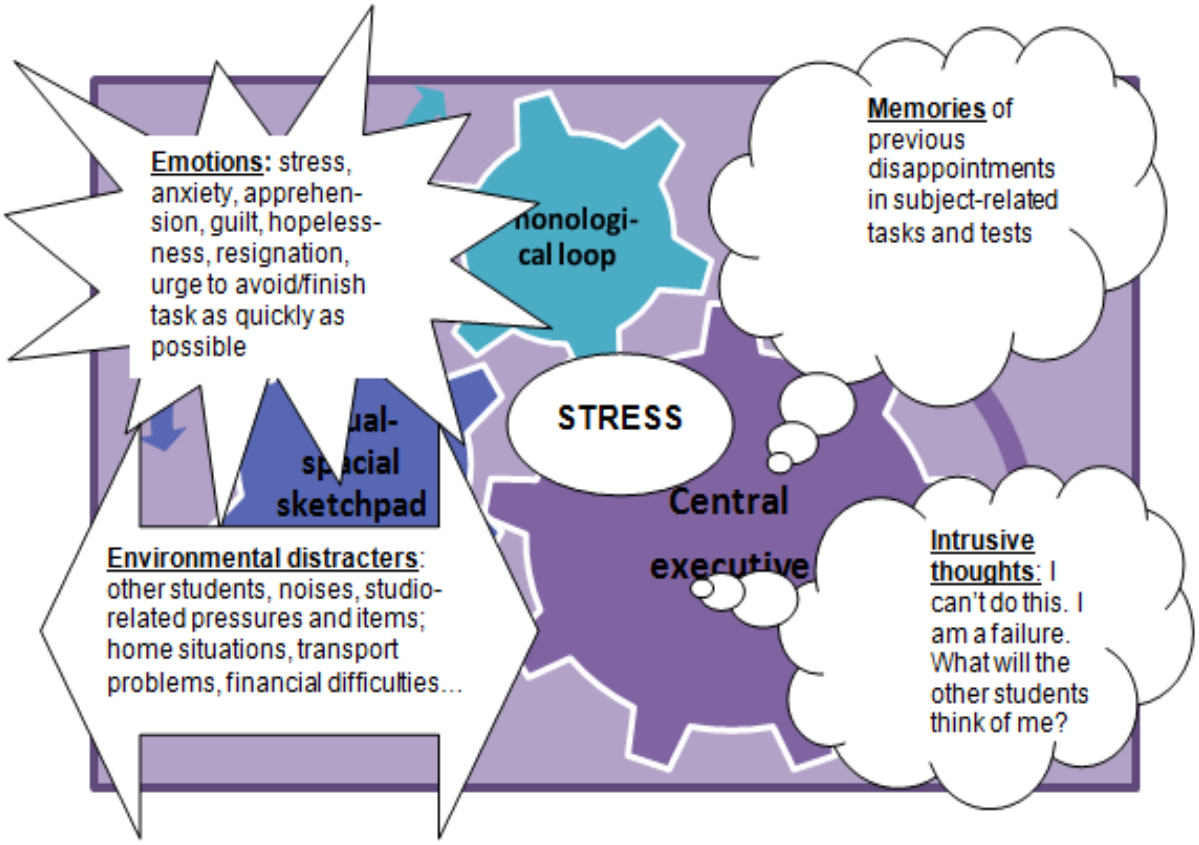


Figure 2.5.: Restricted working memory capacity (WMC)

(Illustration: Rohlwink, 2013)

(b) Maths anxiety and the working memory's central executive system

Weiner (1985:559) speaks of the 'attribution-emotion process', as described above (# 2.4.2.c.). He mentions guilt, shame and, finally, hopelessness and resignation as emotional reactions to repeated failure at a certain type of tasks. In our case, that would be numeracy-related tasks. Such emotions can deepen into anxiety, and, according to Ashcraft and Krause (2007:245), research into the phenomenon of maths anxiety started in the 1970s already. Hopko et al. (2003:649) report that maths anxiety has been included in a range of anxiety conditions called performance-based anxiety disorders. Hopko et al. (1998a) refer to Hopko et al. (1998b) who suggest that "mathematics anxiety be considered a genuine phobia" as it is a learned anxiety and is triggered by stimuli in specific situations.

According to Ashcraft and Krause (2007:243), cognitive literature "shows how critically math performance depends on working memory". They speak of "the cognitive consequences of math anxiety" as an individual's self-doubt, apprehension, fear and, ultimately, anxiety encroach on the working memory's capacity (WMC). This is echoed by Raghubar, Barnes and Hecht (2010:110), as well as Ashcraft and Moore (2009:197). Ashcraft and Moore (2009:198) emphasise that maths anxiety is not the result of a cognitive inability to engage with numbers. However, "maths anxiety *functions* as a disability" (their emphasis) which has negative personal, cognitive and educational consequences.

(i) The complexities inherent in mathematics

According to Ashcraft and Krause (2007:243-247), there are several reasons why, in mathematics, such fears are detrimental to efficient functioning of the working memory:

- Computations involving small numbers can be done with the help of long-term memory retrieval. This method requires almost no working memory capacity and is fast and automatic. However, the larger the operands become, the more WMC is required, as memory retrieval falls away and secondary tasks (e.g. carrying over in addition) demand WMC (See also Ashcraft & Moore, 2009:202).

- Computations with larger operands are also not done as frequently as those with small operands. Ashcraft and Krause (2007:243) speak of the "inverse relationship between problem size and problem frequency". This means that greater effort is required to retrieve necessary information from lower levels in the long-term memory.

- Many mathematical computations require several steps which need to be correctly sequenced to obtain a solution to a problem. This increases the complexity of the mathematical task and, therefore, makes greater demands on the mental working space.

- Furthermore, the more abstract mathematical procedures and symbols become, the more difficult it is for the working memory to store and use such information.

- Finally, still more complex mathematical tasks call for a variety of different types of computations which, in turn, depend on different bodies of knowledge which need to be kept in the working memory, such as geometry, as well as algebra, or a combination of graphs, geometry and algebra (Raghubar et al., 2010:110). Not just that, but, as a student progresses in his or her study of Mathematics, new bodies of information need to be integrated with existing knowledge, and then used in conjunction with each other to solve novel problems. The more advanced such problem solving becomes, the more WMC needs to be available. Ashcraft and Moore (2009:203) speak of a "heavy load on working memory".

(ii) Negative emotions elicited by numeracy tasks

Considering the above discussion regarding working memory capacity it should not be surprising that the more intense negative emotions and intrusive thoughts become, the more difficult it will be for an individual to acquit himself or herself successfully of a mathematical task; so much so, that there is a strong correlation between maths anxiety and maths performance; "the higher one's math anxiety, the lower one's math learning, mastery, and motivation" (Ashcraft & Krause, 2007:245).

Hoffman (2010:278) speaks of an 'intellectual paralysis' caused by maths anxiety and adds that such an anxiety affects persons "irrespective of true ability". The very title of his paper *'I think I can, but I'm afraid to try'* reflects the ambivalence which persons with low self-efficacy beliefs regarding maths experience when faced with mathematical tasks. Ashcraft and Moore (2009:201, 204) go further by adding that their research has shown that not even previous good achievements in Mathematics will abate maths anxiety. They speak of an *affective drop* which refers to underachievement in mathematical tasks due to negative affect and not lack of competence or previous success.

(iii) Coping and compensation strategies

One of the three objectives of conventional attribution retraining treatments is to persuade students to use more efficient study and work strategies than they had

in the past. I have discussed the fact that students who suffer from maths anxiety (or general state or trait anxiety) tend to revert to old and familiar strategies in stressful situations. However, high-maths-anxious students do not only find safety in old and obsolete strategies, they also employ coping strategies, which are counterproductive.

One such strategy is the avoidance strategy (Hopko et al., 2003; Ashcraft & Krause, 2007; Ashcraft & Moore, 2009). Students will come late for classes, they are reluctant to hand in assignments and are tempted to stay away when tasks and tests have been announced (Hall et al., 2004). They will also take their time to settle down to the task or test. Conversely, Hopko et al. (2003:648) note that some students will rush through an assignment or test in order to remove themselves from the stressful situation as quickly as possible, in this way sacrificing accuracy.

Diligent, motivated, though anxious, students, however, will employ a compensation strategy (Derakshan & Eysenck, 2009:169). They will attempt to quieten fears by working particularly slowly and effortfully, thus using an inordinate amount of processing resources. They will read instructions and questions more often than is necessary and hesitate to start answering the questions, because they doubt their own interpretation of the questions and mathematical know-how to do the calculations. They will go over their work several times, second-guessing themselves. This, in turn, limits the working memory capacity and results in additional stress because such students fear that they will run out of time - which they inevitably do (Hoffman, 2010).

(iv) Stereotype threats

Although this dissertation will not delve into stereotype threats, an educator in Mathematics should keep in mind that negative stereotype threats exist.

The most common and widely experienced such threat is the gender stereotype threat. Much has been written about the fact that girls are thought to be less capable at performing well in Mathematics than boys (Ashcraft & Moore, 2009:203; Bonnot & Croizet, 2006; Steele, 1997). It has been established that many girls have internalised this notion to a point where their conditioned low self-efficacy beliefs result in underperformance in Mathematics, even if they have experienced success before (Bonnot & Croizet, 2006:857).

There is also the possibility of socio-economical stereotyping. Jorgensen and Lowrie (2013) posit that failure at school Mathematics may be ascribed to scholars' living in geographically remote areas and/or coming from "low socio-economic status backgrounds" (p. 2). Furthermore, Jorgensen and Lowrie note that both schools in remote areas, as well as those in socio-economically poor urban areas are difficult to staff – and, therefore, often have teachers with little teaching and/or Mathematics experience (p. 2 and 6). The finding that schools in disadvantaged communities become disadvantaged themselves – and will produce disadvantaged young adults - is substantiated by the PISA 2012 report (p. 13) and would certainly apply in the South African context and to the majority of our students at a university of technology. Many of them come from 'previously disadvantaged' backgrounds. The term 'previously disadvantaged' generally refers to a wider set of conditions; however, in the context of education, it would refer to economic and social sub-standards and a lack of adequate schooling (in townships, as well as in the rural areas). The latter condition has been discussed above (# 2.3.1.). Jansen (2012) puts it very clearly: The students who are most disadvantaged by their backgrounds and schooling are inevitably those of colour.

This means that students of colour, especially the observant ones who reflect more deeply upon their life situation, may well have internalised the idea that they have a, possibly insurmountable, disadvantage in the realm of Mathematics. There may, therefore, exist a subconscious perception of socio-economic race-related stereotyping among many students.

(v) Students' perception of low academic control in Mathematics/Numeracy

With regard to Mathematics/Numeracy, Perry et al.'s research (2005:373-377) shows that, if students come to believe that their efforts do not earn them the success which they expect or deserve (or which is expected by the tertiary system), they will conclude that they lack the necessary mathematical ability and will develop a perception of low academic control regarding this subject. This perception may, in the end, deepen into hopelessness (Weiner, 1985:564) and despondency. The sense of being 'out of control' will negatively affect their motivation; they will become less inclined to engage with the subject, will be reluctant to interact with the lecturer, will fail to submit tasks and will, eventually, want to avoid the subject altogether (Perry et al., 2005:377; Hopko et al., 2003).

There are multiple reasons for perceived loss of academic control. In the case of Mathematics/Numeracy there are the issues of novel and/or contextualised (therefore, unfamiliar) tasks, tasks which *seem* to be complex, and tasks (e.g. tests) which need to be completed within a certain time limit, which is problematic for students who were used to very generous time allocations at school level. Furthermore, there is the pressure of having to perform to higher standards coupled with initial more frequent failure (Perry et al., 2005:374; Hoffman, 2010). Ashcraft and Moor (2009:204) add the factor of a 'high-stakes setting'. Students realise the importance of successful performance at university and experience increased pressure to deliver adequately. If they are unsure of their mathematical capabilities, then the added fear of being shown up among 'strangers' as lacking mathematical competencies, and being left behind by their classmates, will deepen their negative affect (Haynes et al., 2009:243).

Hoffman (2010:277) refers to Valli and Buese's (2007) research when he states that there is a "current emphasis on educational productivity". "The ratio of problem-solving accuracy to response time" (OR: "the rate and amount of time or effort needed to attain knowledge") becomes an ever more important concern in higher education. This urgency to produce is passed on to the students of whom the highest possible level of knowledge attainment and performance is expected within certain time constraints and with judiciously conservative expenditure of mental effort. A student with a low sense of self-efficacy in Mathematics is bound to feel out of control, to have lost before s/he has even started to adjust and accept the challenges of Mathematics (or, in our case, Numeracy). According to Ashcraft and Moore (2009:204), such a student will also not be able to profit from class instruction as much as a non-anxious student who feels that s/he is in control. Finally, Hoffman (2010:277) refers to Meece et al. (1990:68) whose research shows that "students' interpretations of outcomes, not the outcomes themselves, have the strongest effects on affective reactions". This means that a student's apprehension regarding numeracy tasks and his or her belief that success is out of reach are the affective factors which will then lead to poor performance - a case of self-fulfilling prophecy which entrenches the perception of low academic control.

2.5.3. Meta-cognitive skills taught explicitly

> "Students who know about the different kinds of strategies for learning, thinking and problem solving

> will be more likely to use them" (Pintrich, 2002:222, as cited by Chick,2015).

Bransford et al. (2004:67) speak of meta-cognition as requiring students to "externalize mental events". These researchers enumerate meta-cognitive activities, such as understanding the nature of learning, how to prepare for successful learning, "identifying and correcting errors", and becoming aware of "one's strengths and weaknesses with specific skills", as summarised by Chick (2015).

If conventional attribution retraining treatments persuade students to adopt new and better strategies in their quest for academic success, then it stands to reason that the best strategies to employ would be those which align as closely as possible with our 'learning organ' - the brain and its working memory. Once students understand '*How people learn: Brain, mind, experience, and school'* (to use the title of Bransford et al.'s book), then they should be able to identify the underlying causes of their academic weaknesses, strengths and errors made - and should be able to rectify that which needs rectifying and further improve on their strengths. Pintrich (2002:223) insists that "there is a need to teach for meta-cognitive knowledge *explicitly*" (author's emphasis) in order for students to acquire, in particular, "accurate knowledge about themselves" as learning individuals.

This explicit teaching of meta-cognitive skills cannot be accomplished in a few lessons (Zohar & David, 2009). Tanner (2012:114) speaks of "building a classroom culture grounded in meta-cognitive strategies".

(a) Free-writing

Free-writing is a concept which has been researched both in psychotherapy and education.

Therapeutic (and ontological) value of free-writing

Elbow (1983:37) postulates that free-writing activates first order thinking which is intuitive and taps into our subconscious. Elizabeth (2008) speaks of free-writing as an exercise during which the writer pens down whatever thoughts, feelings and reactions well up in him or her with no regard for correct language usage. The aim of such an exercise is that the writer silences his or her 'inner-critic'

(Bolton, 1999:120) in order to connect with deep-seated emotions and attitudes towards certain events or subjects. Elbow warns that such writing is guided by personal assumptions, biases and possibly irrational points of view. He maintains that the "chaos and disorientation that takes place when we write" (1973:31) needs to be accepted. In his words (1973:8): "there is garbage in your head; if you don't let it out on paper, it really will infect everything else up there."

Elbow's image powerfully describes the emotional turmoil of apprehension and fear, possibly frustration and anger, often resignation and helplessness, and certainly the maladaptive causal thinking of students with a history of disappointing experiences in Mathematics. For the students it is, therefore, a therapeutic and *liberating* (Elbow, 2000, in Li, 2007:42) exercise to write freely about their relationship with Mathematics/Maths Literacy.

The meta-cognitive gains reaped from free-writing

Li (2007:44) writes about the value of focused free-writing. In this activity, the students are given a prompt or instruction which focuses their writing on a particular topic. In her rationale for free-writing, Li cites Collins (1990:654) who believes that such writing can lead to a greater awareness and understanding of one's own meta-cognitive activities (or lack thereof).

> "By writing down our thoughts we can put them aside and come back to them with renewed critical energy and a fresh point of view. Writing helps us stand outside ourselves." (Elbow, 1983:38)

In an attribution retraining programme it should, therefore, be important for students to be given the opportunity for free 'private writing'[3] in order for them to say all they have ever wanted to say about their interaction with Mathematics (Li, 2007:43). Next, they should be given carefully chosen prompts regarding specific aspects of their history with Mathematics/Maths Literacy. Once they have a better understanding of the brain's plasticity and the working memory's functions, they should be invited to revisit their free-writing with "a fresh point of view" and "stand outside [themselves]" (above quote) in order to realise that, predominantly, the obstacles to their success at Mathematics were internal (or external) unstable and controllable ones - and not an inherent cognitive inability.

[3] 'Private writing', as opposed to 'public writing', is writing which is not shared with the lecturer or the class (Li, 2007).

(b) Kolb's experiential learning cycle

> "Learners, if they are to be effective, need four different kinds of abilities – *concrete experience* abilities (CE), *reflective observation* abilities (RO), *abstract conceptualization* abilities AC), and *active experimentation* abilities (AE). That is, they must be able to involve themselves fully, openly, and without bias in new experiences (CE). They must be able to reflect on and observe their experiences from many perspectives (RO). They must be able to create concepts that integrate their observations into logically sound theories (AC), and they must be able to use their theories to make decisions and solve problems (AE)." (Kolb, 1984:30)
> (author's emphasis)

Kolb's *experiential learning theory* initiated a vast body of research into his concept of the experiential learning cycle. However, according to Atherton (2015), Kolb's theory has also elicited much criticism. I have taken cognisance of the controversies regarding Kolb's experiential learning cycle and learning style inventory, but I do find Atherton's (2009) presentation of Kolb's learning cycle in its basic format of four stages very realistic and useful:

Stage 1: an *experience*,

Stage 2: personal *observation* of and *reflection* upon this experience,

Stage 3: *formulation of a general theory* based on the reflection, or the ability to apply an existing theory to it, and …

Stage 4: … using the gained insight to ensure a future more positive experience (*experimentation*).

Atherton (2013) maintains that "neglect of some stages can prove to be a major obstacle to learning".

The above four stages are reflected in Lee's (2010) report on a reflective journaling project conducted in the Mathematics course for undergraduate Bachelor of Education (Foundation Phase) students at a South African institution of higher education.
The aims of this journaling project were as follows:

(i) Students would become aware of their existing knowledge and skills (*experience*).

(ii) They would, through reflection, come to realise their strengths and weaknesses (*observation and reflection*). Lee (p. 43) mentions Hinett

(2002) who states that students would thus "evaluate their learning experience" …

(iii) ... and make judgements regarding the way forward' (*conceptualisation and formulation of theory*). This would lead to devising better plans for future studies.

(iv) If such plans were then put into practice (*experimentation*), …

(v) … the outcomes should be a more satisfactory (*experience*).

Lee posits that such a learning experience through journaling would encourage students to become independent, self-sufficient and responsible students who come to realise that the locus of control for their successes lies within them (Lee, 2010:46). I would like to suggest that Lee's mention of the *locus of control* completes the circle I started above with Weimer's causal attribution theory.

Implementers of conventional attribution retraining treatments have, in part, ascribed their success to inviting students to adopt new and better learning strategies. However, Sternberg (2001) identifies 13 thinking styles and 15 principles regarding thinking styles, as noted by Coffield et al. (2004). Illeris (2007:17) discusses the issue of "internal versus external learning conditions". My present study does not need to elaborate on these theories. However, considering them and the many hypotheses with respect to learning, one must come to the conclusion that learning strategies should be flexible and multi-faceted in order to be of optimal benefit to the many different kinds of student personalities. Consequently, a very basic application of Kolb's experiential learning cycle with the objective of finding the best strategies for a particular student should be part of revised attribution retraining interventions.

(c) Threshold concepts

One last element in the quest for epistemological access to the core knowledge of any subject - in our case Numeracy - which I would like to discuss in this literature review is Meyer and Land's (2003) idea of threshold concepts.

Meyer and Land (2003:1) postulate that every subject contains concepts ("ways of thinking and practising") which need to be understood and mastered before a student can move on to interact with and comprehend further concepts. Meyer and Land call such pivotal concepts *threshold concepts*. They may be grasped

quickly, but more often than not demand much effort and time to be understood (Meyer & Land, 2003).

Cousin (2006:4) refers to Land et al.'s (2005:59) concept of a 'liminal state' in which a student "oscillate[s] between old and emergent understanding". This space of uncertainty, but also growth, is particularly unsettling if the new knowledge to be internalised is 'troublesome knowledge', as Perkins (1999) labelled it. Perkins distinguishes between several different types of troublesome knowledge:

Ritual knowledge: practised and acquired routines of solving standard problems without genuine understanding

Inert knowledge: knowledge which we have, but hardly ever use

Conceptually difficult knowledge: knowledge which is difficult to grasp and which students often misunderstand (or understand only in part) and then try to master through ritual knowledge (successful mimicry)

Alien knowledge: knowledge which "comes from a perspective that conflicts with our own". Meyer and Land (2003:7) call it 'counter-intuitive' concepts.

Tacit knowledge: concepts which have been accepted and employed implicitly, but have never been made explicit.

Cousin (2006:4) adds that, whereas one student engages with troublesome knowledge and masters it, another "remains in a state of preliminality in which understandings are at best vague". Furthermore, she says that "mastery of a threshold concept often involves messy journeys back, forth and across conceptual terrain" (2006:5).

Although Meyer and Land's formulation of the notion of threshold concepts was an outcome of their research into teaching and learning in Economics, they readily use examples from Mathematics when discussing their theory (2003) and state that mathematicians are aware of the many threshold concepts in their discipline. Meyer and Land (2003:2) quote Artigue's, a professor of Mathematics, idea of "a theory of epistemological obstacles" (2001:210).

It would, therefore, seem that incorporating, as part of one's attribution retraining interventions, discussions on threshold concepts should be a very beneficial

exercise. Anxious students, who prefer to remain in a preliminal state and would rather employ ritual knowledge to "mimic satisfactory performance well enough to pass their assessments" (Atherton, 2010) would need to be convinced that new and better strategies would lead to future success. They would need to accept that being caught in an epistemological 'grey' space, as well as experiencing regular underachievement in mathematical tasks, is not the result of their cognitive inability (internal, stable and uncontrollable cause), but rather the result of moving through a space of conceptual obstacles (external, unstable and controllable cause).

2.6. Conclusion

Learning about learning enhances performance (Watkins et al., 2001). This is the title of their review of close to 100 research studies and sums up perfectly the outcome of these research studies.

''Effective learners have gained understanding of the processes necessary to become effective learners" (Watkins et al., 2001:1) as effective learning "is that which actively involves the student in meta-cognitive processes of planning, monitoring and reflecting" (Biggs & Moore,1993, as quoted by Watkins et al., 2001:1).

Ertmer and Newby (1996) discuss in some detail that such monitoring, reflecting, evaluating and planning are the meta-cognitive skills which expert learners have acquired. Such students are then able to develop a set of effective strategies for better learning, and have the insight to choose appropriate strategies for diverse learning situations, thus transferring learning skills to novel challenges and contexts (Watkins et al., 2001:7). In other words, students must be able to apply meta-learning skills in order to succeed in their studies. For this reason it is also not profitable to teach students generic study skills - divorced from subject context and an understanding of meta-cognitive skills - as an answer to all possible academic challenges (Hattie, Biggs & Purdie, 1996). Specific study skills will be useful only for specific learning materials. As Watkins et al. (2001:2) conclude: "There is no single simple intervention with powerful results."

What emerges from these reports is that students, whether at school or at a tertiary institution, need to grasp the meaning and importance of meta-cognitive

and meta-learning skills in order to develop a repertoire of effective and flexible learning strategies which will lead to academic success.

In the research on attribution retraining, which I have studied, none of the above is discussed. In fact, it is stressed that after "a *brief*, one-time exposure to AR videotape treatment' (Wilson & Linville, 1982, in Haynes et al., 2009) (my emphasis) at-risk students' academic performance improved. Seeing that the selection criteria for admission to American universities are stringent, perhaps students admitted to tertiary institutions come with an at least basic and functional set of learning strategies, and are only temporarily brought out of balance by the demands of this challenging transition, as discussed above. However, many South African students enter tertiary institutions with only the most rudimentary study skills, often consisting of only rote learning and ritual knowledge, as recorded by the Department of Basic Education report (2014) and noted above under the subtitle of *Preparation for the NSC examination* (# 2.3.1.c.).

For the above reasons I contend that a revised and expanded attribution retraining programme is necessary to help our first-time students survive their transition to university and become success stories.

In Chapter 3 I shall elaborate on the philosophy, theories and principles which guided the design and implementation of the extended and adapted attribution retraining programme, as well as on the research design employed.

CHAPTER THREE

RESEARCH METHODOLOGY

The attribution retraining programme under discussion had been devised with very specific objectives in mind (# 4.1.) but its format and implementation had been guided by the needs of the students and the demands of the studio subjects as they presented themselves. The two implementation cycles were thus not structured experiments but quasi-experiments. This has created an unexpectedly multi-faceted scenario to be researched. It has allowed me to examine through various filters what happened in those two years. My research methodology has, therefore, been multi-faceted as well.

3.1. Introduction

This study has several **purposes**. It *explores* the degree to which my attribution retraining programme had an impact on the students' perceptions of their cognitive ability to grasp mathematical concepts and acquire mathematical competencies. The findings would answer the first part of the main research question of "What happened during the two years of presenting an extended and adapted attribution retraining programme?"

It is also an *explanatory* study as I endeavour to find answers to 'Why' and 'How' questions (Gray, 2014:36). The 'Why' and 'How' questions in the case of my research would seek answers to the second part of the main research question, namely "and why did this happen?"

Lastly, it is also an evaluation research (Greene, 1989). It *evaluates* whether the impact of the interventions was positive or negative, and if it was positive, whether it made a significant enough difference to warrant further research and the design of similar teaching modules for other maths-related fields of study as well. The resultant findings would speak to the sub-questions of the research question:

- Which interventions were effective? To what degree were they effective, and why?
- Which interventions were less effective, and why?
- What should be done to render an attribution retraining programme as effective as possible?

Later in this chapter I shall discuss my **epistemological perspective**, which is *constructivist* in nature, as well as my **research philosophy** which is an *interpretivist* one**.** Next I shall elaborate on my **research approach** which reflects a cycle of *deductive and inductive* processes. This dissertation needs to be classified as an ex post facto research, and I would like to view its **methodology** as a *multiple case study* with important elements of *action research*. Having accumulated a considerable amount of data, both quantitative and qualitative, I opted for a *mixed-methods research design* to which "a transformational value- or action-oriented dimension has been added" (Creswell, 2003:168, referring to Caracelli & Greene, 1997:24).

The chapter will then trace the development and implementation of the modified attribution retraining programme, beginning with the **theoretical framework** which underpins it. I approached the remedial teaching of Numeracy from the premise of explicitly teaching the students cognitive skills (the plasticity of the brain and the cognitive processes of the working memory), as well as meta-cognitive skills (Kolb's experiential and reflective learning cycle and the notion of threshold concepts). This approach is advocated by educationists, such as Cornford (2004), Dweck (2008) and Tanner (2012). The logic model which drove the programme is presented in Table 3.1. below, and the various interventions offered to the students are summarised and tabulated in Table 3.2. The method of data collection and processing will be discussed next, as well as the advantages and drawbacks which I experienced while gathering quantitative and qualitative data.

Finally, I shall consider the limitations of this project and discuss my ethical considerations.

3.2. Stakeholders

The stakeholders whom I keep in mind are first and foremost the students I teach. It is their intellectual 'well-being' and academic careers that concern me deeply.

Considering the bigger picture, I view those involved with and those dependent on the successful teaching and learning of Mathematics as stakeholders. Teachers and lecturers of mathematics-based subjects and courses often admit that they are at a loss for helping scholars and students come to grips with

Mathematics. Scholars, who had opted for – or were advised to opt for – Maths Literacy, are barred from tertiary studies which require 'pure' Mathematics. This reduces significantly the number of graduates entering the arena of STEM-related professions.

Finally, in the widest possible sense, society needs to be quantitatively literate. This need has been discussed at some length in Chapter 1. Suffice it here to repeat the following points. The notion that Mathematics is for an elite few blessed with a 'mathematical brain' is a fallacy. Frith et al. (2010) hold "a firm belief that our students should be functional, yet critical, citizens." Jansen (2012) attributes what he calls "the chaos in the land" to a severely inadequate reasoning power among the general population of South Africa which, he argues, is the result of poor quantitative literacy training. Carnevale (in Steen, 2002:8) states that "quantitative literacy is about the democratisation of mathematics". He calls for the "QL movement to focus on egalitarian rather than economic goals."

3.3. Theoretical Background

My teaching has always been guided by the wish to kindle in my students the desire for authentic learning so that they can become contributing members of society and adapt to the constant and rapid changes in all aspects of modern life (UNESCO, 2012; PISA 2012). Such lifelong learning demands the ability to create meaning out of uncertainty and Heraclitean 'chaos' brought about by this change. Constant reorientation necessitates personal evolving and ontological *becoming*. In order to establish whether the extended attribution retraining programme has paved the way towards such personal evolution in my students, I have embarked on this dissertation.

3.3.1. Purpose of the research

The purpose of this research is to answer the research question, namely

"What happened during the two years of presenting an extended attributional retraining module, and why did this happen?"

Answering this question requires finding answers to the following sub-questions:

- **Which interventions were effective? To what degree were they effective, and why?**

- **Which interventions were less effective, and why?**
- **What should be done to render an attribution retraining programme as effective as possible?**

Investigating what happened during the two years of implementing the attribution retraining interventions, as well as to which degree the interventions were effective, necessitates ***exploring*** both the quantitative data which the assessments produced and the qualitative data which were collected by means of various research instruments. Exploration of these data is especially important as the set of attribution retraining interventions implemented is different to the conventional attribution retraining (AR) treatments and, as far as my research could establish, has not been applied in this format to any other teaching and learning situation before[4]. Furthermore, I am also not aware of any attribution retraining research, with relevant data, done in the South African context. According to Gray (2014:36), it is important to ask exploratory questions "when not enough is known about a phenomenon".

For the purpose of lifting out the underlying factors which may have set in motion the shift in the students' performance in Numeracy and their sense of self-efficacy, it is important to discuss the theoretical framework (brain plasticity, the information processing mechanisms of the working memory, and teaching cognitive and meta-cognitive skills explicitly) which underpinned my developing an attribution retraining programme very much based on cognitive behavioural principles. Insight into the above theories is necessary if one wishes to ***explain*** (or interpret) as far as is possible the outcomes of the phenomenon that unfolded in the classes of Year A and Year B:

Gray (2014:34) speaks of the world as being "too complex to be reduced to a set of observable 'laws'." Creswell (2003:164) concurs and refers to Caracelli and Greene (1997) when he states that "social phenomena are so complex, different kinds of methods are needed to best understand these complexities". Nevertheless, by comparing the qualitative with the quantitative data I hope to establish enough correlation to warrant the adaptation of this intervention programme for use in other mathematics-related fields of study.

[4] Dweck (2008) discusses work done with school children, who were taught about the brain's plasticity, and with students, who were taught a growth mindset. In both cases the objective was to improve maths performance. She speaks of "interventions that change mindsets" (p. 6). Dweck mentions researchers who focused particularly on minority groups and students vulnerable to stereotyping. However, she does not refer to attribution retraining itself, and researchers into attribution retraining, to my knowledge, have not yet considered lengthier interventions such as she and her fellow researchers (or I) have implemented.

The question of generalisation requires careful ***evaluation*** of the degree to which two fundamental aims of this attribution retraining programme were achieved: (a) To what extent did the interventions raise the students' sense of academic self-efficacy in the realm of Mathematics – and, therefore, motivated them to improve their mathematical competence which, in turn, would become evident in improved assessment outcomes? (b) To what degree would the interventions induce a paradigm shift in the students (from a fixed to a growth mindset – Dweck, 2005, 2008) so that they would accept and employ the taught cognitive and meta-cognitive skills not only in my subject, but across subjects and future years of study?

The purposes outlined above for engaging in this study lead me to classify the design of my research as being a mixed-methods evaluation design (Greene, 1989:255), incorporating an exploratory, as well as an explanatory (Gray, 2014:36), aspect.

3.3.2. Epistemological Perspective

Gray (2014:19) defines epistemology as "what it means to know". He carries on to state that a constructivist epistemology believes that one constructs meaning from one's experiences of and interaction with the world around one; that persons may arrive at different meanings – and, therefore, different 'truths' – with regard to the same phenomenon. This certainly would apply to students' perceptions of their personal relationship with everything mathematical and their sense of low, average or high mathematical efficacy. Gray (2014:20) speaks of the Heraclitean ontology of 'becoming' and notes that Heraclitus emphasised "formlessness, chaos, interpretation and absence". Certainly many students would identify with the idea of formlessness, chaos and interpretation when reflecting upon their experiences regarding their attempt to *become* mathematically literate. They interpret their inner world of disappointment, and the absence of any inkling regarding how to rectify the situation, as proof of their innate inability to do "maths" (Weiner's concept of an internal, stable and uncontrollable cause!). This is their reality – and their 'truth'. How others, such as teachers and lecturers, perceive the subject of Mathematics is irrelevant to them.

Similarly, I believe that my interventions, and my present research, reflect the same ontological stance. At the time of implementing the interventions, I hoped that my students would *become* more confident in their interactions with

Numeracy, would *become* more cognitively aware, and, therefore, would *become* successful students who felt that they were in control of their academics. However, I could not, to use an analogy, line all of them up in one row of starting blocks, expect them to progress at the same satisfactory pace, and meet them all at the finishing post which they needed to reach in order to be considered numerically literate. The *becoming* numerically literate is an individual journey on which each student experiences different obstacles and successes at different stages, and on which some students make great progress and others drop by the wayside. There are too many variables (situational, environmental and personal) which influence every individual's journey, and their impact is not quantifiable. As much as I would have liked to, I could not control and direct each student's search for personal development. Our experience, mine and the students', of the implementation of the interventions thus contained 'chaotic' and 'formless' elements as well, and it is the quantitative and qualitative data gathered that cast some light on the visible and hidden processes – and the progress! - of the programme.

For the above reasons I also need to approach this research from a constructivist perspective. When I study the data available, I have to keep in mind the situations and circumstances which prevailed at the time of collecting the data.

At the time of teaching the students, I had to establish where they were in their personal and intellectual journey. I had to take cognisance of and try to understand their past experiences with Mathematics/Maths Literacy and the effect these had had on their self-image. I then had to identify existing schemata pertaining to mathematics in the students' minds and start building on to this prior knowledge - however sketchy it may have been (Zull, 2002:91-98). I had to tailor the mode of presentation of the interventions to the emotional and mental receptiveness of the students. It is not possible for such an endeavour to produce data which can be scientifically analysed, verified and quantified by means of carefully structured laboratory experiments. I can compare individual students' assessment outcomes with their written or verbal feedback regarding my interventions to establish to what degree the one validates the other. However, the qualitative data are coloured by personal interpretation, both on the students' part and mine; the quantitative data are coloured by circumstances, as well as by the students' state of being, at the time of the assessments.

Consequently, this research cannot establish certain objective 'truths' regarding the impact which the interventions had on the students' assessment outcomes – even less on their personal academic development. What this research can do is create a graph of 'best fit' from the 'formlessness and chaos' of the teaching and learning that happened in the Professional Business Practice classes of those two years; and the dynamic of and direction taken by this 'formlessness and chaos' can be deduced from the quantitative and qualitative data available. Both the students' and my experiences, as well as the analysis of the data collected and the extensive reading I have done, have allowed me to construct meaning regarding my attribution retraining interventions.

3.3.3. Research philosophy

I subscribe to an interpretivist research philosophy. Davison (1998:3-2) writes the following about interpretivism:

> "Interpretivists contend that only through the subjective interpretation of and intervention in reality can that reality be fully understood. The study of phenomena in their natural environment is key to the interpretivist philosophy, together with the acknowledgement that scientists cannot avoid affecting those phenomena they study. They admit that there may be many interpretations of reality, but maintain that these interpretations are in themselves a part of the scientific knowledge they are pursuing."

As stated under the previous heading, the qualitative data available for this research are coloured by subjective interpretations of what happened during our teaching and learning encounters. My interpretation of the students' interpretations is subjective as well; firstly, because I was both teacher (then) and researcher (now) - and did this as a 'lone' teacher-researcher (Creswell, 2008:325); secondly, because, having been implementer, examiner, observer and data collector at the time of teaching, and having known the students very well, I need to rely on my perception of the fuller picture which many students managed to sketch only vaguely because of language barriers.

Next, I had no choice but to teach the students in their natural (very much studio-orientated) university environment, which presented both advantages and disadvantages. Certainly, it imitated the external reality of their further years of study, as well as their future professional environment. Furthermore, I could not help but affect the impact which my interventions would or would not have, as I

am fully aware of the fact that, as teacher, one is the 'medium' through which information is made available to the receiver, the student, and every such 'medium' colours the information differently and has a different and personal influence on every one of the receivers.

Yet, every one of the personal and joint experiences of the groups taught, every student's interpretation of what was being taught and why it was being taught, my interpretation of the dynamics in the class during the interventions and, later, of the data analysed - all these aspects combined create a reality which cannot be scientifically dissected, but which is, nonetheless, an important 'truth' and worthy of research.

3.3.4. Research approach

Gray (2014:18) maintains that deductive and inductive research processes can be combined.

In my design of the attribution retraining programme I certainly took a deductive approach. As I will explain under the heading of *Theoretical Framework* (# 3.5.1.) the premise from which I proceeded was (a) the theory of the plasticity of the brain (Rosenzweig, 1995; Diamond, 2001; Zull, 2002; Dweck, 1999, 2005, 2008; Schlaug, 2005; Kleim, 2008; and others), (b) the information processing functions of the working memory (Baddeley, 2002; Derakshan & Eysenck, 2009; Raghubar et al., 2010), and (c) the theory that cognitive and meta-cognitive skills should be taught explicitly (Flavell, 1979; Collins, Brown & Holum, 1991; Cornford, 2004; Vockell, 2004; Efklides, 2005) .

The attribution retraining 'treatments' described in the literature which I have studied are based on maximum 30-minute sessions in which students watched a video and filled out a questionnaire or had a discussion based on the video. The videos concentrated on motivation, strategies and perseverance (Haynes et al., 2009). There is no mention of exposing the students to the theories referred to above. This means that, in my attribution retraining programme I am breaking new ground by combining existing theories with a procedure (traditional attribution retraining) which has been hitherto based on a different tenet, namely that of a loss of perceived academic control.

In the analysis of my data I hope to establish a pattern which links my teaching the core principles of my theoretical framework to improvements in the students' mathematical performance in particular, as well as to a general improvement in

their self-esteem and, therefore, a healthier sense of academic self-efficacy. This would mean that I could formulate a hypothesis based on my research findings which could then be tested in future research and, finally, add to the body of knowledge regarding teaching mathematics-based subjects in general and attribution retraining interventions in particular - an inductive process.

3.4. Methodology

The data analysed in this dissertation represent two cycles of relatively loosely structured implementations of the intervention programme. The programme was initiated by the need to find a solution to the students' very real and deep-seated fear of numbers. I would, therefore, consider this research a multiple case study with, as far as purpose is concerned, elements of action research.

3.4.1. Research strategy

According to Davison (1998:3-12), action research may be considered a subdivision of the case study strategy. For this reason I shall first discuss the features of my programme and research which would make it a multiple-case study, and then consider those aspects which would place it into the action research bracket as well.

I am aware of the fact that my classifying this research as partly a multiple-case study and partly action research seems contradictory. At the time of implementing the intervention programme during Years A and B, I certainly worked in cycles as discussed below. The aims and considerations which guided my design of the interventions certainly coincide with the features which Davison (below) ascribes to action research. However, at the time, I did not consider formally researching my interventions and their effect on the students. Consequently, I did not 'stand outside' myself, the intervention programme and the student body in order to observe, clinically, what was happening in class over those four months. It is only now, for this study, that I look back and create a picture of what happened then, using the data I had collected at the time. It is for these reasons that I suggest that my research straddles both types of research strategies.

(a) A multiple-case study

The aim of this research is to investigate and gauge the effect which the interventions may have had on the students' self-perception with respect to their

mathematical competencies and their Numeracy results. The purpose of doing this is to test my hypothesis that explicitly teaching cognitive and meta-cognitive skills would make a positive difference in students who demonstrated poor mathematical proficiency and, therefore, suffered from a sense of low self-efficacy. This dissertation focuses on the results obtained in two consecutive years of implementing the interventions in order to approach a point at which one might claim a certain modicum of convergence – or conclude that there are too many discrepancies to claim any convergence. If the former should emerge, it would allow the hypothesis to become a theory which one might venture to generalise and apply in other mathematics-related subjects.

At the same time the two implementation cycles unfolded against a very realistic backdrop of day-to-day events and experiences. The latter could often not be manipulated by me (as lecturer-researcher) or, to a greater or lesser degree, by the participants (the students). However, the advantage is that the outcomes of the cycles can safely be considered true reflections of real-life, and thus somewhat chaotic, experiences - the 'natural setting' of the quite chaotic studio environment being one of these. Moreover, my findings sketch a picture of the phenomenon of apprehensive students, in often difficult situational circumstances, engaging with potentially paradigm shifting interventions. If the data collected against such a background show promise, then I venture to suggest a generalisation of the intervention programme.

My categorising this research strategy as a multiple-case study is based on the following researchers' theories.

Davison (1998:3-7) defines a case study as follows:

> "A case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups or organizations). The boundaries of the phenomenon are not clearly evident at the outset of the research and no experimental control or manipulation is used."

Farquhar (2012:6) refers to Yin (2009) when she adds that case studies are the ideal choice of research when

(i) "when, how and why questions are being asked",
(ii) "the researcher has little control over events",

(iii) "the focus is on a contemporary phenomenon."

Davison (1998:3-8) goes on to suggest that *multiple*-case studies are particularly suitable if

(iv) one wishes to describe a certain phenomenon,
(v) one wishes to develop and test a certain theory,
(vi) a cross-case analysis is desirable, in order to allow for possible generalisation of the theory and resultant practice.

Davison's and Farquhar's descriptions of the features of a case study, as well as Davison's points regarding the merits of a multiple-case study, thus apply to my research strategy.

(b) Action research

In order to render the extended attribution retraining programme ever more effective, and because I was keen to establish how, and to what extent the various interventions contributed to the 'mathematical rehabilitation' of the students, I taught, intervened and evaluated in a cyclical manner, always keeping the proverbial 'finger' on the affective and cognitive 'pulses' of the students. They were given opportunities to reflect on their understanding of the interventions offered and were invited to give me written and/or verbal feedback.

The 'mathematical rehabilitation' of the students was my driving force: they needed to regain self-esteem and the conviction that they had the intellectual wherewithal to conquer their fears regarding the subject; they needed to become part of a well-skilled workforce which would drive productivity and the country's economy (PISA 2012; World Economic Forum, 2013a). Such redirection of students' innermost self-beliefs could only be attempted if I made a conscious effort to understand and appreciate their personal and past academic history, as well as their present efforts to orientate themselves in the complex transition from school to the university discourse.

The aspects of my intervention programme described above would classify this study as action research as well. Davison (1998:3-9), in his review of literature on action research, has noted the following features of action research which resonate with my study:

(i) Action research focuses on finding solutions to social problems. In the case of my students, this is the erroneous and intellectually

debilitating belief that Mathematics is for the elite few who have a 'mathematical mind' – which hinders a multitude of young individuals from realising their full potential.

(ii) Action research uses existing tools and methods to advance practices (in our case in the teaching and learning of Numeracy), as well as to expand the body of knowledge regarding the field of study under scrutiny. (For my research this would be the role of attribution retraining in the context of teaching and learning Mathematics/ Numeracy.)

(iii) Importantly, the insights gained through a particular instance of action research should lead to the formulation of theories which could be put into practice in other fields of study. (Again: in our case other maths-related fields of study.)

(iv) Lastly, the researcher should consider carefully the beliefs, values and attitudes of the participants in the research. (I certainly subscribe to this principle.)

Davison (1998:3-10) goes on to note that some researchers view action research as belonging under the umbrella of case study research. He speaks of the 'describer' of the case study (which I am now) and the 'implementer' of the action research (which I was then). He labels as 'observer' the person who had 'social interaction with the participants' (1998:3-11). Davison believes that the strength of such a research methodology lies in the fact that the researcher has an 'inside working view of the case'. This I find to be true. However, he admits that the drawback is a possible lack of objectivity on the part of the researcher, which certainly is true as well.

3.4.2. Mixed-methods research design

The phenomenon of underperformance in mathematics-based subjects has been studied by international institutes, and some of their findings have been touched upon in Chapter 1. In the South African context, this phenomenon is particularly disconcerting and is made more complex by virtue of added issues with which first-time students have to contend. This has been discussed in detail in Chapter 2.

I wanted to obtain an insight – even if just partial – into the phenomenon which unfolded in my classes, the 'interface' between mathematically negatively predisposed students and my lectures, which challenged their deep-rooted beliefs; and this against a backdrop of novel, disorientating and distracting experiences. To gain this insight, I needed to use as many different types of data

collecting methods as possible so that they would complement and verify each other - or contradict each other and thus show up discrepancies! I also needed to develop an overview of the entire process from conceptualising the interventions to the final outcomes in order to evaluate the programme. Consequently, my research method should be considered a mixed-methods research design.

Creswell and Garrett (2008:321) suggest that educational researchers should adopt a mixed-methods approach as the most fruitful design to research the present complex educational landscape. They report that proponents of the mixed-methods design, such as Tashakkori and Teddlie (2003), view it "as a process of research that encompasses all phases of the research process ... from the broad philosophical assumptions directing the inquiry to the final interpretation and report of the study" (Creswell & Garrett, 2008:327). Silver (2004:5) refers to such research as a "summative evaluation". Such an exercise would require collecting and analysing the widest range of data possible in order to develop an all-encompassing (and as detailed as possible!) picture of an entire programme or project, from its conception and objectives, through its implementation to its completion and the impact which it has had. This description very much sums up my intentions with the present research into the implementation of the attribution retraining interventions at the time.

Creswell et al. (2003:163), in their review and analysis of literature on mixed-methods studies, have come to the conclusion that there are six core designs, the classification of which depends on four criteria. I have compiled a matrix of these core designs (Appendix A) in order to arrive at a definition for my own mixed-methods design,

Broadly speaking, I would classify this research as based on a 'sequential transformative' mixed-methods study - though somewhat modified, as described below.

(a) Purpose

My purpose for using the mixed-methods design embraces those of several core designs:

(i) I used quantitative data to "characterise students along certain traits ... for purposeful sampling" (Creswell et al., 2003:178).

(ii) I compared the types of data with each other to look for an emergent pattern of cross-validation.

(iii) The degree of cross-validation could strengthen (or weaken!) my theoretical perspective.

(iv) Qualitative data were studied to find answers for "unexpected quantitative results".

(v) The combination of different types of data would afford me a broader perspective on the phenomenon under discussion, and this perspective would facilitate the search for a solution (a more effective attribution retraining programme tailored to the needs of South African students.)

(b) Theoretical perspective

Advocacy. The theoretical perspective is certainly more important than my research methods alone (Creswell et al., 2003:182). As mentioned before, I am guided by my conviction that teaching students cognitive and meta-cognitive skills would be of great academic advantage to them. This echoes Cornford's (2004) belief in teaching cognitive and meta-cognitive strategies for lifelong learning. Furthermore, Creswell et al. (2003:182) speak of advocacy as a theoretical perspective. Advocacy drives my teaching endeavours and this research, as I wish to come to understand the root causes of the frustrations and fears regarding Mathematics with which individuals struggle, and to develop a meaningful and paradigm-shifting teaching tool to allow them epistemological access to, in our case, Numeracy.

A mix of triangulation and complementarity. This study enquires into a complex human phenomenon: whether explicitly teaching cognitive and meta-cognitive skills will lessen (hopefully eliminate!) the paralysing effect which a person's deep-seated sense of low self-efficacy in the mathematical domain has on his or her ability to make headway in Mathematics/Numeracy. The approach to the data analysis, therefore, features aspects which would link it both to the concept of triangulation, as well as that of complementarity.

Applying the classification of "theoretical starting points", as delineated by Greene et al. (1989:256), the concept of triangulation is evident in the following features of my data collection method:

(i) As discussed below, both quantitative and qualitative data have their strengths and weaknesses, and I hoped that the strengths of the one would at least mitigate – if not cancel out – the weaknesses of the other.

(ii) Both types of data, though different in nature, were collected to study one particular human phenomenon.

(iii) Both quantitative and qualitative data were assessed with the same theoretical paradigm in mind.

(iv) The data were not gathered simultaneously, but rather in 'tandem' with each other within each year's implementation of the interventions. However, this does not apply to the final questionnaire, interviews and most recent communications via cell phone.

(v) More often than not, the types of data were collected independently of each other in order to avoid the experience of one type of data collection (the Numeracy assessment outcomes) inadvertently colouring a set of qualitative data. The aim was to ascertain the degree to which the qualitative data, which speak of a particular student's experiences and reflections on these experiences, would converge with his or her assessment outcomes (the quantitative data).

At the same time, however, certain aspects of a complementarity design also featured strongly in my data collection method.

In the words of Greene et al. (1989:266), I wished to "use the results from one method to elaborate, enhance and illustrate the results of the other." Predominantly (though not exclusively!) I used the quantitative data to illustrate tendencies detected in the qualitative data. The two types of data would cast light on different facets of the same phenomenon - the idea of the whole being greater than the sum of the parts. In the words of Caracelli and Greene (1997:23):

> "… an extension can be readily made from the method to the paradigm level. Using interpretivist interviews that aim for depth and contextual relevance to supplement … [in the case of my research: quantitative data] conducted for breadth and representativeness might be considered a classic complementarity component design."

Next the issue of whether the two types of data were collected simultaneous, sequentially or in 'tandem' needs to be elaborated upon. The reason why the data collection cannot be compartmentalised satisfactorily is that it happened in the context of regular academic activities at a university.

3.4.3. Implementation of the data collection

At the time of teaching the students, I gathered both quantitative and qualitative data. The quantitative data accumulated automatically as I needed to establish regularly whether the students were developing the necessary competencies in the Numeracy module. At the same time I also invited the students to give me verbal and written feedback regarding their personal experience of the interventions which I was offering them. The aim of this exercise was two-fold. Firstly, I wished to monitor the impact which the interventions were having on the students. Silver (2004:5) speaks of an 'impact evaluation' which aims at identifying "a credible causation between activity and impact", irrespective of whether the impact would be positive, negative, mixed - or a 'non-impact'. Secondly, I wished to create in the students an awareness of their personal cognitive, as well as meta-cognitive, development in order to initiate a paradigm-shift in them with respect to their innate cognitive potential.

Creswell (2003:177-186), in his delineation of the six core designs, differentiates between 'concurrent' and 'sequential' mixed-methods designs. Neither of the two descriptors offers an exact fit for the data gathering activities during the implementation of my programme. His term of 'tandem' collection of data (Creswell, 2008:327) describes the experiment more precisely, as sometimes the reflections on the interventions and their impact stood in the foreground, and, at other times, the quantitative data took precedence. However, because these two methods of data collection did not happen at the same time, I prefer Creswell's model of 'sequential' mixed-methods design.

A second qualitative data collection exercise took place two years later, when I decided to research what had happened during the two years of implementing the attribution retraining programme.

(a) Priority of qualitative over quantitative data

Due to the fact that my ultimate aim is that of transformation, both in the students' perceptions of their own cognitive potential and their attitude to Mathematics, as well as in my teaching method (with a view to possibly generalising it for broader application), I was primarily interested in the degree to which each intervention had an impact on the students. Consequently, the qualitative data, grouped according to the separate interventions, took precedence over the quantitative data. Creswell et al. (2003:172) speak of "compar[ing] both forms of data to

search for congruent findings (e.g. how the themes identified in the qualitative data collection compare with the statistical results in the quantitative analysis)." Should the quantitative data verify the qualitative data, then one could make the deduction that there was genuine value in pursuing the aim of developing an intervention programme based on the theoretical framework which informed my approach to attribution retraining. For the purpose of academic promotion, of course, the quantitative data were important and needed to be kept in mind constantly.

According to Morse's (1991) notation system, as presented by Creswell et al. (2003:168), my approach would be an example of a "QUAL + quan approach (Type: sequential)".

(b) Integration

Creswell (2003:173) discusses the importance of deciding at which stage of the research process one should integrate the two types of data at hand. My decision to integrate the quantitative and qualitative data at the stage of interpretation was guided by the following consideration. At the very root of my research question are two issues: (a) Was there a credible and positive link between the interventions put in place and the students' performance in their Numeracy assessments (the "What happened" question)? (b) To which degree did the individual interventions have an impact on the students' self-image and sense of efficacy – which would then lead to a more positive approach to Numeracy (the "Why" and "How" question)? These questions are dictated by my wish to "promot[e] change at levels ranging from the personal to the political" (Creswell 2003:177).

Consequently, I interpreted the qualitative data to establish whether, in the students' minds, the shift from a fixed mindset to a growth mindset had begun. Then I would turn to the quantitative data to search for a correlation between the students' increased sense of academic confidence and their performance in Numeracy assignments. And even though, in some cases, there was no evidence of improved mathematical competence, the qualitative data did indicate an improvement in self-image and resultant general motivation. Where there were discrepancies between the assessment outcomes of a student and his or her written/verbal feedback, I tried to find an explanation for this in the qualitative information.

Integration at the point of interpretation would, therefore, lead to gauging the level of personal transformation. Moreover, the picture created by the integration of the data at this stage would also guide reflections on the possible value in refining the attribution retraining programme under the spotlight here into a more standardised model and then implementing it in other subjects, as well as at schools, teaching colleges and universities - thus promoting change on the political level (Jansen, 2012).

(c) Research instruments

Seeing that my study is based on a constructivist epistemology, using a research methodology of multiple-case study/action research, my data collection was based on "sampling, secondary data, observation, interviews, questionnaires [and] unobtrusive measures" (Gray, 2014:35). The secondary data would be the quantitative data which initiated my research. However, none of the data collection methods can be considered 'unobtrusive', as even the questionnaires filled out by the students in their own time, were compiled by me and referred to group experiences of which I had been part.

The various research instruments will be discussed under the heading of *Method of data collection and processing* (# 3.5.4.) below.

3.5. Development and implementation of the attributional retraining programme

Below follows an analysis of the theories which underpin my intervention programme, a brief and tabulated description of the interventions themselves, the methods of data collection, and the advantages and disadvantages of (a) using qualitative and quantitative data, and (b) the collection process of both.

3.5.1. Theoretical framework

As discussed in detail in Chapter 2, the theoretical concepts, on which my attribution retraining programme is based, are

(a) Weiner's (1985) theory of causal attribution,

(b) Rosenzweig's and Diamond's research into the plasticity of the brain (latter half of the 20th century) and based on Hebb's (1949) theory of and research into 'use-dependent synaptic modifications', called the *Hebbian synapses* (Brown et al., 1990:475),

(c) Dweck's (1999, 2005, 2008) concept of a 'fixed mindset' versus a 'growth mindset',

(d) research into our memory systems, in particular the information processing mechanism of the working memory (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Derakshan & Eysenck, 2009; Raghubar et al., 2010), and

(e) the explicit teaching of cognitive and meta-cognitive skills (Thier, 2002; Cornford, 2004, Dweck, 2008; Tanner, 2012).

In the 1970s already I had become aware of Diamond's and Rosenzweig's research into the plasticity of the brain, as well as the importance of understanding how the brain's memory systems function. Consequently, I had routinely taught my scholars about their brain's capacity to learn, about their memory systems and how to employ these to optimise learning both during class instruction and study sessions at home. This approach to teaching and learning had always earned my scholars very satisfactory results, especially when compared with their peers in other classes.

Once I had started teaching at tertiary level, I became aware of the neuro-scientific research and findings which form the basis of the theory of the brain's plasticity, and which underpin Dweck's concept of a growth mindset. Furthermore, teaching cognitive and meta-cognitive skills has been hailed as an important feature of classroom and lecture theatre instruction; and rightly so, I venture to add. If our brain developed for the expressed purpose of thinking and learning, and if we are expected to train and refine our thinking and learning activities, then it stands to reason that we should know how to employ the brain optimally (Zull, 2002).

Developing an attribution retraining programme based on the above concepts and theories was, therefore, a natural, but far more academically orientated, extension of my approach to classroom teaching.

3.5.2. Logic model for the modified attribution retraining programme

Below follows a logic model, as suggested by Shackman (2008), which summarises the intervention programme implemented during the two years under scrutiny. It indicates my assumptions regarding the students' lack of the required quantitative competencies, their generally inadequate schooling in Mathematics/Maths Literacy, and their personal unhappy experiences with and

resultant negative attitude towards the subject. The model lists the interventions which I put in place and my short-term, medium- and long-term objectives which I hoped to achieve with these interventions.

Table 3.1.: Logic model for the envisaged attribution retraining programme (compiled by: Rohlwink, 2015; based on Shackman, 2008)

Assumptions	Diagnostic test	Inputs: Interventions	Expected outputs	Expected immediate outcomes	Expected subsequent outcomes	Ultimate project goals
* A lack of quantitative literacy among students * inadequate classroom teaching and learning * students' sense of failure and lack of control over academic performance * possible maths anxiety * fixed mindset: paradigm of cognitive inability with regard to Mathematics		* free-writing * **teaching:** **1. cognitive skills:** a. plasticity of the brain, neuronal networks b. sensory, working , long-term memories * revisit of free-writing for critical analysis **2. meta-cognitive skills:** a. Kolb's experiential learning cycle b. threshold concepts **3. mathematical concepts (remedial work)**		* intellectual acceptance of cognitive ability * realisation: underperformance in Mathematics due to internal/external, unstable, controllable causes * increased motivation * renewed effort at understanding numerical computations * more effective learning strategies	* reduction in negative affect regarding Maths/ Numeracy * steady, though gradual, improvement in sense of self-efficacy regarding Numeracy, as well as academic activities in general * improvement in assessment outcomes in Numeracy module	* personal and intellectual empowerment of students * future successful engagement with Mathematics * design of generic attribution retraining intervention programme adaptable to various maths-related fields of study, both at school and at tertiary institutions by…… * …… sharing knowledge gained with both teachers/ lecturers and pupils/students and…… * …. thus improving NSC results and creating more opportunities for STEM-related studies

3.5.3. The set of attribution retraining interventions

Below follows a tabulated presentation of the interventions which I implemented in order to initiate a paradigm shift in the students from a fixed to a growth mindset. The intention was to persuade them to accept that epistemological access to numeracy was possible for all of them.

Table 3.2.: A summary of the interventions implemented, the outcomes expected and the rationale for the interventions

Intervention	Description of interventions	Envisaged outcomes	Rationale
Diagnostic test (February) (Appendix G)	administered in Week 1 of teaching; tests competencies in: basic geometric shapes; formulae for area & circumference of circles, area of rectangles, volume of rectangular prisms, metric conversions, basic costing & percentages	to create a profile of the quantitative competencies of the class as a whole and of the individual students; to establish general strengths and weaknesses with the view to tailoring appropriate remedial activities	to make students aware of their particular strengths and weaknesses in Numeracy; motivate them to approach Numeracy requirements one skill at a time
Free-writing (1 session: +/- 1 hr)	After feedback on diagnostic test, students were asked to free-write about their gut-reaction towards Maths (+/- 10 min.) Next they did focused free-write (*), reflecting on specific experiences at school, in class, during exams, their attitude towards Maths classes and homework, their teachers' and parents' input.	to afford the students the freedom to 'tell it as it is' without having to fear criticism, either from me or themselves; to give them a sense of safety in my class – that their apprehensions and fears were affirmed and respected; and then to focus on specific aspects (*) of their history with Mathematics/Maths Literacy The vitally important underlying objective was to help them realise that their inability to cope with Maths was not due to a cognitive deficiency on their part.	"By writing down our thoughts we can put them aside and come back to them with renewed critical energy and a fresh point of view. Writing helps us stand outside ourselves." (Elbow, 1983:38) The students were to evaluate their free-write later, with the hindsight of knowledge gained during the interventions.
Brain plasticity (1 session: 1½ hrs)	Notes (in layman terms) on and images of the neuronal networks of the brain and on the growth of dendritic spines; video clips demonstrating, through medium of animation, the life of neuronal networks class discussion on the information offered, as well as written reflections on their personal previous perception of their 'brain power' and the possible shift in this perception initiated by the lesson materials	to afford the students a basic insight into the neuronal pathways of the brain • to open their minds to the fact that their brain has unlimited learning capacity • that negative neuronal pathways can be 'silenced' and positive ones be grown/ strengthened • that even just 20 minutes of concentration • can start the growth of new dendritic spines, i.o.w. greater cognitive power ('intelligence') • to initiate a paradigm shift from 'fixed' to 'growth' mindset	This intervention is based on the research done by Hebb (1949), Rosenzweig and Diamond (2nd half of 20th century), Rosenzweig and Bennett (1996), Diamond (2001), Zull (2002), Schlaug (2005), Dweck (2008) and others into the plasticity of the brain; Understanding and internalising the information presented would, hopefully, persuade the students to accept that the root of their difficulties was NOT altogether/necessarily an *internal, stable, uncontrollable cause*.

Sensory, working & long-term memories (2 x 1½ hr sessions)	Session 1: General information re the sensory, short-term/working and long-term memories; anecdotes to demonstrate some important features of these memories; fun exercises for students to test certain aspects of their working memory capacity; Session 2: More detailed information re the two information processing systems and the executive system of the working memory, with emphasis on amount of working memory capacity at any given time;	for students .... • to realise the fleetingness of sensory and working memories, • to appreciate the damage to cognitive effectiveness which class interruptions caused at school • to understand the importance of concentration during class and homework sessions; • to guard against unnecessary working memory overload • to realise the effect which personal attitude towards a subject can have on the working memory's processing efficiency	This intervention is based on research done by Baddeley (2002), Hopko et al. (1998), Ashcraft & Moore (2009), Derakshan & Eysenck, (2009), Hoffman (2010), Raghubar et al. (2010) and others. The information processing mechanisms of the working memory, as well as the effect which various kinds of stress exert on the efficiency of the working memory, have been studied extensively. Maths anxiety/ phobia is one such stressor, as are many others (personal, environmental, situational) which our students have to contend with. Further indication that **some** causes for failure at Maths are *internal or external, unstable* and, therefore, *controllable*.
Revisit free-write (1 session: 1½ hrs)	The students were asked to read their free-write and to compare what they had written to what they had learned about the brain and its memory systems. The class discussion reflected on their discoveries.	The aim was to create for them an opportunenity to discover to what degree factors regarding their attitude to Maths/Maths Lit., elements in their class environment, and utterances by parents and teachers had contributed to the efficiency or difficulty with which their working memory had processed Maths concepts and procedures.	This would be the final link which would close the circle, take the students back to their history with Maths and help them understand that a set of diverse factors had enabled/hindered their progress in Mathematics. This was not an exercise at shifting blame, but at assigning responsibility where it belonged, both to external as well as internal sources of distractions.
Kolb's experiential learning cycle (several shorter sessions spread over two weeks and reinforced regularly)	• a very basic version of the experiential and reflective learning cycle (notes and diagramme) • used initially in class as a whole and with individual students to practise solving situational challenges • then applied to academic challenges	The objective was to teach and foster meta-cognitive skills. • to help students regain control of their academic life - and personal life where this would support them in their effort to succeed at their academics; • to demonstrate to them that some causes of their lack of success were controllable.	Kolb and Kolb (2005) state that, in general, students come from a previous educational system in which they learned passively. This certainly applies to our students. Kolb and Kolb believe that students need to take control of their learning experience, which supports the concept of teaching meta-cognitive skills explicitly (Cornford, 2004). Again, this cements the idea of being able to eliminate some underlying causes of low performance in Maths.

Threshold concepts (2 x 1hr sessions)	Session1: Notes and discussion on the notion of threshold concepts with examples from the Numeracy and Communication classes, as well as studio projects. Important is to give the students ample examples as the threshold concept, by definition, is not easy to grasp. Written task on an adapted and abridged version of Atherton's (2010) article on threshold concepts (with his permission!). Session 2: Discussion and examples of 'troublesome knowledge' versus 'transparent knowledge'	The aim was to teach and practise both cognitive and meta-cognitive skills: • meta-cognitive skill: to discern and identify threshold concepts in any given subject, and to have the motivation and perseverance to work through the concept. • cognitive skill: to determine how best to analyse the challenge, establish what the stumbling block is, and then to devise the best strategy to conquer the obstacle	According to Meyer and Land (2003, 2006), in any given subject, performance will not advance beyond mimicry if certain crucial concepts are not mastered. A student will, therefore, never BE a professional in his/her field, unless he/she has internalised these concepts. Furthermore, students will encounter 'troublesome knowledge' (Meyer & Land, 2003; Perkins, 2006) which is 'transparent knowledge' (Lave & Wenger, 1991) for the lecturer. Knowing about such concepts will enable the students to negotiate these apparent impasses. This is the final intervention which, it is hoped, will facilitate in them the paradigm shift from internal, uncontrollable causes to internal controllable ones, from a 'fixed mindset' to a 'growth mindset' (Dweck, 2008).

3.5.4. Method of data collection and processing

Data collection happened both at the time of teaching and two years later. Several methods of data gathering were used, and the processing of the information was done, for different reasons, both at the time of teaching and during the preparation for this study.

Reasons for data collection at the time of teaching

Quantitative data were collected for the following reasons:

- to gauge the students' academic progress in Numeracy,
- to produce official assessment results for the purpose of promotion,
- to infer the effectiveness of the attribution retraining interventions.

Qualitative data were collected to:

- promote reflective self-awareness among students,
- stimulate meta-cognitive monitoring,
- gauge the students' experience of and reaction to the interventions, as "interpretive studies seek to explore peoples' experiences and their views or perspectives of these experiences" (Gray, 2014:37).

Reasons for data collection two years later

For the purpose of this research, which began in earnest only two years after Year B of the interventions, recent qualitative data were collected based on purposive sampling. According to the quantitative data, the task/test/examination results, many students had shown significant improvement, while a few students' performance had dropped considerably. It was from these two groups that I wanted to select individuals who would be prepared to reflect upon and discuss the effect which the interventions may or may not have had upon them and their engagement with the Numeracy module.

Quantitative data collection and processing

Each year the results of the diagnostic test in February were entered on a spreadsheet which contained the class list of the students. Each student's marks were entered question by question into separate columns, one column per question (see Appendix B: marks of Year B), as well as the total mark obtained for the test. The same procedure was followed when I entered the June examination marks. Both the marks for the diagnostic test and those for the June

examination were converted to a percentage; so were the class averages for every question. The reasons for this layout of the marks were as follows:

(a) Each student's percentage for the diagnostic test would indicate his or her general mathematical competency.

(b) The average percentage for the class would give me an idea of the overall performance of the group.

(c) Most importantly, each student's mark for the various questions indicated the specific strengths and weaknesses of the student; and calculating the class average for every question highlighted the strengths and weaknesses of the entire class.

(d) After the June examination, and having followed the same procedure, I could compare the class averages to gain an impression of the general progress of the class.

(e) In the same manner each student's individual progress would become apparent.

(f) Finally, by comparing the averages for individual questions, I could establish, where possible, whether certain initial shortcomings had been rectified by June.

By using the students' averages I could also make the following comparisons:

How many students had passed the diagnostic test with 50+%, and how many had achieved this in the June examination?

Keeping in mind that one-third of a test or examination should always be accessible to even those who struggle, one-third should cater for the average student, and one-third should challenge the more competent student, I could establish whether a shift in proficiency had occurred. Did more students, who in the diagnostic test had not managed to achieve even 33.3%, move up to the 34%-67% category in June? And had some average students improved to a point where they had been able to master a mathematical challenge?

The findings of the investigation into the quantitative data will be discussed in Chapter 4.

Qualitative data collection and processing

After every assignment, test and examination I have always given the students very detailed feedback on their performance. The objective was not so much to show the students *where* they had lost marks or had done well, but to create in

them an awareness of *why* they had obtained satisfactory or disappointing marks in any particular question. To this end they were always instructed to make careful notes of their reading, reasoning and procedural skills and shortcomings. In this way I hoped to (a) develop their meta-cognitive skills and (b) draw their attention to the fact that it was not an inherent inability on their part to acquit themselves successfully of mathematical tasks, but a lack of certain skills which could be pinpointed, analysed and improved upon. This method, among several others, led to the collection of very valuable qualitative data.

Class discussions. The feedback on tasks, tests and examinations led to very honest, mature and fruitful discussions in class, important points of which I noted down afterwards.

Informal chats. At times I also invited to informal chats small groups of students (two or three at a time) who obviously struggled to cope with the Numeracy syllabus. These were students who would not have spoken up in class due to feelings of inadequacy.

Personal observations. Per week we had three early-morning lecture sessions (1¾ hrs each) plus one 1-hr lecture. This arrangement allowed me to observe the students uninterruptedly as we interacted during lectures, and as they went about their tasks and assignments. Their attendance and punctuality (or lack thereof), their approach to tasks and tests, their individual requests for more exercises, as well as their very body language and degree of participation during lectures gave me much material for written notes.

Questionnaires. After the first intervention which dealt with the neuronal networks of the brain and its plasticity, I asked the students to complete a questionnaire (Appendix C) with open-ended questions regarding their reaction to the lectures. The aim of this exercise was to stimulate reflection and introspection in the students and persuade them to form a 'personal relationship' with their own brain - and cognitive powers.

During the fourth term of Year B I asked the students to fill out a more comprehensive questionnaire (Appendix D), again with open-ended questions, which asked them to reflect on the entire Professional Business Practice subject. Two years later a final questionnaire (Appendix E) was given to some students whom I then invited to an interview. These students were asked to fill out the

questionnaire prior to the meeting. The aim of this arrangement was to give the students an opportunity to think back of their experiences in my subject, to remind themselves of the various interventions I had implemented, to reflect on these, and to consider whether any knowledge and skills gained during the interventions had benefited them in their further years of study.

Interviews. Subsequently, I invited the selected students for interviews, based on whether their Numeracy marks had shown a remarkable improvement or had dropped. These interviews were recorded and transcribed (Each transcription can be accessed via a link.) The information gleaned has been used to give the students' perspective of the interventions and thus gauge the latter's possible effectiveness.

Communication via cell phone. Since then I have also been in contact with students via WhatsApp messaging. Using this form of communication had a three-fold purpose: (a) I hoped to be able to cast some more light on the possible effect of certain interventions, (b) some of the students who fared poorly in the Numeracy component had also dropped out of the design programmes altogether and have been difficult to meet in person as they have moved away, and (c) others have finished their studies and are employed across the entire country.

As mentioned above, my data analysis would be considered a "QUAL + quan" approach, according to Morse's (1991) notation system. The rationale for this approach is that, in order to be able to suggest an answer to the research question of "Why did certain interventions have an effect on the students' Numeracy results?" this study needs to have a "thematic focus on understanding a central phenomenon" (Creswell, 2003:174). The 'central phenomenon' is the general improvement in the students' performance in Numeracy during the implementation of my attribution retraining programme. The various interventions make up a cluster of sub-themes or phenomena the impact of which needs to be ascertained as far as is possible. This is of pivotal importance as the purpose of the entire study is to establish whether there was, and to what degree there was, a relationship between the interventions and the students' performance in Numeracy.

The advantages and disadvantages of the data collection process

Heraclitus' notion of "formlessness, chaos, interpretation and absence" (Gray, 2014:20) would characterise, to a certain degree, the data collection process of Years A and B. The intervention programme implemented developed out of a first trial in Year A, repeated and somewhat modified in Year B. For both me, as the implementer, observer, and data collector, as well as for the students, as the participants, both years were fraught with complications of personal, situational and environmental nature. Although such circumstances are not conducive to formal experimentation (which was certainly not my intention at the time) and, therefore, are not ideal for conclusive data collection, they do present the reality of life as our students experience it. For this reason I wish to believe that the data collected are noteworthy: they portray the students' interaction with what they may well have considered to be the 'cross' of their academic existence ('maths' in all its forms!) while at the same time dealing with the passage through their first year at a tertiary institution with all its complexities.

There are, therefore, gaps in the data, as will be described below, as well as inconsistencies. Consequently, the result of the analysis is more akin to a graph of best fit than a detailed and statistically sound representation of what happened during those two years. Nevertheless, as noted by Creswell (2003:174), combining quantitative and qualitative data still offers a picture of rich detail.

Advantages of the quantitative data

Quantitative information is important for the following reasons:

- They give an indication of the students' individual mathematical competencies in the various teaching units of the syllabus.
- Studying the students' procedural methods in their assessments gave me a fair insight into their cognitive development as far as the subject was concerned.
- The overall data presented an impression of the class's, as well as individual students', progress in Numeracy as the weeks and months of lectures unfolded.
- My method of analysing the data in the afore-mentioned spreadsheets highlighted aspects of the subject which required remedial teaching, either with the entire class or with individual students.
- Quantitative data are objective to a certain degree. They translate the student's comprehension of a problem presented and his/her ability to select and apply certain mathematical procedures into a set of numerical values.

- Considering the disadvantage of not being able to do pre- and post-intervention assessments with identical tests, the data gathered do create a record of the students' ability to cope with a very steep learning curve.

However, these data are objective only to 'a certain degree' as will become apparent from the disadvantages discussed below.

Disadvantages of the quantitative data

An analysis of the quantitative information could only be done with the following restrictive factors in mind:

- Because of the many factors (which would be substance for another valuable study) that exerted a negative influence on the students, and which could not be lessened or eliminated altogether, the assessment results cannot be regarded as the *best* performance that the students were capable of. If a student arrives half an hour before the end of a two hour June examination because he had to scramble to find the taxi fare to come to campus (a genuine anecdote), I cannot expect his work to reflect his actual abilities. His working memory capacity will have been seriously compromised. That quantitative data are adversely affected by distracters is borne out by Kellogg et al.'s research as well (1999:598).

- My observations of the students before and during formal assessments indicated clear instances of avoidance tactics. A few students resorted to staying away from classes altogether; others arrived late (for no acceptable reason!); some took a long time to settle down and focus on the assessment; others spent valuable time second guessing themselves and laboriously going over calculations. Such behaviour affected their marks adversely.,

- As I was both the implementer and assessor I am aware of the fact that my formative and summative assessments were influenced by my approach to teaching and my knowledge of the group of students. My assessments were strictly contextualised and tested important and relevant competencies. However, the students would have grown used to my formulation of the questions, for instance.

Advantages of the qualitative data

Creswell's (2003:175) remark that "many inquirers actually go back and forth between confirming and exploring in any given study" certainly applies to my analysis of both types of data, and where the one is inadequate, the other adds further detail to the information, until, in Creswell's (2003:174) terms, "a rich description of the phenomenon" has been achieved.

- Quantitative data cannot identify any of the underlying causes for the performance of the students, whether satisfactory, outstanding or disappointing. Qualitative data, however, can more readily do this - by filling in a fair number of background gaps, hinting at undercurrents, giving nuance to quantitative outcomes and affording the students a 'voice'. In this respect class, group and private discussions proved to be valuable sources of information.

- Creswell (2003:175) continues by saying that one should attempt to "keep the study as open as possible to best learn from participants". I certainly concur with this point. Without the students' feedback I would not have been able to monitor the effect of the interventions on their perceptions of the subject, as well as of their own sense of self-efficacy with regard to Numeracy.

- Both verbal and written reflections invited the students to analyse their performance and monitor their progress (meta-cognitive skills).

- Silver (2004) believes that "impact evaluation assesses the changes in individuals' well-being". Even if the quantitative data indicated disappointing results (or minimal improvement) for some of the students, the qualitative data did highlight many students' positive affective shift which would imply a certain well-being on various personal levels.

- Personal observation on my part added valuable insights into the students' often instinctive behaviour when confronted with either lecture material, assessment tasks or feedback and impromptu discussion sessions.

- The questionnaires completed at the time of teaching the students allowed the more introverted students to voice their opinion on the impact which the interventions may have had on their mathematical performance, as well as on their personal intellectual and affective development.

- The final questionnaire completed by a select few students whom I wished to interview, as well as the interviews themselves, afforded us a retrospective perspective of the students' experience of the Numeracy classes and intervention programme. It was interesting to note which interventions were clearly remembered, and which had not been understood or had slipped into oblivion over the two years. Some students consciously employed certain cognitive and/or meta-cognitive skills; others admitted that they did not. However, this may indicate that they had internalised the skills to a point where they did not consciously employ them anymore. Specific details will be discussed in Chapter 4.

- The use of cell phones as communication channel led to very specific information gathering as one needs to be brief and to the point when communicating via WhatsApp.

- Finally, as much as I am aware of the fact that I could not be completely objective in my gathering and analysis of the qualitative data, I also realise that, having been both implementer and participant in the intervention programme allowed me to know many of the

students very well, and to be able to read between the lines in more ways than one.

Disadvantages of the qualitative data

Collecting qualitative information highlighted its own shortcomings.

- Students, in general, did make an effort to be present when formal assessments had been scheduled. This cannot be said for verbal or written feedback and discussion sessions. Very often students missed classes, and therefore discussions, for various reasons. Some students also declined taking part in either discussions or written feedback. The qualitative data, therefore, do not reflect the entire class's experiences and reflections on these experiences.

- Class and group discussions are normally dominated by more extrovert and better articulated students. This may present a skewed picture of the phenomenon under scrutiny.

- Especially written reflections were not done regularly after every intervention, the main reason being lack of time, as well as circumstantial interruptions.

- My interpretation of their reflections is subjective, coloured by my aims and objectives for the class as a whole and the individual students themselves.

- To add to the complexity of this method of data collecting: For most students English was a second, if not third, language. This hampered many in expressing accurately enough their opinions.

- It became apparent to me that many students, being first-time students, found it difficult to express in words very abstract notions. They struggled to connect meaningfully with their inner world. However, this aspect of communication was addressed relatively successfully both in the studio subjects and the theory subjects.

- The interviews, although they produced some very valuable insights, were conducted under difficult circumstances: the students, now in their third year, had very little time to spare; they were scattered over various campuses and difficult to track down; there was no private space, away from the general noise of classes, in which to conduct an interview. Some interviews needed to be broken off abruptly because the students had to join other activities.

- Finally, some students who had not benefitted from the interventions, who had dropped in their Numeracy marks from February to June and some of whom had deregistered from the Design course as a whole, have been difficult to contact. Others, whom I could contact, were not prepared to revisit their experience in the Numeracy classes. It is their input which would have been very valuable for understanding what held them back, and then to devise appropriate supportive interventions to help them overcome their difficulties.

Nevertheless, the picture created by interweaving the two types of data is an important one. It is an accepted adage that often the whole is greater than the sum of the individual parts. Where one type of data have fallen short of lifting out certain aspects of the intervention programme, the other type of data have cast light on issues of importance. There has been sufficient convergence between both types of data to allow "not only for theory testing, but also theory building and/or expanding" (Davison, 1998) regarding attributional intervention programmes suitable for South African first-time students.

3.6. What I cannot claim regarding the implementation and analysis of this programme?

The compilation of the interventions programme came about in answer to the distress signals and needs of the students. It was woven into the fabric of the students' and my everyday situations and experiences. Thus it cannot be considered a carefully structured research experiment; neither can I consider myself a completely objective researcher, as I was the lecturer, collector of data, as well as an interpreter of the information gathered.

3.6.1. A quasi-experimental design rather than a scientific experiment

The entire implementation and assessment of the intervention programme would be considered a quasi-experiment (Gray, 2014:29) for several reasons:

(a) The participants/subjects could not be randomly chosen or matched according to certain criteria as they were that year's student intake and constituted only one class.

(b) There were no control groups whose outcomes could be compared to those of the Foundation Course groups who had been exposed to the intervention programme. It is, therefore, not possible to establish whether the recorded outcomes could have also happened without the interventions. I cannot prove beyond doubt a "credible causation between activity and impact" (Silver, 2004:5).

(c) There was no time to do repeat identical assessments. Consequently, the quantitative data available cannot be used to establish the students' progress in *all* the mathematical competencies dealt with by comparing 'before' and 'after' results. The Numeracy syllabus, and thus the assessments themselves, had to be aligned with the requirements of the studio subjects. This meant that each assessment tested new mathematical competencies differently contextualised and of greater complexity. However, certain basic competencies did feature in all assessments and the relevant quantitative data were certainly investigated.

(d) The assessments could not be done under strict laboratory conditions.

(e) According to Gray (2014:29), quasi-experimental research is often based on a particular conceptual framework, the aim being to test the theory. Such research is, therefore, deductive. This is certainly the case with my study.

(f) Because the implementation of this particular attribution retraining programme was not intentionally an experiment, data collection was not done systematically and scientifically (Silver, 2004:4).

3.6.2. Personal objectivity

Because I was the designer, implementer, observer, assessor and, eventually, the evaluator of the intervention programme, I cannot claim complete objectivity.
I believe firmly that all students need to be taught cognitive and meta-cognitive skills (which reflects the beliefs of international researchers such as Dweck, 2008, and Cornford, 2004).

Keeping in mind the above theoretical framework to which I subscribe, I am fully aware of the need to be objective when setting assignments and assessing them, of evaluating students' participation and efforts, of analysing the data presented to me. However, I am also aware of the fact that my personal conviction of and enthusiasm for the information I was imparting to the students would have added a dimension to the teaching and learning situation which cannot be ignored, but which can also not be isolated and quantified. The time constraints, in particular, forced me to teach in a manner which would make the greatest impact in the shortest space of time.

Finally, the fact that I was interacting with the students on a daily basis, that I invited them to have open and frank discussions with me when necessary, that many of them saw in me a confidant, means that the entire experience was a double-edged sword from the point of objectivity. I cannot gauge to what extent I was not completely objective. However, my involvement with the students helped me interpret both the quantitative and the qualitative data collected from a vantage point of an 'insider' who could 'read between the lines' in more ways than one and sometimes could express the students' thoughts and perspectives better than they themselves could.

3.7. Ethical considerations

> "As professionals, instructors have a responsibility to examine their pedagogical practices and curriculum implementations, in short, to be 'reflective practitioners'." (Mount Royal University Human Research Ethics Board, 2012:3)

The concept of being a 'reflective practitioner' has been my stance for the past 40 years of teaching. Consequently, I also agree with MacLean and Poole (2010:2) that the "fundamental value in [any] research should be that we strive to be fair to our students with every decision we make regarding their educational experiences." Furthermore, I do "hold students' educational interests paramount" (MacLean & Pool, 2010:3). For that reason there is no conflict of interests at all. This dissertation discusses a particular model of attribution retraining which, I hoped at the time, would help my students overcome their fear of Mathematics and persuade them to believe that they could gain epistemological access to quantitative literacy.

I wish to discuss the issue of research ethics under several headings.

3.7.1. Did the implementation of this set of attribution retraining interventions put the students at risk?

As an erstwhile Mathematics/Maths Literacy teacher (and then as lecturer at a university of technology), I am focused both on teaching and learning methodology, as well as on the pedagogy and curriculum of my subject (MacLean & Poole, 2010:1).

(a) Having taught at high school level for many years, I am very familiar with a first-time student's school background, experiences and attitudes, especially in the realm of Mathematics/Maths Literacy. As mentioned above (# 3.5.1), I have known about brain-based learning and teaching for four decades, and had implemented it in a very elementary manner in my school syllabus. I had seen the success of this approach and knew that I would not put my Foundation students at risk if I used the same approach with them, though considerably more academic in nature and extent.

(b) For many students, their engagement with Mathematics/Maths Literacy at school had been an unhappy and fruitless one. Therefore, I needed to approach the Numeracy component of my subject from a completely different angle. Teaching in the same manner as that to which the students had been exposed at school would not have resulted in different, and more positive, outcomes.

(c) Furthermore, there is no question of having wasted the time of those students who did not need this particular intervention programme because they had fared well in Mathematics/Maths Literacy. The interventions should have been of interest to and could have inspired all students, irrespective of their level of competence. Also, the cognitive and meta-cognitive strategies learned could be employed in any area of studies. The feedback I received proved that the competent students did value being taught these strategies and aimed to use them in their further years of study. In fact, it was these students who consciously employed the strategies learned and benefitted most.

(d) Lastly, as there were no control groups because these interventions were part and parcel of my course material, no students forfeited any potentially valuable information and instruction.

3.7.2. "Trust is an essential element in building a sense of safety [in the classroom]" (Maclean & Poole, 2010:6).

My classroom atmosphere has always been a non-confrontational and supportive one. Students have the freedom to speak up, ask questions, critique and initiate discussions. They know that I am on a journey of discovery with them.

We had a lengthy discussion after the feedback on the diagnostic task in February during which I explained to the students how I proposed to help them master their aversion to everything numerical. They were, therefore, aware of the path ahead.

The students were not coerced into participating in the intervention programme (MacLean & Poole, 2010:2) as it formed an integral part of their Professional Business Practice syllabus. Consequently, they were not expected to do additional work or invest time in additional training sessions for the sake of collecting research data. Because at the time I did not intend to research my intervention programme, I did not subject the students to formal surveys. The discussions and questionnaires during Years A and B were meant (a) to teach the students to reflect meaningfully on their reactions to the interventions and their approach to Numeracy tasks and tests, (b) to provide them the opportunity to voice their opinions, fears and satisfaction at progress made, as well as (c) to allow me to gauge the effect which the interventions had on individual students. It should follow that the students were not put under any additional work-related pressure (MacLean & Poole, 2010:4). The very aim of my interventions was to reduce students' existing stress levels regarding mathematics, as well as to offer

them coping strategies with which to ease the stress brought about by other new subject- and environment-related challenges.

3.7.3. A 'captive audience'?

Admittedly, the students did not, officially, have the educational choice of participating in or excluding themselves from these attribution retraining interventions. However, I observed that students, who had decided not to participate in a lecture, would simply withdraw and work in the studio next door. They, therefore, did have the choice to remove themselves from a lesson (MacLean & Poole, 2010).

3.7.4. Giving informed consent

With regard to the recent questionnaires and interviews, as well as the WhatsApp discussions, the selected students were told that I was writing up my research with the view of sharing the results and insights far and wide with other institutions. In this way other students could be inspired to surmount their fears and build up their sense of self-efficacy with regard to Mathematics (MRU Human Research Ethics Board, 2012:4). I explained to my students that this would create opportunities for their many peers to enter the STEM fields of studies and careers. They were certainly informed and made aware of the potential value of the research, and they were happy to be part of this enterprise.

I drew up a document (Appendix F) which explained the above-mentioned considerations again, and the students indicated YES (I am willing to be interviewed and/or have my marks used) or NO (I am not willing to take part in reflections on the effect of these interventions). They signed the document and handed it back to me – or sent me messages via cell phone that they were willing to share their experiences with me.

3.8. Conclusion

Standing back then and reflecting on the implementation of this expanded attribution retraining programme, I would reiterate that the guiding objective which drove the development and execution of this set of interventions was the desire to liberate hesitant students from their misgivings (and fear!) when faced with "maths". Moreover, I hoped to set into motion in them a shift from a fixed mindset to a growth mindset so that they would become lifelong students. This

shift could happen only if they internalised the concept of the plasticity of the brain, consciously took into consideration the information processing of the working memory systems and, thus, became motivated to employ more effective strategies in their studies.

To gauge the extent to which my objectives were realised, I opted for a sequential transformative mixed-methods research design, knowing that neither the quantitative nor the qualitative data in themselves would be reliable, but wanting to evaluate the scenario which would emerge if I overlaid the two types of data..

In order, therefore, to fathom the effect which the attribution retraining interventions had on the students and their performance in the Numeracy component of my subject, I shall next study the two sets of data to trace tendencies, convergences and discrepancies. Because I wish to understand what kind of impact each intervention had on the students, I shall use the qualitative data as the dominant set of information to gauge the students' experience of each intervention. The quantitative data are studied to establish to what extent the intellectual realignment of the students had translated into better assessment outcomes.

CHAPTER 4

FINDINGS

4.1. Purpose of this chapter

Note:

- As I report on my findings in this chapter, I shall use verbatim quotes from the students' written feedback. In order to protect their identity I have changed their names. In the class lists I have removed their names altogether.
- I shall also not report on the findings for Years A and B separately. Although Year B's students were a weaker group than Year A's group, the weaknesses and reasons given for such weaknesses followed the same pattern as fir Year A. Consequently, I have collated the findings.
- Memoranda for all assessments: Please go to: https://drive.google.com/file/d/0B-X4SpGuMP0QTUV6NmlhUzliUDQ/view?usp=sharing

As stated in Chapter 1, students' underperformance in the Numeracy module of the Professional Business Practice subject initiated my introduction of the set of interventions which, I hoped, would convince them that they could gain epistemological access to Numeracy. My objectives with these interventions were to:

(a) introduce the students to the concept of a 'growth mindset' which would foster in them a sense of greater academic control, specifically with regard to Numeracy,

(b) motivate them to renew their efforts at Numeracy and employ more effective strategies when engaging with numerical tasks, and …

(c) … thus improve their performance in this subject,

(d) provide them with the quantitative literacy skills which they would need for their further studies in the various design programmes,

(e) provide the students with cognitive and meta-cognitive tools which they would hopefully employ in their future studies as well.

Weiner (1985:551-552) (as discussed in Chapter 2) defines underlying causes of certain personal outcomes as having three dimensions. One attributes outcomes of one's activities either to internal or external, stable or unstable, and controllable or uncontrollable causes. Therefore, in order to achieve the objectives mentioned above I needed to devise a set of interventions which would persuade my students to make a vitally important paradigm shift: Instead

of attributing their underachievement in Numeracy/Mathematics to internal, stable and uncontrollable causes, they would have to come to understand that the causes were partly internal, partly external, and certainly unstable and controllable.

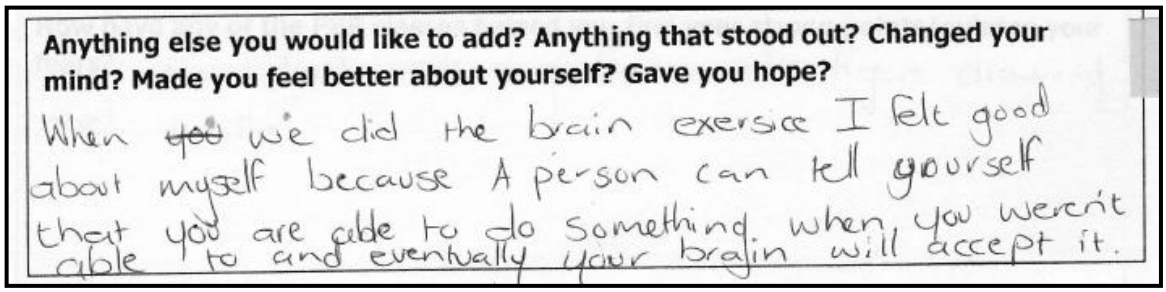


Figure 4.1.: Jessica's comment about accepting cognitive limitation regarding mathematics

> "When we did the brain exercise I felt good about myself because a person can [now] tell yourself that you are able to do something When you weren't able to - eventually your brain will accept it." (Jessica - Questionnaire – Appendix B)

(Jessica explained what she meant. At school, when her failure at tasks and tests had seemed to prove a lack of cognitive ability, her brain had accepted that this was an innate and, therefore, to be accepted (internal, stable and uncontrollable) state. However, now it was clear to her that we have the mental ability to succeed, and this was an uplifting realisation.)

In this chapter, therefore, I shall scrutinise the findings to establish whether, and to what degree, the attribution retraining interventions had an effect on the students' academic self-image with regard to numeracy in general, as well as on their assessment results in the Numeracy module. The information I glean from this exercise will suggest answers to the main question of this research, namely,

"What happened during the two years of presenting an extended and adapted attribution retraining programme, and why did this happen?"

As well as to the sub-questions:

(a) Which interventions were effective? To what degree were they effective, and why?
(b) Which interventions were less effective, and why?

(c) What should be done to render this attribution retraining programme as effective as possible?

4.2. The layout of this chapter

My reflections on the quantitative outcomes of the first semester of both Years A and B will answer one of two aspects of the main research question: What happened with regard to the mathematical competencies of the students in those two years? I shall analyse the results of the diagnostic tests in February of Year A and Year B. The weaknesses in the students' mathematical competencies became evident from their approach to the questions and will be discussed below. Next I shall report on the students' comments during class discussions after the tests had been handed back to them. These comments lift out clearly the weaknesses in the teaching of Mathematics/Maths Literacy at high school level..

I shall then give a tabulated summary of the results of the formal assessments in June of both years with the purpose of showing that there was a marked improvement in the students' performance. In Year B I included numerical tasks in the formal September assessment as well, and the results showed a drop of 5,6 percentage points. My assumptions regarding this drop will be mentioned as well.

I shall then turn to the other aspect of the main research question – the 'Why'? Why was there a shift in the assessment outcomes? What happened with regard to the students' sense of self-efficacy, perceived level of academic control and willingness to engage with Numeracy - and to do so successfully. These findings will be presented in the following manner:

I shall take the first two sub-questions and use them as a lens through which to evaluate the interventions in the order in which the latter were offered during the course of the subject. The information on which the evaluation is based is derived from the qualitative data gathered at the time of teaching, as well as two years later.

Next I shall reflect on the set of interventions as a whole to gauge whether, and to what extent, my original objectives (mentioned above, # 4.1.) which had led me to introduce this programme were achieved. I shall do this in the light of feedback given by my students.

The quantitative data will play a secondary role in that they will be woven into the discussion of the qualitative data to lift out convergences and discrepancies.
The final sub-question regarding refinement and further development of the interventions programme will be dealt with at the end of Chapter 5.

4.3. Findings regarding the diagnostic test

If one wants to appreciate the difficulties which the students experienced with regard to numeracy at the beginning of the year, one needs to pause for a moment and study the results of the diagnostic test (Appendix G), as well as the students' reflections on the test during class discussions.

The students' apprehension concerning this test was very obvious from their reactions to my announcement that we would do such a test. When asked for written feedback about their instinctive reactions, they responded with comments such as: "I was worried and my brain shutt (sic.) out." and "I was shocked and had fear (sic.)."

I was aware of the difficulties which some students might experience with reading too much text in a formal assessment, as most of them were English second-language speakers. Consequently, with the purpose of settling them down and familiarising them with the questions, I discussed the test with them, gave them the authentic background to Question 3, and contextualised Question 4 with regard to their future design studies. I also gave them unlimited time to complete the test as I wanted to establish their quantitative literacy levels and not how quickly they could complete the test.

4.3.1. The students' performance as reflected by their marks

Note: For the purpose of easy comparison between the outcomes of the diagnostic tests in February of each year and the June assessments, the relevant tables and figures have been grouped on pages 112 and 113. Both groups of students wrote the same diagnostic test.

The marks obtained for the diagnostic test at the beginning of both Year A and Year B are given in tabular format (Tables 4.1. and 4.3., p. 112 and p. 113).

Both groups of students were comfortable with identifying geometrical shapes and elements of such shapes (Question 1, Appendix G). However, as soon as they were asked to do calculations pertaining to these shapes, they were in a quandary. The mathematical knowledge and competencies required to perform the tasks (Questions 2 – 4) had partly been taught in primary school already, and were certainly required at junior high school level (Grades 8 and 9). In the results of Year B, I separated the calculations of rectangular areas (Questions 4.1. and 4.2.) from the calculations involving costing and percentages (Questions 4.3.–4.6.). The class averages indicate a substantial difference in performance, and the students ascribed their good marks in the latter section of Question 4 to their Maths Literacy and Accounting background from school.

Figure 4.6.: Year A – Feb. test – number of students performing at lowest, average and top levels

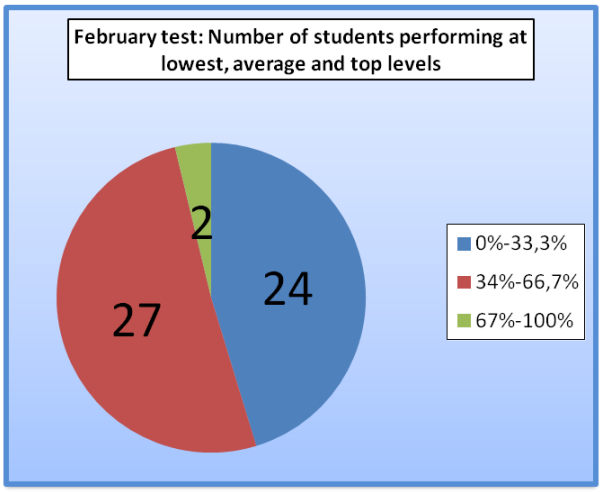
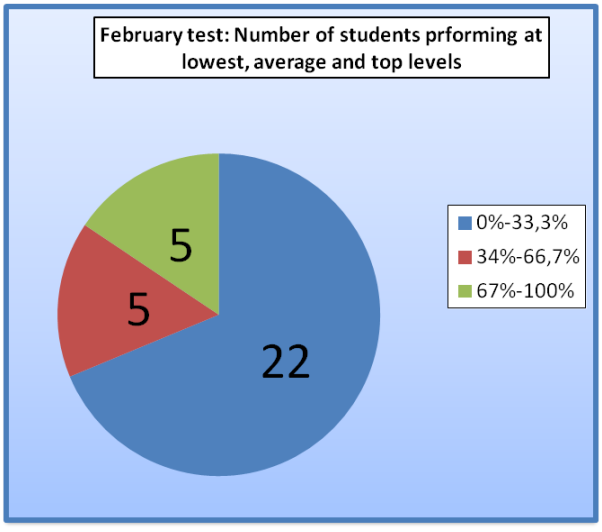


Figure 4.7.: Year B – Feb. test – number of students performing at lowest, average and top levels



Figures 4.2. and 4.4. (p. 112 and p.113) illustrate the distribution of the level indicators for Years A and B respectively. The percentage ranges for each level are given on p. 29. Level 4 represents 50%-59%. This means that in Year A only 15 out of 53 students passed the test. In Year B, 6 out of 32 students passed. The bar graphs in Figure 4.4. highlight the fact that the class of Year B was particularly weak, as 18 out of 32 students could achieve only at Level 1.

The second analysis (Figures 4.6. and 4.7.) groups the marks into three categories for the following reason. When setting summative assessments one is to allocate a third of the marks to questions aimed at those

students who experience difficulties with the subject in question, one third of the marks should be allocated to questions directed at the average student in the class, and one third of the marks to questions which challenge the top students in the class.

The pie chart (Figure 4.6.) indicates that the competencies of almost half the class of Year A fell within the lowest stratum of marks. Twenty-seven students attempted the questions of moderate difficulty (with some success), and only two students were successful at solving the more complex problems. In Year B (Figure 4.7.), the majority of students could not acquit themselves successfully of any tasks beyond those at the lowest level.

When the June results of both years are discussed, the pie charts in Figures 4.12. and 4.13. (p. 120) will illustrate the marked redistribution of the level indicators in both classes.

The shorter class list of Year B (with complete sets of marks for all questions, as well as totals and averages) is given in Appendix B. For the class list for Year A, please go to the following link: https://drive.google.com/file/d/0B-X4SpGuMP0QX3QweUlYTzhCZzg/view?usp=sharing

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4.3.2. Problem areas with regard to numeracy itself

The tasks in the test showed up the following problem areas:

(a) The students could either not remember - or confused - the formulae used to calculate the area and perimeter/circumference of rectangles/circles.

(b) They could not perform metric conversions for the following reasons:

(i) a general uncertainty about the concepts of cm, cm^2 and cm^3 (in other words, length, area and volume – with the specific difficulty being the distinction between length and area),
(ii) a hesitancy regarding how many millimetres there are in a centimetre, how many centimetres in a metre, and how many metres in a kilometre,
(iii) the inability to decide when to divide and when to multiply,
(iv) a general inability to apply metric division and multiplication (when to move the decimal comma to the right or the left, and by how many places).

(c) They could also not decide on specific, but very basic, computational sequences. An example of this was their inability to calculate the area of one pizza slice.

Table 4.1.: Year A (53 students) – Diagnostic Numeracy test (February)

Numerical competencies tested in the questions	**Q.1:** Identifying geometrical shapes & elements	**Q.2:** Area & circumference of a circle	**Q.3:** Vol. of rectangular prisms; metric conversion	**Q.4:** Area of rectangles; costing & percentages	**Class average**
Average mark (%) of class per question	**79 %**	**33,0%**	**30,0%**	**20,5%**	**40,5%**

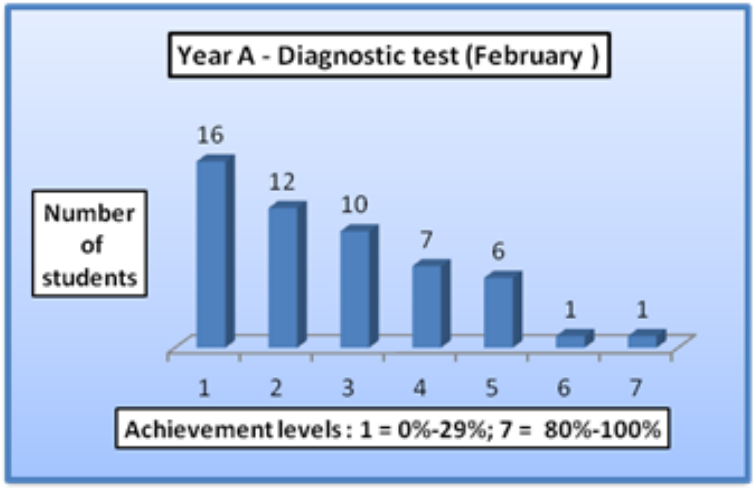


Figure 4.2.: Year A (Feb.) – distribution of level indicators

Table 4.2.: Year A - Summative Numeracy assessment (June)

Numerical competencies tested in the questions	**Q.1:** Metric conversions	**Q.2:** Area & volume (basic)	**Q.3:** Regular prisms: total surface area	**Q.4:** Regular prisms: volume	**Q.5:** Costing & percentages	**Class average**
Average mark (%) of class per question	**40,6%**	**47,8%**	**38,0%**	**58,8%**	**59,3%**	**49,3%**

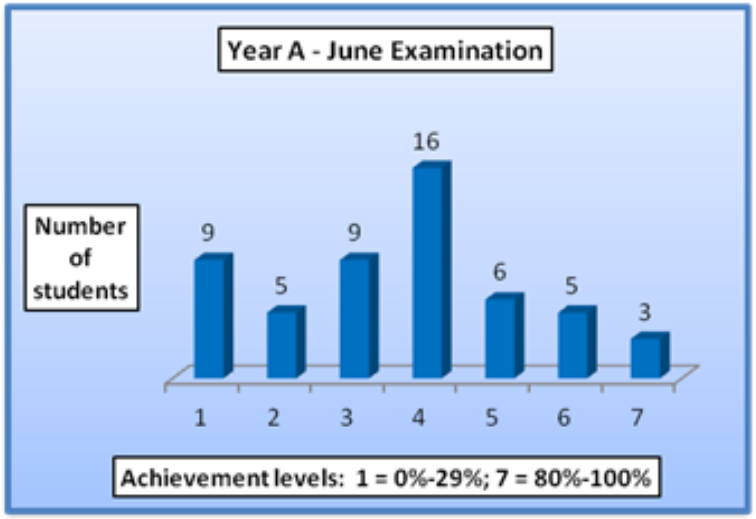


Figure 4.3.: Year A (June) – distribution of level indicators

Table 4.3.: Year B (32 students) – Diagnostic Numeracy test (February)

Numerical competencies tested in the questions	Q.1: Identifying geometrical shapes & elements	Q.2: Area & circumference of a circle	Q.3: Vol. of rectangular prisms; metric conversion	Q.4.1 , 4.2.: Area of rectangles;	Q. 4.3.-4.6. Costing & percentages	Class average
Average mark (%) of class per question	**60,7%**	**25,7%**	**23,0%**	**25,4%**	**51,4%**	**34,8%**

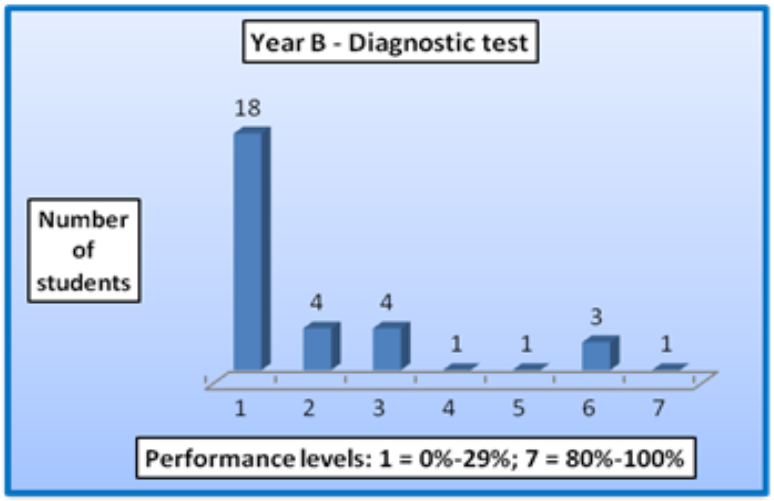


Figure 4.4.: Year B (Feb.) – distribution of level indicators

Table 4.4.: Year B - Summative Numeracy assessment (June)

Numerical competencies tested in the questions	Q.1: Metric conversions	Q.2: Area & volume of composite rectangular prism	Q.3: Costing & percentages	Q.4: Complex areas	Class average
Average mark (%) of class per question	**40,6%**	**47,8%**	**38,0%**	**58,8%**	**49,3%**

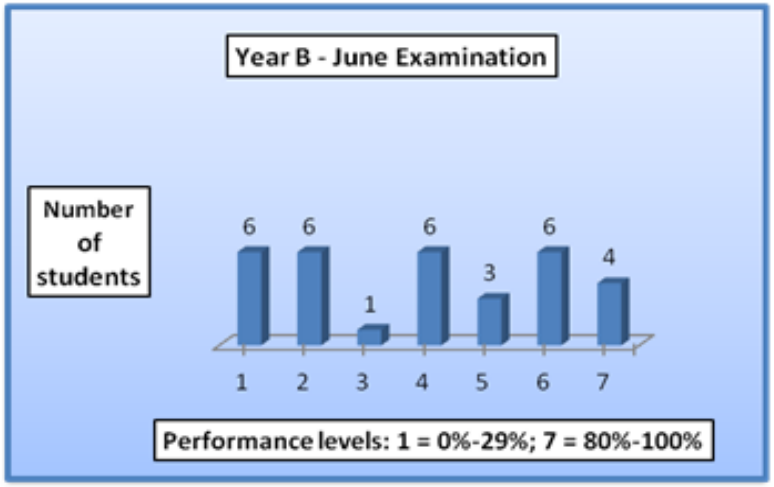


Figure 4.5.: Year B (June) – distribution of level indicators

(d) Their ability to concentrate and follow through with several steps in a calculation was poor. In Question 3 (Figure 4.8.) they would calculate the volume of wood for one table leg and the tabletop, but they would not multiply the volume of the table leg by 4, and then add the volume of the tabletop.

(e) Difficulties with Question 4.2. indicated that their ability to visualise was not well-developed either. Even after detailed elaboration and sketches on the board many found it difficult to visualise the idea of two metres of wallpaper (50cm wide) being needed to cover $1m^2$ of wall.

(f) Many students lacked the critical thinking skill which should have alerted them to the incongruity of some of their answers. The severity of this inability to judge the meaningfulness of one's answers is demonstrated by answers such as: It takes 7 metres (or, in another instance: 2,5cm) of sausage to wrap into the crust around a pizza with a 30cm diameter.

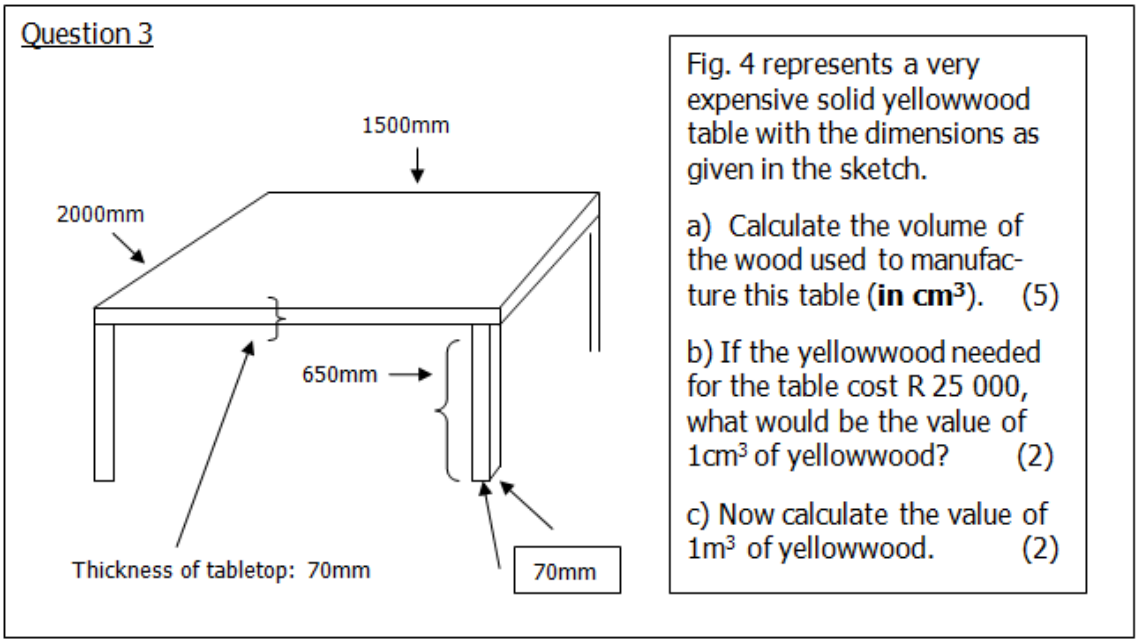


Figure 4.8.: Question 3 (diagnostic numeracy test) - Yellowwood table

Question 3 (Figure 4.8.) was contextualised for the sake of the future Industrial Design students in the group and tested the students with regard to the volume of rectangular prisms, visual literacy, systematic follow-through of separate computational steps, as well as metric conversions and pricing.

Although this question required various types of basic mathematical knowledge, part (a) which was by far the easiest part was allocated 5 marks so that even those students who struggled with Numeracy, were given a chance to obtain just over 50% for this question. And yet, in Year A, the class average for Question 3 was 30%, and in Year B it was 23%.

4.3.3. Students' verbal feedback regarding their performance in the diagnostic test

My feedback session regarding the outcomes of the diagnostic test stimulated lively class discussions, during which the students reflected on the following difficulties:

(a) Foremost was the comment that they had never needed to remember formulae as these had always been provided in formal assessments. (When I paged through a Maths Literacy paper prepared for the National Senior Certificate examination, I saw that even the formula for the volume of a basic rectangular container had been given: length x breadth x height - a formula which every pupil from Grade 6 onwards has worked with.)

(b) Next, and a close second, was the comment by both the Mathematics and the Maths Literacy students that too much text in a question distracted and confused them. They wanted to be given a task that was clearly stated only in numerical characters. This would trigger the correct pattern in their minds, and they would know how to solve the problem. Words obscured the picture, and they could not select the appropriate method to be applied. This is due to the manner in which scholars are often prepared for their final examination, as indicated by the National Diagnostic Report on the 2013 NCS examination (Department of Basic Education, 2014).

(c) Thirdly, the students observed that they had been 'trained' to answer National Senior Certificate papers in the following manner: The papers are set according to a particular format and contain a certain range of questions which can be answered in various ways. If the students had worked through as many papers as possible, using the methods available to solve the questions, then, when they were faced with their own examination paper, they would recognise the questions and would know which route to follow to answer them. Consequently, when I gave them very fundamental, but contextualised, numerical problems to solve, they were lost. This became abundantly clear to all of us when I asked them whether they would have been able to calculate the circumference of a plain circle. They agreed that they would have been able to do this - had I given them the correct formula! However, because I had asked what length of sausage it would take to wrap around a pizza, they had not realised that I was asking them to calculate the circumference of the pizza.

(d) A further general comment was that students felt they had not worked with the basic formulae which I had expected of them since their early high school years, and had, therefore, forgotten them. It led me to assume that they had not understood and assimilated the concepts taught in those late primary school and early high school years. Possible proof of this is the fact that many students did not know that π is a letter of the Greek alphabet, that its value is a constant value derived from dividing the circumference of a circle by its diameter, and that it has an as yet unknown number of decimal places.

Bongi wrote the following (Appendix D) which seems to support my assumption regarding teaching methods at many schools:

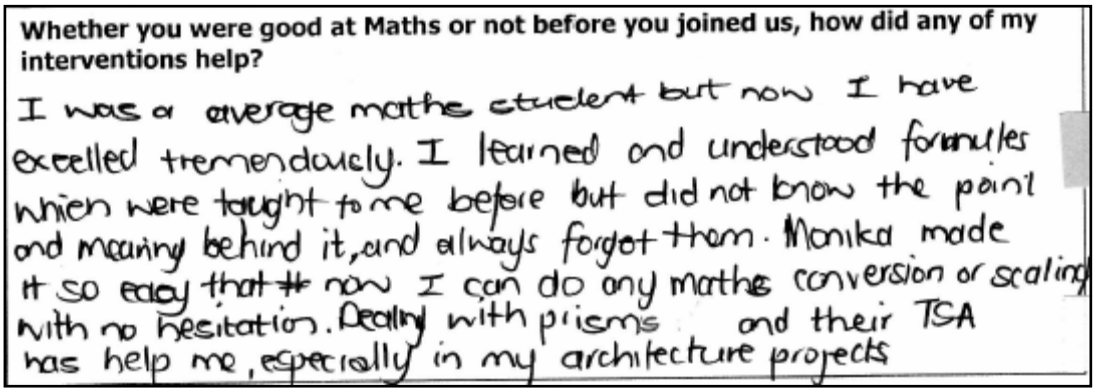


Figure 4.9.: Student's comment concerning formulae and metric conversions

> "I was a (*sic.*) average maths student but now I have excelled tremendously. I learned and understood formules (*sic*.) which were taught to me but did not know the point and meaning behind it, and always forgot them."

(e) Finally, the admission that they did not trust their mathematical abilities and, therefore, lacked the self-confidence to engage with numerical tasks was a recurring comment in private and small-group discussions. The reason given for this low sense of self-efficacy was always a history of poor performance in Mathematics/Maths Literacy at school.

The discussions reported upon here clearly echo the criticism which the Department of Basic Education (2014) has levelled at the general method of preparing scholars for their National Senior Certificate examinations in Mathematics/Maths Literacy. However, in the Design programmes, students need to have a sound grasp of basic mathematical concepts, principles and skills - particularly those students who register for Industrial Design, Interior Architecture, as well as Architectural Technology.

Before I analyse the qualitative data which offer some insight into the effect which the interventions had on the students' academic self-image, I wish to complete the picture created by the quantitative data and briefly reflect on a tabular analysis of the June results of both years (Tables 4.2. and 4.4., p. 112 and p. 113). It was, after all, the marked improvement in the June results which led me to believe that the interventions programme in its entirety had had a positive effect on the students' relationship with basic mathematics.

4.4. Results of the June assessments of Years A and B

The results of the June assessments of both years are presented in similar tables to the results of the diagnostic tests for easier comparison of the overall assessment

outcomes. The questions themselves can be compared only with respect to certain computational skills embedded in them. As the year progressed, the Numeracy component of my subject had to be tailored to the mathematical demands of the studio subjects.

Year A

Although some questions in the summative June assessment (Appendix H) were still answered relatively poorly, the average of the class indicates an improvement of 8,8 percentage points increase (or 21,7% improvement) in the students' results since the diagnostic test of that year.

Question 1 on metric conversions still posed a problem. The steps involved in doing metric conversions entail several minor threshold concepts which students find difficult to grasp.

Question 3 presented a complex problem – that of calculating the total surface area of regular prisms. Question 3.1 (Figure 4.10. below) tested the students' ability to read information closely, visualise a 3-D form, and adapt a standard formula. This task should have been by far the easier of the two tasks in Question 3. Yet it was poorly answered. This is due to three issues.

Firstly, students do not read questions carefully. In the case of Question 3.1 they did not realise that the lights were closed at the bottom, but open at the top; that, therefore, they were regular prisms with a base but no top. Secondly, they could not adapt the relevant formula for calculating the total surface area of a prism. Those who realised that the light fittings had no tops applied the standard formula, and then subtracted the area of the top. Finally, several students, who had realised that this prism was open at the top, calculated one side, multiplied it by 4 and then adding the base. In their cognitively inhibiting uncertainty, but eagerness to acquit themselves successfully of the task, they took refuge in old and time-consuming strategies rather than employing the more efficient formula I had taught them. The old method did help them answer Question 3.1, but certainly was of no use in Question 3.2. I must also add that the formula for calculating the total surface area of a regular prism presents a threshold concept which most students find difficult to work through, although, objectively speaking, it should certainly not present an obstacle.

3.1. You have designed decorative lights like the one on the right. They are open at the top, are covered on all sides and the base with silver mosaic pieces which reflect light, and are suspended from the ceiling.

Calculate the total surface area which needs to be covered with the mosaic pieces. **(in mm²)**

_____

_____ (3)

If the mosaic pieces are 20mm long and 20mm wide, how many will you need for one such light.

_____

_____ (3)

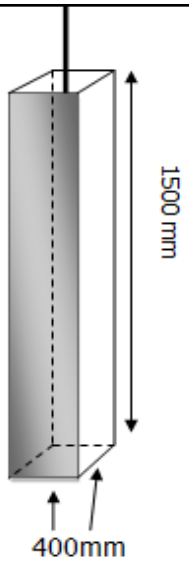
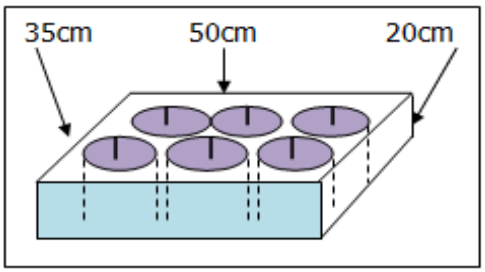


Figure 4.10.: Question 3.1. (Year A - June assessment) – Light fitting

Question 4.2. (Figure 4.11. below) is taken from the June paper (Appendix H) of Year A as well. If one compares this task to Question 3 (Figure 4.8. above) of the diagnostic test, and considers that the class average for Question 4, as a whole, was 58,8% (as opposed to 23% for Question 3 of the diagnostic test), then one realises that the group had made good progress.

4.2. Your client asks you to design a decorative glass container to hold six candles. The space between the candles is filled with glass beads. The diameter of each candle is 10cm. Calculate the volume of glass beads which you need to buy. (For convenience, consider that the candles reach down to the floor of the container.)



_____

_____

_____

_____

_____ (6)

Figure 4.11.: Question 4.2. (Year A - June assessment) - Glass container

A comparison of the results of the February diagnostic test and the June examination with regard to the shift in level descriptors (See Figures 4.2. and 4.3., p. 112), creates a clear picture of the general improvement of the group of students of Year A.
The June assessment was far more demanding than the diagnostic test in February. The redistribution of the level indicators demonstrates that, despite the relatively steep mathematical learning curve, the adjustment to a new lifestyle and an unfamiliar academic environment, as well as the distractions and pressures of the studio subjects, many students could record a substantial improvement in their Numeracy results. These improvements were accomplished within four months. Furthermore, the Numeracy module had to be broken up into sections and intertwined with lessons of a completely different nature; so much so that students requested I teach them Numeracy in uninterrupted units to allow them greater focus on this module. Unfortunately, this was not possible.

Year B

Please refer to Appendix I for the summative June assessment of Year B. The tabulated results for both the February and the June assessments are to be found on page 113 (Tables 4.3. and 4.4.).

The class average of this group improved from 34,8% for the diagnostic test in February to 52,6% for the June examination. This is an increase of 17,8 percentage points (or a 51% improvement). If one considers that the average for the entire Question 4 of the diagnostic test was 38,4%, then it is interesting to note that for the diagnostic test results (Table 4.3.) the class average lay *above* 50% for only one question. Table 4.4., however, indicates that the class average lay *below* 50% for only one question. That is a noteworthy improvement.

The bar graphs in Figure 4.5. (p. 113) illustrate the positive shift in level indicators from the February to the June results – despite the increased complexity of the questions in the June assessment. The shift is most prominent at the bottom end of the level indicators. The number of students who passed the June assessment with 50+% (Level 4 and upwards) had increased threefold.

Final comparisons

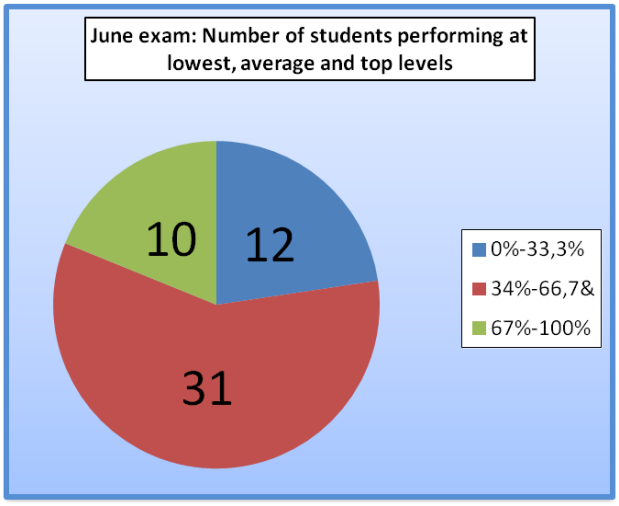


Figure 4.12.: Year A – June exam – number of students performing at lowest, average and top levels

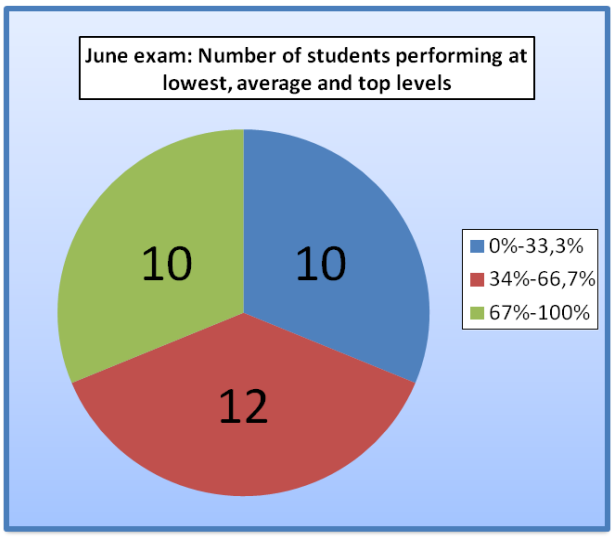


Figure 4.13.: Year B – June exam – number of students performing at lowest, average and top levels

I wish to return to the pie charts for some further comparison. If one studies Figures 4.6. and 4.7. (p. 110) and compares these to the pie charts in Figures 4.12. and 4.13., then the following observations can be made. In Year A, the number of students who were still performing within the lowest bracket in June had dropped by half, and the number of students who achieved within the top category (67+ %) had increased from two to ten students. The majority of students (31) had taken heart and attempted questions (with varying degrees of success!) which, to them, would certainly have appeared beyond their imagined reach in February. In Year B's group, which was by far the weaker one, the spread is now divided into thirds. Although a fair number of students could still not perform beyond the bottom and easiest level, the number of students who attempted and succeeded at the top level had doubled.

The graphs below illustrate by what percentage points each student's marks improved (or dropped) in the June examination compared to the February test. At the lowest end of the graphs (Figures 4.14 and 4.16), one would find those students who either had already done well in the February test and, therefore, did not have much scope, in terms of percentage increase, for improvement, or who perhaps had not benefited greatly from the interventions. At the same time these latter students need

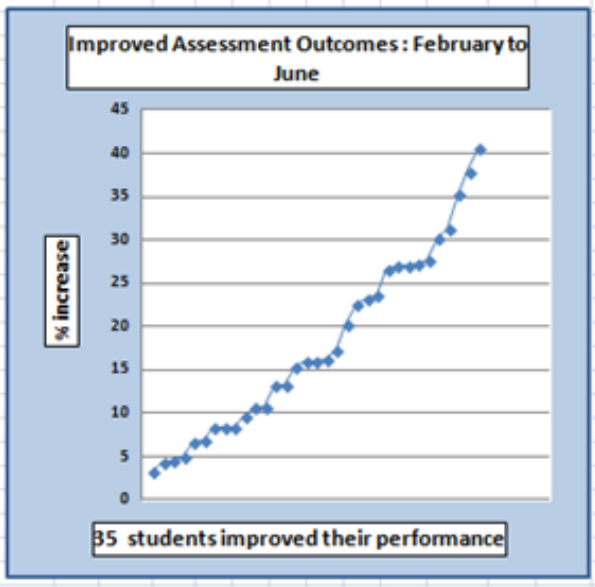


Figure 4.14: Year A improvement (in %)

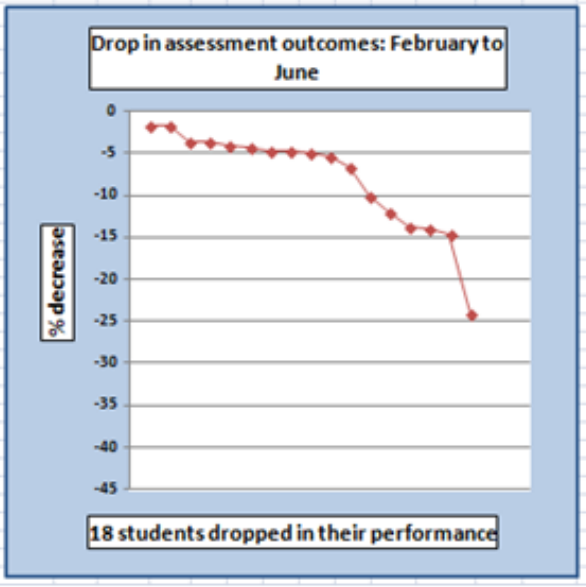


Figure 4.15: Year A Drop in marks (in %)

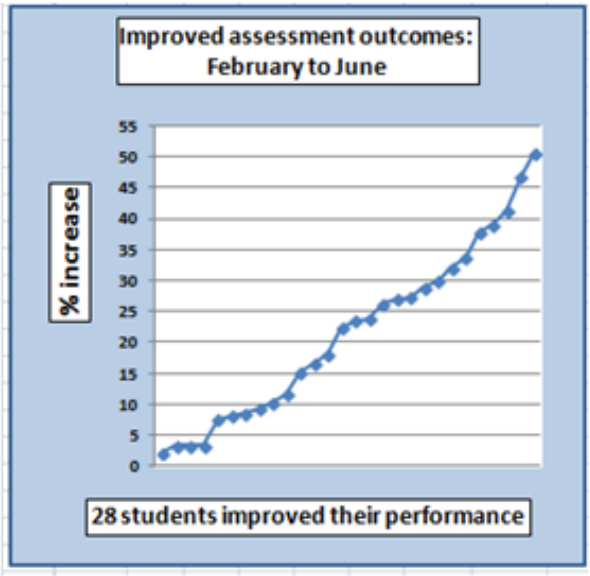


Figure 4.16: Year B improvement (in %)

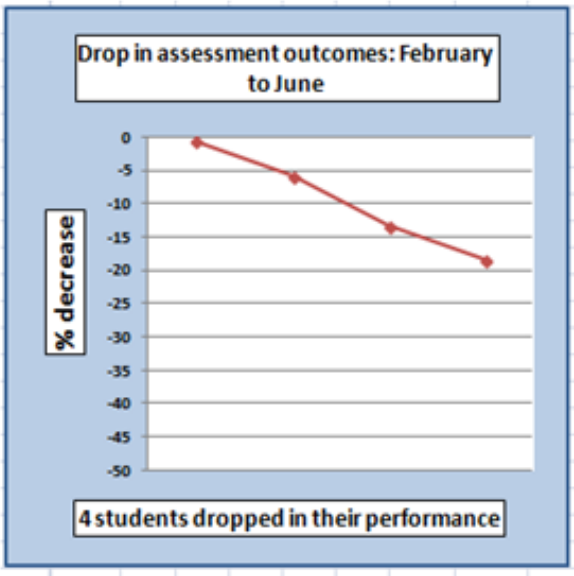


Figure 4.17: Year B Drop in marks (in %)

to be commended for their tenacity and perseverance which prevented them from dropping back. They coped with the increased level of difficulty of the work and the added pressures of the other subjects, which would have certainly compromised their working memory capacity. As for the more noteworthy percentage increases, one should remember that the greater the increase was, the lower was the starting point at the beginning of the year. It is also interesting to note that the students whose

efforts had earned them the greatest percentage improvement in June were those who had regained a sense of academic control relatively early in the year.

Turning to the graph in Figure 4.15, one notices that, in Year A, a fair number of students dropped in their assessment outcomes. Eleven of these students had already failed the diagnostic test and seem not to have been able to surmount their difficulties in Numeracy. One student had passed the diagnostic test with 50%, and then fell back by 14 percentage points. I tried in vain to interview this student. Five students had passed the diagnostic test with good results, and lost ground slightly in the June examination. The student who dropped by 15 percentage points did not fail the June assessment. From my observations I came to the conclusion that this student did not consider the theory subjects important (unfortunately, not a rare instance) and simply made sure that the June result would still be a pass.

In Year B (Figure 4.17), which represents the weaker group, the drop back in June was far less pronounced than in Year A in that only four students fell back. However, these four students did not pass the diagnostic test either. In the case of the student whose marks dropped by 13,3 percentage points it had been a matter of lack of commitment, as well as absenteeism. When it became clear to this student that the chances of joining the Architectural Technology programme the following year were dwindling, there was a marked improvement in work ethic, and the September score was 65,7%.

4.5. General reflection

Firstly, the improved performance in the two years may have been due to several factors which need to be added to the equation. A few students had taken a gap year and felt that my Numeracy module had been a much needed refresher course. My teaching was based on Vygotsky's zones of proximal development and Collins et al.'s (1991) cognitive apprenticeship theory. This approach made a substantial difference to the students' ability to grasp basic mathematical principles. Several of them observed that my breaking down these principles (which are threshold concepts!) into separate steps and building up and outward from the very basic ones, had helped them master certain mathematical procedures. I am also aware of the fact that my own approach to Mathematics, my students and teaching would have influenced the teaching and learning activities in the class.

Secondly, the quantitative data cannot, in themselves, contribute towards my investigation into the effectiveness or ineffectiveness of the individual interventions. At the time of teaching the students I had no intention of *formally* researching the effect which each of these interventions would have on the students. It was also practically impossible to launch a formal research project as I taught only one group of students per year and, therefore, had no control group; we had limited time at our disposal, and all students needed to achieve the required level of mathematical competency within the shortest possible time. Consequently, no formal experiments were conducted to link specific interventions to specific shifts in the assessment outcomes.

However, the copious feedback which I received from students indicates that the interventions had had a significant effect on them. It is, therefore, necessary to investigate their responses to each intervention separately - and then to analyse their response to the intervention programme as a whole.

Such an analysis affords me the opportunity to establish which interventions were most appreciated – and then to hone these into even more effective teaching tools. The interventions which were more difficult to benefit from, but which did have a very positive effect on the academic work of some students, could be reformulated in order to become more accessible to the group of students as a whole. It is not possible, though, to evaluate each intervention *quantitatively* for reasons already mentioned. Chapter 5 will consider a possible research programme to test the effect of each intervention separately.

4.6. Why and to what degree were the attribution retraining interventions effective?

I shall first focus on the two interventions which elicited the most positive responses from the students. They happen to be the first two interventions which introduced the students to their cognitive faculties.

Note: Where applicable, I have indicated from which questionnaire (which Appendix) I have cited the students' responses.

4.6.1. Which interventions were most effective? To what degree were they effective, and why?

As I discuss the interventions below in the light of the students' comments and reflections (the dominant data), I shall include relevant quantitative data in order to detect instances of convergence and discrepancies between the students' perception of themselves vis a vis Numeracy and the general academic demands of a university and their performance in terms of assessment outcomes. In some cases, I shall also be able to trace academic successes (and failures!) beyond the Foundation Course. I do not wish to imply that any one particular intervention had led to a particular student's improvement in Numeracy. I maintain that the improved performance of students is the result of the adapted attribution retraining programme as a whole. However, outcomes, such as improved assessment results and successful passage through the diploma years, do add credibility to the students' personal reflections on and evaluation of my attribution retraining programme.

Because this study cannot link any one intervention to an improvement in certain assessment outcomes, I have opted for a *dominant* method of evaluation (Creswell, 2003) by focusing on the qualitative data as I can link them to specific interventions. As I examine the response of the students to the intervention I shall turn to the quantitative data pertaining to those students to establish whether the two types of data converge at all, or whether there is a discrepancy.

(a) Teaching about the plasticity of the brain

The lessons which introduced the students to the concept that their brain has an almost unlimited capacity to learn and store knowledge were received with enthusiasm.

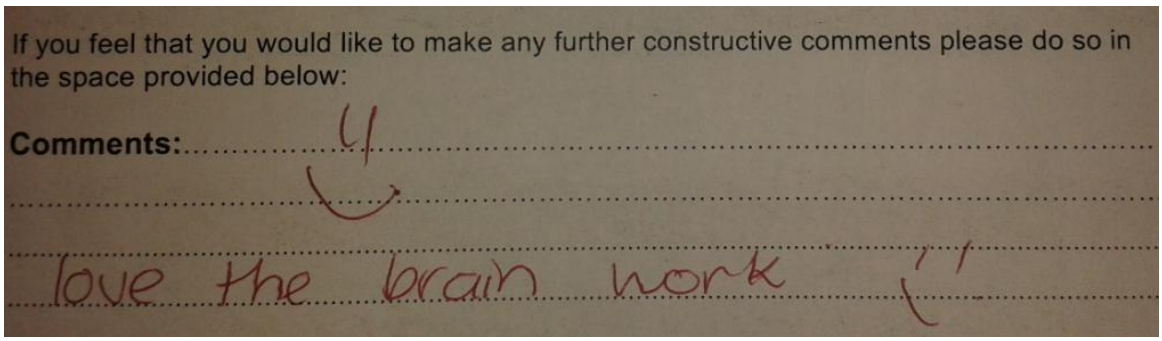


Figure 4.18.: Student's response to lectures on the brain

That knowledge is stored in physical entities, the neuronal pathways and networks, and that these can be strengthened or weakened (and even 'silenced'), depending on whether they would aid or hinder the students' cognitive activities, was new to the students. The idea that they were increasing their 'intelligence' by 'growing' new dendritic spines while attentively engaging with lessons and work fascinated them. I deduced this from the noticeably positive atmosphere in the class, the students' complete concentration on what I was telling them, as well as on the video clips I showed them. Khanyo told me the next day that he had not been able to fall asleep the night before because "I was thinking about my brain".

My aim with this intervention had been to convince the students that their brain has the ability to master the fundamental principles of any subject, not just Numeracy or Mathematics. Below are two responses which echo comments from a fair number of students.

James: "It has changed the way I will work in the future."
(Appendix D)

Shafiek: "I've learned how to think about something and if I actually understand that specific task. This lesson changed my mind on how I see things in life. This creates a new open mind for future projects."
(Appendix D)

In order to appreciate the effect which this intervention had on the students, it is necessary to digress briefly and sketch the history which led me to the inclusion of lectures on the plasticity of the brain.

As noted in Ch. 2, every group of students I have lectured in the Foundation Course admitted that they had never wondered about their brain and its ability to learn. A typical comment, which echoed those of many other students in my two groups, is given below.

Wayne: "I didn't know much about my brain. I never thought my brain could do so much."
(Appendix C)

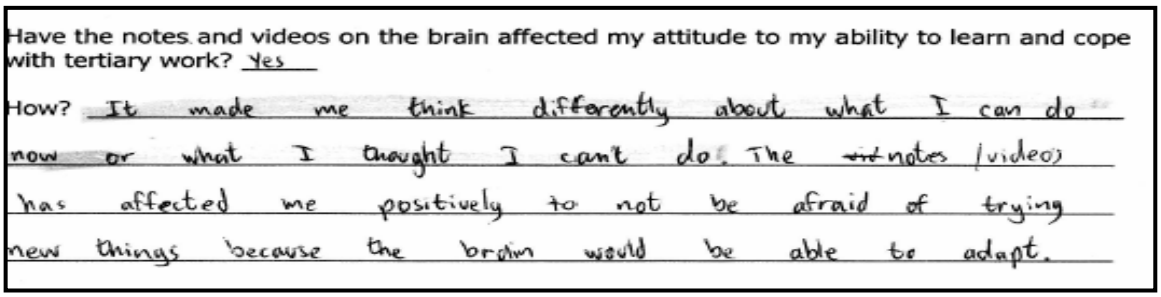
Throughout my entire teaching career, the erstwhile idea of I.Q.'s and I.Q. testing had always been a favourite topic for class discussions. For educators, as well as scholars, the thought that there were files in the office which contained each scholar's verbal and non-verbal I.Q. automatically fostered in them the notion that their I.Q.'s

were fixed entities. This, of course, led to the belief in a 'fixed mindset' (Dweck, 2008) as discussed in Chapter 2. Many scholars were keen to know their I.Q. scores. However, these same scholars did not think to ask their Biology or Physiology teachers about the learning processes of the brain – nor how and where knowledge was stored in the brain which harboured this 'intelligence'. (The belief, of course, that I.Q. scores give an accurate indication of an individual's cognitive abilities has long since been debunked.)

Having always taught my scholars about their brain and learning capacity, I was particularly sensitive to the general effect which the lectures on the brain's neuronal networks, and the accompanying video clips, had on the students.

To what degree was this intervention effective?

Wayne's response to the question whether the lectures on the brain had affected his attitude to his own ability to cope with tertiary work was as follows:


Have the notes and videos on the brain affected my attitude to my ability to learn and cope with tertiary work? Yes

How? It made me think differently about what I can do now or what I thought I can't do. The ~~it~~ notes /videos has affected me positively to not be afraid of trying new things because the brain would be able to adapt.

Figure 4.19.: Student's response indicating a shift from a fixed to a growth mindset

> "It made me think differently about what I can do now or what I thought I can't do. The notes/videos has affected me positively to not be afraid of trying new things because the brain would be able to adapt."

Wayne's admission to having been 'afraid of trying new things' is a noteworthy observation on his part and validates the theory that the transition period from school to university is a difficult one in which students, facing unfamiliar situations and tasks, tend to lose control – even if only temporarily. At the same time his comment hints at the beginnings of a paradigm shift from a fixed to a growth mindset.

Irene: "I struggled to believe in myself……."
(Appendix E)

Irene's comment that she 'struggled to believe in [herself]" reflects the sentiments of Wayne and Jessica as well. However, in the questionnaire which invited the students to reflect on the entire set of interventions, and which followed immediately after the implementation of the attribution retraining programme, Irene made the following remark:

> "The notes on the brain and the video clip also help me to understand how my brain works and that I can determin (*sic*.) what I can do or not."
> (Appendix C)

Nomie's comment below (Appendix D) hints at the same tentative shift from a fixed mindset to a growth mindset.

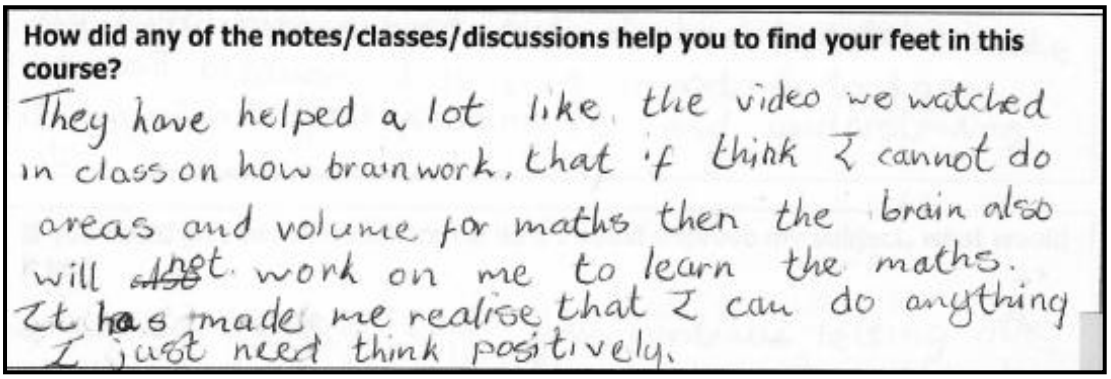

How did any of the notes/classes/discussions help you to find your feet in this course?
They have helped a lot like the video we watched in class on how brain work, that if think I cannot do areas and volume for maths then the brain also will ~~also~~ not work on me to learn the maths. It has made me realise that I can do anything I just need think positively.

Figure 4.20.: Student's reflection on self-doubt limiting cognitive engagement

> "They have helped a lot like the video we watched in class on how brain work, that if think I cannot do areas and volume for maths then the brain also will not work on me to learn the maths. It has made me realise that I can do anything. I just need think positively."

Did the lectures on the plasticity of the brain, accompanied by the video clips, therefore, have a positive impact on the students? Yes. Ten out of a group of twenty-one students (Year B) who had filled out questionnaires commented that they appreciated their newly acquired (though very basic) insights into the brain's neuronal pathways. They felt optimistic with regard to their ability to master the academic challenges which they faced. These sentiments are clearly demonstrated by the comments of Wayne, Irene and Nomie.

The lectures on the plasticity of the brain engaged the students on both an intellectual, as well as affective level. Khanyso's admission that he could not fall

asleep carries an undertone of excitement kindled by a basic understanding of the 'life' of neuronal networks.

Xolani: "Ma'am, you make me feel that I can accept myself and breathe more proudly 'coz you understand my problem & give me hope." (Appendix D)

This comment attests to a sense of relief - relief at the idea that he had the cognitive ability to succeed at his studies, and relief at the lightening of the burden of previous academic disappointments and the consequent sense of low academic self-efficacy. Xolani's progress from a hesitant student in Numeracy to one with a healthy sense of self-efficacy in the subject can be deduced from his remarks below.

Xolani: "…. as a learner who is not that good at it [Maths]……"

And then:

Xolani: "I have learned to trust myself when it comes to Numeracy…."

Xolani's results in the Numeracy module improved from 23% for the diagnostic test to 50% in the June assessment (a 117,4% improvement). He passed the Numeracy admission test at the end of the year to allow him into Architectural Technology, and he finished his studies last year.

The degree to which this particular intervention had a positive effect on the students' ability to gain epistemological access to Numeracy cannot be determined quantitatively, as noted above. However, the positive feedback from the students, both spoken, written and non-verbal, leads me to conclude that this intervention made a significant, positive and lasting impression on the students.

Why was this intervention effective?

Three factors played an important role in the effectiveness of this intervention.

Firstly, as discussed above, students are interested in their intellectual capacity. Their natural curiosity in their own 'intelligence' made them an eager audience, the conundrum being that their preoccupation with their 'intelligence' had never led them to ask questions about the workings of their brain.

Secondly, extremely large numbers and the vastness which they represent seem to intrigue both young and old people. The brain's limitless ability to learn, its vast storage capacity, the speculations of neuroscientists as to the number of neurons in a human being's brain, as well as the multitude of connections possible among neuronal networks, inspired the students.

Lastly, visual material is a powerful teaching tool. The video clips of the 'life' of neuronal pathways and networks, which also demonstrated in a very creative and realistic manner the vastness of the brain, made a lasting impression on the students. The images which illustrate the 'birth' and growth of new dendritic spines (Chapter 2), initiated by the person's willingness to focus on and engage with new information and experiences, led us to the conclusion that, within one lecture period, students could increase their intellectual capacity by concentrating on their work. For a student who harbours a belief of low academic self-confidence, such information is bound to set in motion a paradigm shift from a fixed to a growth mindset.

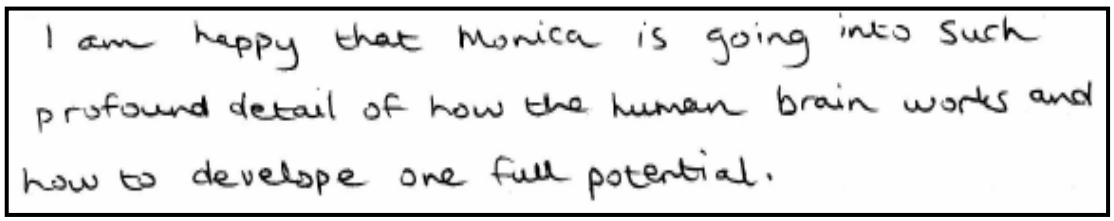

I am happy that Monica is going into such profound detail of how the human brain works and how to develope one full potential.

Figure 4.21.: Student's comment regarding lectures on brain plasticity

> "I am happy that Monica is going into such profound detail of how the human brain works and how to develop one full potential."

(b) Explicit teaching with regard to the memory systems, with special emphasis on the working memory

In my personal interaction with scholars, as well as students, my observation has been that they have never been introduced to their own cognitive processing mechanisms. It is difficult to imagine how a student should be expected to study meaningfully, if s/he is not aware of how the available 'tools' for such an activity should be used constructively. The knowledge of how to employ one's cognitive faculties optimally should rekindle previously discouraged students' motivation and perseverance (major aims of the traditional attribution retraining treatments as well) in their academic challenges. Below is one of several comments by students who felt

that they had been given a second chance at success after the lectures on their memory systems

Nthandi: "The most thing that I like (*sic*.), Monika, is that you give us hope even though we do badly & this motivates me to work my best (sic.)." (Appendix D)

However, in Nthandi I watched the battle between her willingness to accept and internalise the idea of being able to gain control of her cognitive abilities – and her deep-seated misgivings regarding Numeracy. She never missed classes and often asked me for supplementary exercises. Her motivation and perseverance were exemplary. Nonetheless, her marks did not improve. She presented the typical case of a student who eventually succumbed to her ingrained sense of low self-efficacy. Under the heading regarding Kolb's experiential and reflective learning cycle (# 4.6.2. a) I shall elaborate on my observations of her attempts at mastering Numeracy.
(See WhatsApp communication with Nthandi: https://drive.google.com/file/d/0B-X4SpGuMP0QZGhxeDg1a2RFMjQ/view?usp=sharing)

Sipho's comment (interview transcript No. 1; use link below) on the lectures which dealt with the working memory encapsulates the difficulties which many scholars and students have with regard to optimal study methods:

Sipho: "I knew there was a way that I can make my brain work in the way that I want to. I just didn't know how to do it."
https://drive.google.com/file/d/0B-X4SpGuMP0QQlN2MEpuTXd1SEE/view?usp=sharing

I will show in the next section that Sipho became a success story.

To what degree was this intervention effective?

Sipho came to a better understanding of the working memory's information processing when …

> "… you [I, the lecturer] broke it down into how the brain works and how you can – like – can tap into what you want and then focus on that. ... and how you can shift and put your focus on what you're doing…"
> (interview transcript No. 1)

With his last remark, Sipho was referring to the executive system's attentional control ability. It is worth noting that he still remembered this detail two years later - proof that he had understood, internalised and applied this knowledge.

Sipho obtained 27% for his diagnostic test in February of that year. For his summative June assessment he obtained 44% (a 63% improvement). Although this was still a failure (being below 50%), it showed a marked improvement. Sipho had registered for Architectural Technology for the next year (his normal first year) and passed his entrance assessment for Mathematics at the end of the Foundation year. He was offered a bursary, has completed his diploma course and is now working for the company who sponsored his studies. This indicates that, during his years in Architectural Technology his command of Mathematics must have steadily improved as it is common knowledge that Applied Building Sciences (a subject based very much on Mathematics) is a serious first-year hurdle for many students.

Lizwe's comment runs in the same vein.

Lizwe: "…when I started learning about the memory as well, I started seeing - Okay - wow - this is how it works." (interview transcript No. 2; use link below) https://drive.google.com/file/d/0B-X4SpGuMP0QbnA4OVhfaURwR0U/view?usp=sharing

Lizwe's results improved from 44% for the diagnostic test to 63% for the summative June assessment of that year (a 43,2% improvement). He, too, had registered for Architectural Technology and is in his final year of studies now.

Sabelo's comment on the intervention regarding our memory systems and how they function reflects the kind of reaction which I had hoped to achieve with the students:

Sabelo: "It motivated me and it opened my mind to - into a new concept of learning. …. It helped me a lot in such a way that also in my first year, especially in my theory subjects and all that… The way I approached my studies – it was now different from the way I used to in high school." (interview transcript No. 3; use link below) https://drive.google.com/file/d/0B-X4SpGuMP0QZGtGUWJQbW5VTlE/view?usp=sharing

Sabelo had taken Mathematics ('pure Maths') at school and had passed it. For our diagnostic test in February, however, he obtained 33,3% and was crestfallen. He admitted in our recent interview that it had been a negative attitude which had held him back at the beginning of his Foundation year with us. However, he also admitted in our interview that "when I decided to come to you and you showed me all that…" it was the interventions which "opened my mind." In June he obtained 73% for the

summative Numeracy assessment (a 119,2% improvement). This result was the outcome of a young man's determination. He would walk past me and repeat to me what I had advised him to do at the beginning of the year: " 'perseverance', Ma'am, 'perseverance'."

Why was this intervention effective?

For several reasons the students were very receptive to the lectures which introduced to them the idea of different memory systems and how they function.

I illustrated certain features of the working memory by means of memory games which we played in class. This meant general involvement by all students, they were given the opportunity to test their own memory skills, and the presented information could be validated. Furthermore, by sketching certain scenarios which all students had witnessed at school and experienced in their personal lives, I gave them the opportunity to identify with what they were being taught and link this new knowledge to prior knowledge. At the same time sketching very familiar scenes from school classrooms caused much mirth in the group which created positive learning experiences.

Finally, revisiting their initial free-writing task from the perspective of this newly gained insight regarding their memory systems enabled them to recognise the 'minefield' which they had unwittingly experienced in their Mathematics classes at school. The realisation dawned on them that their performance in Mathematics (or Maths Literacy) at school had been largely governed by certain factors (whether internal or external, stable or unstable, controllable or uncontrollable) which had slowed down their academic progress in this subject. These factors included, for instance, their own attitude towards the subject, the composition and attitude of their class, as well as the approach of the teacher(s) who taught them Mathematics or Maths Literacy. This realisation also opened their eyes to the fact that their past disappointments in these subjects were not immutable – and not due to their own innate shortcomings. Below follows an example of such an experience:

Tom (interview transcript No. 4), thinking back to his Grade 8 year, made the following observations:

Tom: "… unfortunately, the teacher I had - he didn't - it wasn't only me - so - it wasn't really a problem with me - like - half our class failed… His train [of thought] was - was - if we

had a problem with things - say: I struggled with something, then it would have been my own problem……"
https://drive.google.com/file/d/0B-X4SpGuMP0QeFFpOHVvT2xjRmc/view?usp=sharing

When I asked him how this experience in Grade 8 had made him feel, his response was:

Tom: "….that made me feel very stupid. I actually - I gave up on Maths in the sense that I did not actually want to do it. I developed *this mindset* where I - I'd do Maths and I said to myself: Okay. I just want 40%.... and that was something that grew with me…. - and that was my goal - Grade 8 - Grade 9 - Grade 10. To think now, if I had to get 40% I'd be so depressed. And to think I was fine with it."

The italicised phrase in his last comment illustrates how, in this case, an external negative factor could influence a young scholar's mind to accept, seemingly permanently, a state of academic mediocrity with regard to Mathematics. His last two sentences clearly indicate his critical reflection on his erstwhile school results.

In the Foundation Course, Tom obtained 30% for the diagnostic test and 64% for the formal and summative June assessment (a 113,3% improvement). He had registered for Architectural Technology and is now in his final year.

(c) A matter of control

The students' engagement with and response to the above two interventions highlighted what researchers (Ruthig et al., 2004; Perry et al., 2005; Haynes et al., 2009) report concerning a student's perceived level of control. Several students, when asked about their sense of control, admitted that they had had self-confidence at school, but that they had faltered and lost this sense of being in command of their situation when they arrived at university. However, they did regain it and fared very well. All the students who experienced this temporary loss of perceived control, and whom I interviewed, credited certain interventions of the attribution retraining programme with a positive role in their progress.

Loyiso: "At high school I felt like I'm in control. I was focused and in most of the subjects I understood the subject matter at once." (recent WhatsApp discussion)
https://drive.google.com/file/d/0B-X4SpGuMP0Qc3cyRmRLc0dxOHc/view?usp=sharing

After the diagnostic test, Loyiso had lost his sense of domain-specific control:

> "My self-confidence was very low, disappointed at myself because I reflected to my maths last year (during matric) and it was a big drop."

However, he had also lost a sense of general academic control:

> "No, I didn't feel in control because I was not confident much to myself as it was my first time being engaged to design studies as a whole."

And then he found his feet, both in a general academic sense…

> "End of the third term: I felt in control again because was getting to understand the course quite well and I think the passion I had for design as a whole was the one which kept me going the most."

...as well as in the domain-specific sense (in Numeracy):

> "You made your lectures so fascinating and the fact that you repeat things over and over again they tend to stick to mind. Even though sometimes one gets annoyed when repeating one thing but now I realise it helped."

I did explain to him that that was my method of building new neuronal networks in their brains; he was surprised and grateful. Loyiso's marks in Numeracy improved from 27% in February to 77% in June (a 185,2% improvement). Xolani, Sabelo, Lizwe, Bongi and Tom experienced the same shift in perceived control. Having had self-confidence at school, and having lost it at the beginning of their Foundation year, they found their inner equilibrium again and performed well in their subsequent studies.

4.6.2. Which interventions were less effective, and why?

Whereas the students were very receptive to the two interventions which dealt with the cognitive aspects of learning, they struggled to employ the meta-cognitive skills at the core of the next two interventions. They certainly could identify with examples I gave them from everyday life and their school experiences, but they found it difficult to recognise threshold concepts in their syllabi and to apply Kolb's reflective learning cycle to both their situational and academic challenges. They could do it only with my guidance. I venture to suggest that, to a large extent, this was due to their having

come to university with an already low level of self-confidence, and then having developed a sense of being out of control in this very unfamiliar environment. It was only those students who came with an intact sense of control, lost it temporarily, and then regained it as the year unfolded, who reported back to me that both these interventions had been of great value to them.

(a) Kolb's experiential and reflective learning cycle

The literature regarding conventional attribution retraining treatments emphasises that students who had been exposed to such treatments were willing to adopt and employ new and more effective learning strategies.

By teaching my students a very simplified version of Kolb's experiential and reflective learning cycle I endeavoured to equip them with a method of analysing their academic successes and failures as well as their situational challenges. They could then, hopefully, devise strategies to reduce or eliminate obstacles to their personal and academic success. Moreover, this approach to challenges in Numeracy in particular should also lead them to the realisation that it was not an innate inability to succeed at Numeracy, but a matter of analysing and evaluating their working methods in this subject - and then developing new and more effective strategies on the basis of their newly gained insights.

This intervention did not elicit the same *general* positive response from the students as did the first two interventions discussed above. There were those students who benefited from applying Kolb's experiential learning cycle to their situational environment (more often than not with my guidance), but not their academic work; there were those who successfully incorporated this meta-cognitive skill into their situational environment, as well as their study strategies; and there were those who failed to do either.

<u>Successes regarding situational challenges</u>

Kolb's reflective learning cycle is an abstract concept, and would remain an abstract concept when applied to academic challenges. For this reason I used practical, problematic situations to introduced Kolb's strategy to the students. We dealt with their situational difficulties. We looked at issues, such as cooking healthy meals (in the residences) in the shortest possible time with the least equipment and the least expenditure. We looked at transport problems, analysed them, devised new plans and tested them. We considered how best to use the opportunities which the library

offered, especially with regard to the many students who were forced to work under very difficult circumstances at home. In some memorable cases the results were excellent as the students reorganised aspects of their lives and profited greatly, both personally and academically, from the adjustments made.

Academic successes

There were a few students who had come to university with a sense of relatively high academic control. They were motivated and ambitious. When I asked Sipho in the recent interview whether he felt that he had come to university with a sense of being fairly in control of his academic activities, this was his response:

Sipho: "Yes, I did. I did. And that really helped me ... to plan in my head how I needed to structure my time and ... my energy and on what I should focus my energy ... in order to achieve what I want." (interview transcript No. 1)

However, some of these students did falter temporarily because of the new academic and situational environments and, in the case of our Numeracy, seemingly novel tasks - seemingly novel because the tasks, though very basic, had been contextualised in design fields with which the students were not yet very familiar. Nevertheless, these students had the academic self-confidence to experiment with new methods and strategies of solving the mathematical challenges with which they were confronted.

Irene: "It [this intervention] helped me unraffle (*sic*.) and to process work." (Appendix E):

Lizwe stated that he employed the reflective learning cycle, but admitted that

> "it was more subconscious than conscious ... what do I do now, and then - like - you know - I start looking at things and saying: What steps did I miss? Where do I go from here?" (interview transcript No.2)

Bongi described a similar approach to academic challenges. She, too, would analyse her execution of projects and attempt to establish how and why she had underperformed.

Bongi: "…you have to go back and ask: Why am I not finishing my projects on time? Why am I not doing this? … And then you go back having to think: Did I go to the lecturers enough to ask how… You need to know in order to - because if you

[don't] you keep on doing the same thing over and over."
(interview transcript No. 2)

Her assessment results in Numeracy improved from 44% for the diagnostic test to 86% for the formal summative assessment in June. What makes both Lizwe's and Bongi's comments gratifying is the fact that they were made in our recent interviews (conducted towards the end of their second year of Architectural Technology). This indicates that they had internalised this meta-cognitive skill and have applied it in their post-Foundation academic years as well.

Liana wrote: "Found it very valuable, helped with my design thinking"
(Appendix D)

The above comment is echoed by similar remarks made by other students and indicates that one of my aims, namely, that the students would transfer these meta-cognitive skills to their other subjects as well, was being realised.

Lack of academic success

The questionnaire (Appendix D), which asked the students for feedback on the set of attribution retraining interventions as a whole, did not ask for feedback on Kolb's reflective learning cycle in particular. However, the question "How have any of the Professional Business Practice classes helped you find your strengths/quieten your fears?", and which elicited many very positive comments on the lectures regarding their brain, did not show up any feedback regarding the reflective learning cycle. This would indicate that this intervention did not seem to have made a meaningful impression on many of the students.

Furthermore, although I had explicitly applied the reflective learning cycle to their academic work in class, both to their Numeracy tasks and assignments in another theory subject, many students did not profit from this approach and reverted to old and more familiar, though ineffective and often counterproductive, approaches and strategies.

Possible interpretation of this finding

The fact that the students were not very communicative regarding this intervention is, in itself, perhaps an indication of their inability (a) to grasp the meaning and significance of the reflective learning cycle, and (b) to identify specific problems in their engagement with Numeracy which presented obstacles to their academic progress, and then to employ the reflective learning cycle in order to find solutions to these problems.

Furthermore, in preparation for the lectures on Kolb's reflective learning cycle, and Meyer and Land's threshold concepts, the students had been briefly introduced to the notion of meta-cognitive skills. This latter concept is not an easy one to understand; the term is foreign and its meaning elusive. It leads me to think that, perhaps, the idea of a reflective learning cycle – on an academic level! - was as elusive to many students.

As discussed in Chapter 2, students had resorted to fixed methods of studying at school – often, especially in Mathematics, rote learning without understanding. I was asked regularly whether I would provide the correct formulae in summative assessments. Students asked me for extra sets of exercises - which is most commendable as it speaks of their willingness to put in extra effort. However, the reason I was given was that at school they had passed their exams by doing multiple sets of exercises - in other words, by means of rote learning. As mentioned above, Bongi admitted, when she was still in our Foundation year, that

> "…I learned and understood formules (*sic*.) which were taught to me before [at school] but did not know the point and meaning behind it, and always forgot them."
> (Appendix D)

Furthermore, the very basic and simplified version of Kolb's experiential and reflective learning cycle which I presented to the students is, essentially, an exercise in reflecting upon one's own learning experiences, both positive and negative, and then making meaningful adjustments. Weiner (1985:548) postulates that, "once a cause, or causes, is assigned, effective management may be possible and a prescription or guide for future action can be suggested." However, one example of the students' inability to grasp the importance of analysing one's failures (and successes) is their lack of interest in and appreciation of feedback after tasks have been marked and returned to them. They are eager enough to be given their marks, but my observation has been that they are not interested in a 'post mortem' of their assessment tasks. Despite my regular reminder that they needed to make notes regarding where and why they had lost marks, this exercise did not bear fruit in many instances.

Ertmer and Newby (1996:4-6) describe novice learners as being individuals who are seemingly helpless in the face of their own failure to perform satisfactorily at academic tasks. They do not know how to analyse their underachievement, find the root causes, and then strategise accordingly. This description certain fits many of the students in my classes and explains their lack of interest in feedback.

However, there is another explanation which may cast light upon the above mentioned impasse. Many students came to our Foundation course with a sense of very low self-efficacy in the realm of Mathematics. This has been discussed at length in Chapter 2. Engaging meaningfully with Kolb's reflective learning cycle necessitates the willingness (and confidence) to employ new strategies, once one has discovered that the old ones are not efficient anymore. If at school it was acceptable to calculate separately the areas of the several faces of a regular prism and then add them all up to arrive at the total surface area of the prism, at university and in the future workplace time is of the essence, and using the *formula* for the total surface area is the efficient method of calculation. My observation, however, was that hesitant students, students who sensed that they lacked academic control, would revert to previously employed, and ineffective, strategies during formal assessments. This cost them precious time and often led to incorrect answers.

If such students also suffered from state anxiety, their ability to perform well in formal assessments was even further compromised. This was the case with Nthandi who, by nature, was an anxious person (trait anxiety) faced with tasks in a subject that she felt most uncomfortable with (added state anxiety). She would revert to ineffective, but familiar, strategies from anxiety. During assessments, I watched how she delayed starting the task, finding other urgent matters to attend to first, and then would work slowly and with deep concentration, second-guessing herself by going over her calculations repeatedly, thus wasting precious time - and then battling with the added stressor of not being able to finish the assessment on time.

Nthandi was the student who wrote that my interventions gave her hope, even though she was not performing to her satisfaction (p. 130). In our recent WhatsApp communication (link p. 130 above) she still holds fast to the idea that her brain can do anything if she puts in enough effort and hard work. However, at the same time she admits that she was too shy to ask questions because she believed this would make her look "stupid". (See WhatsApp communication, date: 19/9/2015.) Nthandi understood intellectually that she had the cognitive ability to achieve her goals, but was a 'novice learner' who could not apply the relevant strategies to translate this knowledge into academic success.

The above observations are documented in the literature on Maths anxiety as well (Ashcraft & Kirk, 2001; Hoffman, 2010). The reason given for this reverting to older and more familiar strategies is the effect which the pressures of (a) being expected to perform satisfactorily and (b) having to do this within a set time limit, have on the

academically insecure student. In my classes and assessments I have watched this escape into the 'safety' of school strategies many times. Furthermore, I have observed that the reversal to previously learned and used strategies is often employed by the students who are most anxious to do well. This means that one of the outcomes for which traditional attribution retraining treatments are praised and recommended, namely, increased (or renewed) motivation and perseverance, does not necessarily apply to some of our students (They are motivated.); neither does the notion that such increased motivation and perseverance will necessarily lead to academic success. And, whereas the proponents of traditional attribution retraining also emphasise the positive effect which adopting new strategies has on the outcomes of students' academic work, our students often shy away from new strategies because of their sense of low academic control.

Is there a solution to this impasse?

The answer to the above question is a 'Yes' and a 'No'. And this duality applies to the fourth intervention (that of introducing the idea of threshold concepts) as well.

The first two interventions were accessible to the students in a far more tangible manner. The information imparted to the students was memorable in the sense of easily remembered as well as worth remembering – and accompanied by visuals and anecdotes. Acquiring this knowledge took four lessons only.

However, Kolb's reflective learning cycle requires abstract thinking and regular practice and application! To achieve a lasting effect, students needed to demonstrate the willingness and determination to employ the reflective learning cycle whenever they experienced a stumbling block in their studies. Internalising and applying this skill takes time, and time constraints present a serious hindrance in the Professional Business Practice subject. To my question (Appendix E) whether the students felt that they had had enough time to gain noticeable benefits from the interventions I had put in place, Liana wrote:

Liana: "It was just enough time; any less would have been to (*sic*.) little time."

Liana was the top student in the class of Year A. In response to being taught meta-cognitive skills she wrote (Appendix D):

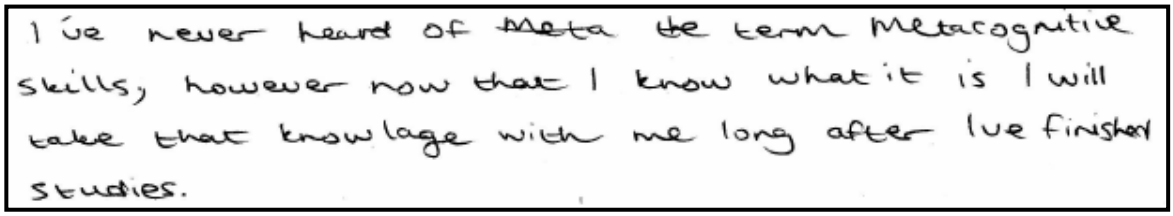

I've never heard of ~~Meta~~ the term Metacognitive skills, however now that I know what it is I will take that knowlage with me long after I've finished studies.

Figure 4.22.: Student's comment on meta-cognitive skills

> "I've never heard of the term meta-cognitive skills, however now that I know what it is I will take that knowledge with me long after I've finished studies."

If Liana, a confident and self-driven student, felt that the time we had at our disposal was only 'just' enough, then one may assume that for many students the time was too little.

Irene's response to the same question regarding time was a "NO" (written in capital letters). She admitted in her recent questionnaire that she had been particularly apprehensive about Numeracy. She described her reaction to this module and its assignments as "shaky", "panicky", "scared" and "worried". The fact that her marks for the Numeracy module, which had improved from 20% in February to 50% in June, dropped back to 23% in September attests to her not having had enough time to become proficient at applying the meta-cognitive skills she had been exposed to. Irene was a conscientious student and had commented that understanding the reflective learning cycle had "helped me to unraffel (sic.) and to process work."

Consequently, the answer to the question whether there is a solution to the partial failure of this particular intervention would be: Yes. We need more time; time distributed over the entire year so that the students have the opportunity of applying this meta-cognitive strategy regularly. With time they would learn to recognise their problem areas more clearly and could become adept at analysing them and devising new strategies which they could put into practice – and then analysing the outcomes again, and thus completing the reflective cycle. With time they could also complete the paradigm shift to a growth mindset which would give them the courage to venture out into new, hitherto not experienced, domains of cognitive and meta-cognitive skills.

Unfortunately, the present structure of the Foundation Course in its entirety forces one to answer: No, there is no immediate solution. The course does not allow us enough time to delve more purposefully and at greater length into attribution retraining interventions. Despite the fact that the curriculum of the Professional Business Practice subject is crowded, as it is expected to address several academic literacy skills, the time allocated to this subject is limited. Consequently, the

Numeracy module is concluded by June, and the meta-cognitive skills, which have been put in place to help the students become quantitatively literate, threaten to become 'stunted' in their development during the second semester.

(b) Meyer and Land's threshold concepts

Although an understanding of threshold concepts is particularly important as part of acquiring meta-cognitive skills, recognising threshold concepts appears to be difficult. Consequently, the introduction to threshold concepts elicited a mixed response.

Often a seemingly impenetrable 'screen' exists between a lecturer's teaching specific concepts embedded in a subject, and his or her students' understanding of such concepts. What appears to be obvious and clear to the expert in the field appears opaque and inaccessible to the students. One particular lecturer, who is considered an expert in his field (a field which depends very much on mathematical concepts) admitted to me that he was at a loss for ways of helping his students cope with his subject. "I can only tell them to learn," was his final comment.

If I could teach my students to recognise such blockages for what they are, namely threshold concepts, to understand and accept that it was not a lack of intellectual ability on their part, but a hurdle which needed to be approached with patience and the employment of specific strategies, then they would be able to work their way *through* such concepts (meant quite literally, as some threshold concepts require very focused and persistent effort to be mastered). Sabelo, who had struggled with Numeracy at the beginning of the Foundation year but who had succeeded in the end, came to visit me the next year (he was doing Architectural Technology) and thanked me for having introduced them to the idea of threshold concepts as now he was able to deal successfully with all mathematical challenges in Applied Building Sciences.

Irene: "It is the point [at which] you understand something; when you get how something works." (Appendix E)

<u>Sparse successes achieved</u>

When I explained the *effect* which threshold concepts have on the teaching and learning situation involving both scholars (or students) and their teachers (or lecturers), the students could immediately identified such instances in their previous learning situations.

Tom: "He [the Maths teacher at school] would teach us and then automatically expect us to grasp. He thought everyone was at this level of Maths because we got into this school. … I did Maths, but I actually never really understood it." (interview transcript No. 4)

The above comment indicates that there was a disjuncture between what the teacher expected his scholars to grasp in Mathematics, and what the scholars were able to understand. The fact that Tom did pass his Mathematics, but did not understand what he was doing points to what Atherton (2010) describes as "mimicking performance well enough to pass assessments". In retrospect, Tom was acutely aware of the futility of his efforts at school.

The students were noticeably relieved that there was an alternative explanation for their inability to grasp certain mathematical concepts; that it was not necessarily an intellectual shortcoming on their part. The thought that concepts which seemed to be 'transparent knowledge' (Lave & Wenger, 1991) to their teachers, presented 'troublesome knowledge' (Perkins, 1999) to them as scholars, was a novel, but enthusiastically embraced, idea. And rightly so!

Once again, it was the students who brought with them a relatively sound sense of self-efficacy, who felt that they had only temporarily lost control, but who were convinced that they would regain it once they had acclimatised to academic life and the demands of our Foundation Course - it was these students who were prepared and able to transfer the idea of threshold concepts into their academic reality and ascribed some of their successes to having done so.

Sabelo: "I had pure Maths [at school]…It [his school experience in Maths] was good. … I had an *attitude* towards it [our Numeracy course]." (interview transcript No. 3)

He admitted that his poor marks for the diagnostic test "made me feel bad - and at the same time *it made me to change the attitude* I had." Sabelo certainly felt that he could take control of his situation.

Sabelo, found it difficult to express his understanding of threshold concepts in words. However, it was obvious to me from several conversations (he was the Architectural Technology student who visited me the following year to tell me that he was successfully applying the idea of threshold concepts in his studies!) that he could identify hurdles in his subjects and would purposefully engage with them in the light of

what he knew threshold concepts to be. He explained (interview transcript No. 3) that he would “study with the mindset that segregates things” and that in the end he would “enter the other side”. This last comment was his way of echoing what Meyer and Land (2003) describe as “a portal, opening up a new and previously inaccessible way of thinking about something”, and what we in class called ‘breaking the sound barrier’. He assured me that he refused to “mimic performance”, which is a phrase used by Atherton in his article on threshold concepts, an article on which I had based a task. Sabelo had remembered this phrase – and knew what it signified.

One student who had done reasonably well in his diagnostic test and had performed well in most tasks and assignments, experienced a particular stumbling block: metric conversions. Once we had broken down the process of doing metric conversions into its various steps, he came to realise that one particular step caused him problems. I identified this step as an example of ‘troublesome knowledge’. In primary school, children are taught that, when they multiply a number, the answer is bigger; when they divide a number, the answer is smaller. This concept is firmly encoded in their neuronal pathways - right through their school years. And, although they have been taught metric conversions, even the Education Department’s annual report (2014) on the 2013 National Senior Certificate results notes that this particular computation is causing scholars difficulties. Now, at university, revising metric conversions, I was emphasising that, when one converts smaller units to larger units, one has to divide; when one converts larger units to smaller units, one needs to multiply. Many students, including this young man, could not grasp this concept. It seemed to go against their ‘grain’, their well-established neuronal pathways that ‘knew’ that the transition from ’small’ to ‘big’ required multiplying, and that the transition from ‘big’ to ‘small’ indicated dividing. It was this concept that had blocked the young man’s ability to perform metric conversions. His feedback in the questionnaire (Appendix D) was:

> “I learned to identify problem areas in certain subjects I’m taking, e.g. conversion in Maths. I also learned to find a solution to these problems.”

Bongi: “Monika made it so easy that now I can do any maths conversion……..”

Bongi continued: “I learned a lot of things that I struggled with – the small things that I struggled with at high school - you made them clear to me ... Now people come to me with conversions, wanting me to help them. Don’t worry, it’s easy. The pattern - and then I draw this … I think you ironed out a lot of things [answer to my question regarding concepts]. The basics of Maths, the conversions…..” (interview transcript No. 2)

Below I have given one more positive comment from a student who had come to understand that threshold concepts were not exclusive to Numeracy in the Professional Business Practice subject, but would be encountered in other subjects, too, as well as in life itself.

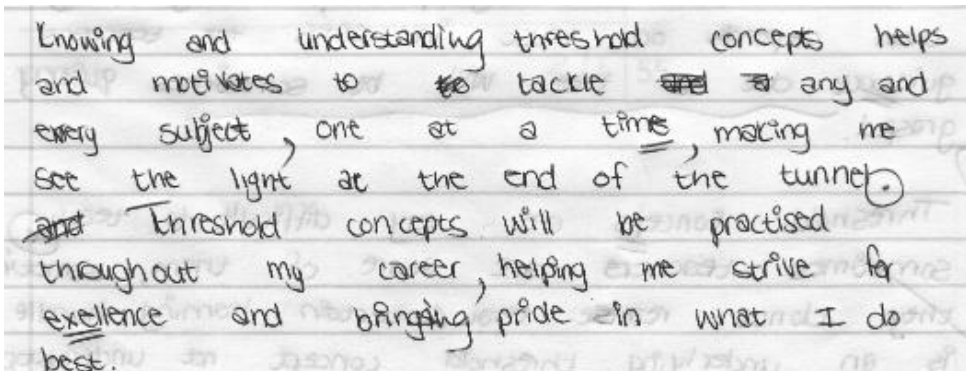

Knowing and understanding threshold concepts helps and motivates to ~~to~~ tackle ~~and~~ ~~a~~ any and every subject, one at a time, making me see the light at the end of the tunnel. ~~and~~ Threshold concepts will be practised throughout my career, helping me strive for excellence and bringing pride in what I do best.

Figure 4.23.: Student's comment regarding threshold concepts

> "Knowing and understanding threshold concepts helps and motivates to tackle any and every subject, one at a times, making me see the light at the end of the tunnel. Threshold concepts will be practised throughout my career, helping me strive for excellence and bringing pride in what I do best."

<u>The elusive concept - of threshold concepts</u>

Unfortunately, many students groped for an understanding of this concept and faltered. In answer to the question "Explain what you understand threshold concepts to be" (Appendix D) they attempted to express their thoughts on threshold concepts, but had either not grasped the meaning of the latter at all, or their comments hint at only a partial understanding of this concept.

Abdullah: "They are a means to understanding the bigger problem. It is the stepping stones that are required to be understood." (Appendix D)

Lizwe spoke of trying to "break a barrier through something." (interview transcript No. 2)

<u>A possible interpretation of this finding</u>

The notion of threshold concepts is the more abstract of the two interventions which had a less noticeable effect on the students, both at the time of implementation of the attribution retraining programme, as well as after two years.

The search for an interpretation of this finding has led me to ask the following questions.

Was the language register of the text of the article, on which I had based my teaching this concept, not accessible enough to the students? However, the task which I had set on the article produced a class average of 62% in Year A and 67% in Year B. I need to note, though, that 10 out of 57 students in Year A did not engage with the set task at all. Considering what I had taught the students regarding cognitive skills, this meant that 17,5% of the class had not allowed their intellect to grapple with the concept of threshold concepts.

Was it the demands of other areas of the students' studies which absorbed valuable time and occupied vital space in their working memory capacity? Because the idea of threshold concepts is more complex, I had introduced it only in Term 3 of each year. The rationale was that I would deal with thinking skills, as well as critical thinking, in the second term in order to foster in the students the ability to think analytically. This, I had hoped, would make the meta-cognitive skill of identifying threshold concepts more accessible to the students. However, in the third term the pressure of the studio subjects, their more demanding practical projects, as well as the final preparations for the imminent portfolio moderations, intensified, and attendance in the Professional Business Practice subject showed a marked decline.

There was also an unavoidable disconnect between the Numeracy module and the presentation of this final meta-cognitive skill. The Numeracy module needed to be completed before the end of Term 2 of every year in preparation for the final studio project in Term 2 which had always been a major Interior Design project, and the first project of Term 3 which was an even more demanding Architectural Technology project. Consequently, I would concentrate single-mindedly on the Numeracy syllabus in the first semester (along with other academic literacy skills which needed to be taught) and only touch on the notion of threshold concepts. Nonetheless, when we came upon instances of such concepts, I would weave the term into my teaching in order to start the construction of a foundation of prior knowledge for the third term's more detailed work on threshold concepts. The outcome of the misalignment between Numeracy and the intervention regarding threshold concepts was that the students' first personal opportunity to identify threshold concepts in their maths-related curricula, and then to engage with these hurdles constructively, presented itself only in the year following the Foundation Course.

Can this intervention be rendered more effective?

The answer is: Yes, it can - but with difficulty.

As discussed in the section above on Kolb's reflective learning cycle, our lecture time was limited. For this reason it would be advisable to engage other lecturers' support for this intervention. Threshold concepts present themselves in practical studio subjects as well. If all lecturers involved in the Foundation Course could reinforce in their own subjects what the students were taught regarding threshold concepts in the Professional Business Practice subject, the students might develop a better understanding of this concept more quickly. The argument which informs this suggestion is as follows.

By their very nature, threshold concepts are elusive. According to Meyer and Land (2003) every subject has its own threshold concepts; some of these are easily recognised and mastered; others may take a long time and great effort to identify, analyse and master; not all students find the same threshold concepts in any given subject challenging. This means that students must have (a) the meta-cognitive self-awareness to identify threshold concepts which cause them to falter, (b) the academic self-confidence to believe that the impasse is not due to internal, uncontrollable causes (such as cognitive inability), (c) the analytical thinking skills to determine the exact nature of the obstacle and to break it down into its elements, and (d) the necessary resourcefulness, motivation and perseverance to work through it. The development and meshing of these skills takes time and practice.

Finally, as with Kolb's reflective learning cycle, it was the students with the most pronounced sense of academic control who profited most from this intervention. It is my contention, therefore, that the more profoundly the first three interventions could take root in the students' academic self-image, the greater their sense of academic control would be, and the more readily and easily they would identify and master threshold concepts. Thus, in my view, the intervention regarding threshold concepts, despite the fact (and because of the fact) that this meta-cognitive skill is the most important skill to be acquired, should come last in the attribution retraining programme. Only then would the students hopefully be ready to experience what one student, referring to threshold concepts, described as

"when you are at the gateway of a new journey."

4.6.3. Were the overall objectives of this programme realised?

If one considers the less than optimal circumstances under which this extended attribution retraining programme was implemented, as well as the fact that it was not a predetermined and carefully structured programme, but an evolving, fragmented module wedged between (a) other units of the subject which urgently needed to be taught and (b) very demanding studio subjects, then the outcomes showed promise, and the objectives were met to varying degrees in individual students.

(a) Objective (a): Introduce the students to the concept of a 'growth mindset' which would foster in them a sense of greater academic control, specifically with regard to Numeracy.

Several students used the phrase 'it opened my mind' when they commented on the interventions. Lizwe, in his answer to my question whether he had come to realise that he was equipped with the necessary cognitive 'tools' to confront and conquer academic challenges, answered

> "Ja. – Ja. It was very helpful because I started to see that … Oh, this is the sort of things I was missing - if I knew that information I would have done better at school." (interview transcript No. 2)

Another student, in an anonymously written feedback exercise, wrote:

> "I've learned how to think about something and if I actually understand that specific task. This lesson changed my mind on how I see things in life. This creates *a new open mind* for future projects."

Sipho, when I asked him whether learning about the plasticity of the brain and the information processing of the working memory had helped him, answered:

> "Did very much. … And then you can achieve what you want. So that really *opened me up*." (interview transcript No. 1),

The answer to the question whether the students experienced a paradigm shift is a 'Yes'. However, this 'Yes' needs to be qualified. Although most of the students in class were keen to know that their brain's learning capacity was limitless, and although I received very positive feedback from many of them, there were those whose motivation to perform well dwindled. One such instance was Khanyo who

could not fall asleep because he was thinking about his brain. His academic results dropped significantly, and he eventually left the course. My observation of him indicated a case of a student having lost his sense of academic control and not having been able to regain it despite several attempts on my side to motivate him. I invited him several times to an interview or a discussion via WhatsApp, but he has evaded the invitation. I must assume that he does not want to revisit the experience of his Foundation year.

(b) Objective (b): Motivate the students to renew their efforts at Numeracy and employ more effective strategies when engaging with numerical tasks.

Again, the answer is a qualified 'Yes'. Bongi, Xolani, Tom, Sabelo, Loyiso and Lizwe are excellent examples of students who tenaciously worked at their Numeracy tasks, despite original set-backs, and succeeded admirably well. Below is a quote from an anonymously written feedback exercise:

> "By admitting about the problems which I have with regards to numeracy and research, I realised that a lot more attention has to be paid and dedication to the particular subject."

However, as observed above, less academically confident students who, nevertheless, were motivated and industrious in their efforts to improve their Numeracy performance, reverted to ineffectual strategies when under pressure and thus thwarted their own efforts to perform well. Nthandi, who could not have been accused of lacking motivation and perseverance, commented:

> "The interventions helped me but I feel like there was not enough time; that is because I am a slow learner…" (Appendix D)

Her remark regarding time referred to both the time we could spend on teaching and learning, as well as the time allowed for formal assessments.

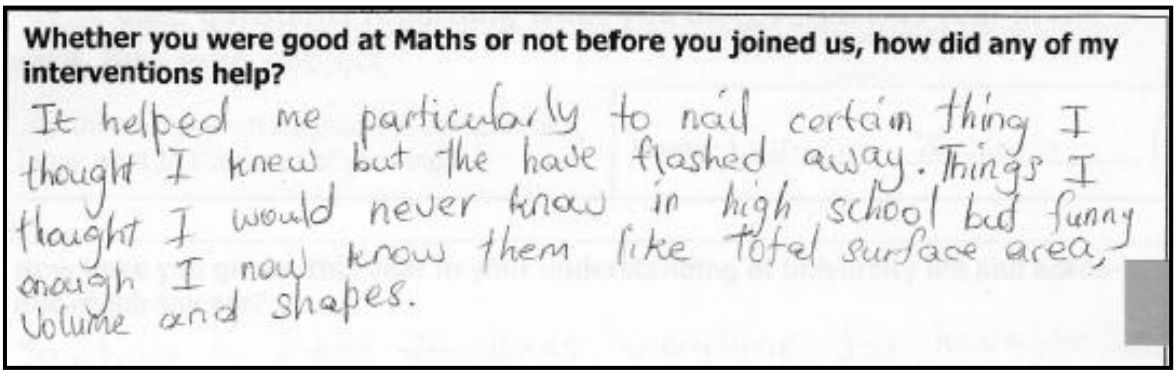
(c) Objective (c): Assist the students in their effort to improve their performance in Numeracy.

In answer to the above question, one should consider Yolanda's comment below.

Yolanda: "I was not good at Maths but I have seen improvement throughout this year. I hate numbers but if I just apply myself and practice (sic.) more I can be just as good as anybody…" (Appendix D).

In a questionnaire filled out at the time of being taught, she also noted that "the PBP [Professional Business Practice] classes helped quieten my fear toward maths….' Her results improved from 19% for the diagnostic assessment in February to 66% in the summative June assessment (an improvement of 247,4%).

Lizwe's comment (Appendix D) was as follows:


Whether you were good at Maths or not before you joined us, how did any of my interventions help?

It helped me particularly to nail certain thing I thought I knew but the have flashed away. Things I thought I would never know in high school but funny enough I now know them like total surface area, volume and shapes.

Figure 4.24: Student's reflection regarding his improvement in Numeracy

"It helped me particularly to nail certain thing I thought I knew but the(y) have flashed away. Things I thought I would never know in high school but funny enough I now know them like total surface area, volume and shapes."

The fact that the class average for Year A improved from 40,5% for the diagnostic assessment to 49,3% for the June examination is an indication that many students experienced an improvement in their Numeracy results. In Year B, the class average for the diagnostic assessment was 34,8% and the average for the June examination 52,6% (a 51,2% improvement). The graphs (Figures 4.14. and 4.16., p. 121) illustrate the improvement in individual assessment scores. At the same time it is also important to keep in mind that not all students registered success in Numeracy (Figures 4.15. and 4.17., p. 121). This serves as motivation for me to refine the interventions.

(d) Objective (d): Provide the students with quantitative literacy skills which they would need for their further studies in the various design programmes.

The Design programme which most certainly required mathematical competencies (more so than basic numeracy skills) is Architectural Technology. Consequently, my questions regarding mathematical performance in subsequent years were directed more at students who had registered with this programme. The Architectural Technology students mentioned in this dissertation had all begun their Foundation year with a marked uneasiness (and low assessment outcomes) regarding the Numeracy module.

I also need to mention that there is a significant shift in the level of difficulty between the syllabus of our very elementary Numeracy module and the Basic Applied Sciences subject in the first year of Architectural Technology. The students' comments indicate that it was predominantly the cognitive and meta-cognitive skills acquired in their Foundation year which helped them bridge the gap in their first-year studies.

Bongi was in her second year of Architectural Technology when I interviewed her and, referring to mathematical competencies, she made the following comment:

Bongi: "I think I am in a much better place now." (interview transcript No. 2)

Lizwe,: "From my experience it has happened. [He referred to applying the notion of threshold concepts in his first year of Architectural Technology.]. … now when I do .... when something doesn't work, I try something different, and when that doesn't work I try something different and I actually get to find solutions doing that, and that is a skill…." (interview transcript No. 2)

(e) Objective (e): Provide the students with cognitive and meta-cognitive skills to be employed in their future studies.

When I asked the students to reflect on the general usefulness of the cognitive and meta-cognitive skills they had been taught, their responses indicated the determination to employ these skills in future studies. One anonymous written reply was:

> "It has changed the way I will work in the future."

Yolanda: "I think your mission was successful, not only by preparing us for our first year but also helping us in areas (such as maths) to improve. Next year I don't think we will feel as overwhelmed as others." (Appendix D)

It is interesting to note that Yolanda's interpretation of my mission was that I wanted to prepare them for their future studies, and the remark regarding maths is put in parenthesis. Her anticipation regarding the following year shows that she felt ready to face whatever challenges would come her way.

Nathi looked even further ahead.

> "She [I, the lecturer] wanted us to learn new things that can carry you through life's challenges…"(Appendix D)

Nathi's comment below (Appendix D) addresses both objective (a) and objective (e).

> "The Lifeskills part about the brain stood out for me, and knowing more about the course as the year went by change (sic) my mind and made me feel kind of better. It gave me hope about first year and the future.

Lizwe (Appendix D) thought that my mission with them was

> "to be able to think critically in a subject matter and to be academically well prepared for first year."

Finally, the following anonymous, written comment implies that this student would use his or her understanding of meta-cognition to surmount future obstacles.

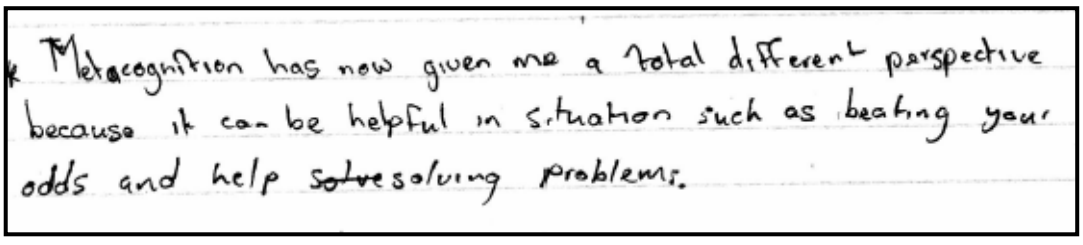

Metacognition has now given me a total different perspective because it can be helpful in situation such as beating your odds and help ~~solve~~solving problems.

Figure 4.25.: Student's remark with respect to transferral of meta-cognitive skills

> "Meta-cognition has now given me a total different perspective because it can be helpful in situations such as beating your odds and help solving problems."

In conclusion then, the students' reflections on my attribution retraining programme indicate that my objectives had been realised - to different degrees in different students. I have not been able to follow up sufficiently many students in their subsequent years of study to come to a reliable conclusion as to their effective application of cognitive and meta-cognitive skills. Nevertheless, the seeds of these skills had been sown in the Foundation Course, and it was up to the individual students to nurture and develop them in their future studies. How many of them did so – and did so successfully! - would make for a very worthwhile longitudinal study.

Recommendations for further research, for realigning educational policies and practices with present demands, and for further development and refinement of the interventions programme are discussed in the next chapter.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

Having implemented the extended attribution retraining programme for five years, and having investigated, in this study, the unfolding of the programme and its impact on the students in two of those five years, I now step back and summarise the programme and what has come to light in my present investigation. This section superimposes my findings, both those gleaned from the literature examined and the quantitative and qualitative data collected and analysed, on the educational landscape of South Africa. This superimposition shows up some of the weaknesses in our educational practices with respect to mathematics-related subjects and, consequently, leads to recommendations which may afford our scholars and students easier and more authentic epistemological access to such subjects.

In this chapter, therefore, I shall restate my research question, recapitulate the rationale which led to my implementing the extended attribution retraining interventions, give a brief overview of the implementation process, and summarise the outcomes of the programme. I shall also reflect on the merits and drawbacks of the data collection and interpretation process.

I shall compare the extended attribution retraining programme under discussion to the attribution retraining treatments administered in other countries, as well as the results recorded by international implementers and researchers to the results I have registered. It is of interest to establish to what degree my research, and its outcomes, can add to the existing theory regarding the explicit teaching of cognitive and meta-cognitive skills - and, in particular, whether teaching these skills explicitly in a maths-related context will alleviate the fears which scholars and students harbour concerning everything numerical.

Lastly, this chapter will also present recommendations regarding possible adjustments in South Africa's educational policies and practices. It will suggest areas for further research: (a) into the value of each individual attribution retraining intervention, (b) longitudinal studies involving both pre-service student teachers, high school scholars, as well as first-year students, (c) into the effect which a more structured and refined intervention programme might have on university students taking Mathematics, as well as (d) to what extent a generic

model of such a programme might be beneficial in other maths/science-related courses. In order for such a generic model to be optimally effective, I also need to consider further development and refinement of the interventions pertaining to Kolb's reflective learning cycle and the idea of threshold concepts.

5.2. Summary of the extended attribution retraining programme

The programme grew out of the need to address a practical problem: that of students underachieving in the Numeracy module of my subject. The academic challenge was to establish whether, and to what extent, affective factors, such as low academic self-esteem with respect to Mathematics, as well as maths anxiety, interfere with a student's cognitive development in this subject. In order to assuage the students' misgivings with regard to our Numeracy component, I had to convince them that they had the intellectual ability to engage meaningfully with numerical computations. The interventions which I implemented were aimed at initiating a paradigm shift in the students, the result of which would be their more positive approach to Numeracy and subsequent improvement in their performance in this component of my subject.

My personal rationale for going about attribution retraining in the manner which has been detailed and discussed in this dissertation is my erstwhile positive experience with employing similar teaching tactics at high school level – though scaled down to the niveau of scholars! Finally, the academic rationale for this study is to come to a deeper understanding of the interaction between the affective and the cognitive domains in the realm of teaching and learning Mathematics. Insights into this dynamic, embedded in the neuronal pathways and networks of every individual, will hopefully lead to a transformation in the way in which we teach Mathematics and maths-related subjects at school and university.

5.2.1. The research question

With the above-mentioned broad academic aims in mind I embarked on this research to explore and gauge the affective and cognitive implications which an extended attribution retraining programme would have on underperforming students in the Numeracy component of our Professional Business Practice subject. Consequently, my present study has been driven by the following question:

What happened during the two years of presenting an extended and adapted attribution retraining programme, and why did it happen?

The answer to this question depends on answering the following three sub-questions:

- **Which interventions were effective? To what degree were they effective, and why?**
- **Which interventions were less effective, and why?**
- **What should be done to render this attribution retraining programme as effective as possible?**

5.2.2. Rationale

In order to appreciate the importance of a country's citizenry being mathematically literate, I recapitulate briefly (a) the role which a mathematically literate citizenry plays in the economic competitiveness of a country, and (b) the state of Mathematics education in South Africa.

(a) The importance of a mathematically literate citizenry

As discussed in Chapter 2, The World Economic Forum (2014:4-6) considers a "well-educated and trained workforce" which can "perform complex tasks and adapt rapidly to [its] changing environment" as indispensible to a country's prospects of becoming and remaining globally competitive. In order to contribute constructively to a country's productivity and to society as a whole this workforce, as well as the rest of the citizenry, needs to be able to reason responsibly and understand such concepts as, for instance, cause and effect (Jansen, 2012). An authentic grasp of basic mathematical principles leads to these sound reasoning powers (De Lange, in Steen, 2002; Frith, 2010;).

(b) The state of Mathematics education in South Africa

Against the backdrop of global shortcomings (UNESCO, 2012) in the realm of Mathematics and Science competencies among scholars, South Africa has fared dismally, coming last out of 148 countries in the 2013-2014 Global Competitiveness Report (World Economic Forum, 2013a:347). This poor performance is locally verified in reports by the National Science and Technology Forum (2009, 2010) and the National Education Evaluation & Development Unit (2013), as well as by the Department of Basic Education's 2014 analysis of the

2013 National Senior Certificate examination results. South African educationists have joined in the call for improvement in South Africa's Mathematics and Science education (Brombacher at the NSTF, 2009, 2010; Scott, 2009; Frith, 2010, 2011; Jansen, 2012).

(c) Affective and cognitive barriers to Mathematics

Chapter 2 discusses the intellectually and emotionally debilitating experiences which many scholars endure in their Mathematics classes during their school career, from primary school through to the end of their secondary school years. At primary school level, pupils are inadvertently influenced negatively by their teachers' fears regarding Mathematics (Ashcraft & Krause, 2007; Peker, 2009; Ashcraft & Moore, 2009; Hoffman, 2010). These pupils enter junior high school, being already at a disadvantage in this subject.

Brombacher (NSTF, 2009) states that Grade 8 scholars, already on shaky ground mathematically speaking, will find it difficult to catch up during their high school years. They will, consequently, struggle to perform satisfactorily in the National Senior Certificate Mathematics examination. The reasons for their mathematical demise are as follows: they will have been perplexed by the gap between primary school Arithmetic and high school Mathematics with all its new concepts (Haynes et al., 2008; Hoffman, 2010); in many schools, these scholars will have been exposed to more ineffective teaching (Department of Basic Education, 2014; Jansen 2012); the pressure to perform and the competitiveness among classmates increases (Haynes et al., 2009); the girls may possibly fall prey to gender stereotyping (Bonnot & Croizet, 2006); and, specifically in the South African context, schools pressurise scholars into choosing Maths Literacy if they underperform in 'pure' Mathematics – which creates another kind of stereotyping, that of being 'just not intelligent enough' (Jansen, 2012). All these factors, as well as regular failure at Mathematics, and the resultant spectrum of negative emotions, have a profoundly negative effect on their willingness and ability to engage with Mathematics.

Many of our first-time students in the Foundation Course, who believed firmly that they were unable ever to cope with "maths", experienced my announcement that we would start with the Numeracy module of my subject, as a 'free-fall' further down the spiral mentioned in Chapter 2. One student described his reaction to my announcement as "my insides flushed to my lower body". Another spoke of his brain becoming "paralysed".

It was my encounter with the students' disappointing performance in the diagnostic test, their very obvious apprehension regarding Numeracy, as well as their general willingness (with some exceptions) to work at "maths" once more, which led me to develop the extended attribution retraining programme discussed in this dissertation.

5.2.3. Conceptualisation of an *extended* attribution retraining programme

Weiner (1985) conceptualised the theory of causal attribution. Every person wishes to understand the causes underlying his or her achievements and failures – in order to be able to repeat the former and avoid the latter. The causes which seem to determine the outcomes of our actions have certain features: they can be internal or external, stable or unstable, controllable or uncontrollable. Unfortunately, we sometimes attribute our achievements and failures to the wrong causes - "maladaptive failure attributions" (Haynes et al., 2009:234). In the case of mathematical underachievement, individuals predominantly attribute their failure to an innate inability (an internal, stable, uncontrollable cause) to understand Mathematics. This attribution leads to despondency, de-motivation and a sense of "hopelessness and shame" (Hall et al., 2004:592).

Since the early 1980's (Haynes et al., 2009:241), attribution retraining treatments of various descriptions, but following the same basic pattern, have been administered to at-risk first-time students. These very brief, once-off treatments were considered to be motivation-enhancing in that they stressed the importance of adopting more effective strategies, as well as perseverance. Researchers have reported that these treatments have had good and lasting results.

However, the majority of our students have persevered at school, against many odds, and have shown motivation – even in my Numeracy classes! – but to no avail. And, although they were willing to adopt more effective strategies, they reverted to old and ineffective ones under pressure of timed assessments and due to a low sense of self-efficacy in the realm of mathematics.

It is at this juncture that I considered the following: if our brain is a learning tool, we need to know how best to employ it. Based on this premise I embarked on teaching the students both cognitive and meta-cognitive skills explicitly, which is also advocated by educational researchers (Their, 2002; Cornford, 2004; Efklides, 2006; Dweck, 2008; Tanner, 2012, and others).

5.2.4. The interventions themselves

The first two interventions of the extended attribution retraining programme dealt with cognitive aspects of learning; the third and fourth interventions imparted meta-cognitive skills to the students.

(a) The plasticity of the brain

Of greatest importance to me was that the students would come to understand that their brain is not an immutable entity (Dweck & Leggett, 1988), that knowledge is chemically encoded in neuronal pathways and networks which can be 'grown' or 'silenced' (Hebb, 1949; Diamond, 2001; Zull, 2002); that engaging seriously with information even just for a few minutes could stimulate the development of new dendritic spines - and, thus, increase their 'intelligence'. In Dweck's terminology: I wanted to initiate a paradigm shift in the students from a *fixed mindset* to a *growth mindset.* If the students could make this shift, they would realise that at least basic access to any subject, in our case Numeracy, was possible.

(b) The memory systems

Once students understand how our three memory systems function, they would know how to employ them optimally, and they would, hopefully, avoid disruptive elements (both external/situational as well as internal/personal) as far as possible. Students need to understand, in particular, the information processing mechanism of the working memory and its limited capacity. They would then appreciate the paralysing effect which negative self-talk and emotions, subject avoidance of any kind, intellectual disengagement, as well as all external interferences, have on their ability to decode, grasp, evaluate and store incoming information within the briefest space of time; not only that, but also to select, retrieve and activate stored knowledge in order to solve ever more complex mathematical problems.

(c) Kolb's experiential and reflective learning cycle

I introduced Atherton's (2009) very basic version of Kolb's experiential learning cycle to the class to help students analyse their experiences, both situational and academic, and devise strategies to remedy academic disappointments and

reduced the impact of situational challenges. This would help them regain control in a period of transition wrought with unfamiliar challenges.

(d) Threshold concepts

Meyer and Land (2003) formulated the notion of threshold concepts which are core concepts (or "conceptual building blocks", 2003:2) embedded in every field of study, as well as in the unique discourses of every environment - in our case, the academic discourse of a preparatory Foundation Course in a design faculty. The objective of offering this intervention was to alert the students to impasses in their encounter with the subjects taught, as well as with the particular design (as well as tertiary!) discourse into which they were being initiated.

Of particular importance to me was discussing the concept of 'troublesome knowledge' (Meyer & Land, 2003). At a very basic level, I explained that what seemed perfectly obvious and easy to a lecturer (or teacher) might be difficult to grasp for the student (or scholar); that it was tempting for an instructor to become impatient with individuals in his or her class and label them as intellectually limited; and that it was equally tempting for the struggling scholar/student to consider himself or herself intellectually limited because he or she was vainly groping for the understanding of a principle which seemed so very easy to the teacher or lecturer.

Again, my aim was to persuade the students to move from the premise of "I cannot do Maths; I am not gifted with a mathematical mind" (the fixed mindset) to a position of "I have the ability to cope with Mathematics, but I am not there YET" (the growth mindset). My rationale was: if students know about threshold concepts, they can identify them when they arise, and they can then work through these concepts successfully.

5.2.5. Implementation of the extended attribution retraining programme

In February of every year I administered a diagnostic test in order to ascertain the level of numerical literacy of the class as a whole and of individual students themselves. The test probed several basic competencies as described in Chapter 1. Over the course of the first semester, and slotted in among many other academic skills which needed to be taught (including studio-related numeracy skills!) I implemented the interventions as an integral part of my subject. I followed the order in which I have discussed them in this dissertation: (a) the

plasticity of the brain, (b) the memory systems, (c) Kolb's experiential and reflective learning cycle, and (d) Meyer and Land's threshold concepts.

The first two interventions were 'sandwiched' between activities related to free-writing. Straight after feedback regarding the diagnostic test, the students were invited to free-write about their relationship with "maths", and then to do focused writing (guided by specific questions) which would lift out salient incidents, habits and attitudes pertaining to their personal history with Arithmetic/ Mathematics/Maths Literacy at primary and high school. After the second intervention they returned to their free-writing to evaluate it with respect to internal/ external, stable/unstable and controllable/uncontrollable causes which had interfered with their ability to perform well in these subjects at school. The aim of this exercise was to add momentum to the desired paradigm shift in the students' minds.

5.2.6. Collection of quantitative and qualitative data

Short tasks and tests were administered right through the semester, with a summative assessment in June. In Year B the students also wrote a formal summative September assessment of which certain questions tested relevant numerical competencies. The tasks gave the students an opportunity to practise new strategies learned, at first in questions which tested their content knowledge only, and then in contextualised problems. These tasks were also meant to help the students gauge their own progress in their mastery of basic numeracy. The formal assessments were necessary for promotion purposes. The outcomes of the tasks and formal assessments provided the quantitative data for this study.

The qualitative data have been extracted from written and verbal feedback given at the time of teaching the students, my own observations of the students and my notes on their remarks regarding the Numeracy module, as well as more recent interviews, questionnaires filled out and communication via cell phone.

5.2.7. The results of the intervention programme

In Chapter 4, I have discussed the findings of my research; here I wish to give a brief overview of the results on which to base my conclusions and recommendations.

Although in Chapter 4 I analysed the qualitative data, taking my cue from the four interventions, and compared them to the quantitative data with the aim of establishing convergence, here I shall begin with the quantitative data. The reasons for this order are that (a) it was the quantitative data which drew my attention to the fact that something positive was happening in the classes of both years, and (b) the students' promotion through the subsequent years of study is governed directly by their continuous assessment results of the entire year and only indirectly by their personal development.

(a) Findings regarding the quantitative data

In both Year A and Year B, the results of the diagnostic test were alarmingly poor. However, by June the class averages had improved satisfactorily, and some individual marks had shown significant improvement.

Year A

In Year A, I had 53 students in my class. The average of the class for the diagnostic test, administered in February, was 40,5%. Sixteen students' obtained Level 1 (0%-29%) results; fifteen students' results lay above 50% which is the required pass mark at university. In the June examination of that year the average for the class was 49,3%, and only nine students had still not progressed beyond Level 1. Thirty students had achieved results of over 50%, and fourteen of these had improved by between 20 and 41 percentage points (Figure 4.14, p. 121) . This pass rate is a 100% improvement on the number of students who had passed in the February test. However, 18 students dropped back in their June examination compared to their February test results (Figure 4.15.). This has been discussed on page 122. These results are noteworthy if one considers the following: (a) the increased level of complexity of the June examination compared to that of the diagnostic test, (b) that the shift in assessment outcomes happened within a matter of about four months, (c) that teaching Numeracy was interwoven with teaching various other non-numerical academic skills, and (d) that the pressure of the studio subjects was increasing.

Year B

In Year B, 32 students had enrolled in the Foundation Course, and the class average of the February diagnostic test 34,8%. Eighteen students in the class performed at Level 1, and only six achieved above 50%. In the formal June

examination, the class average had risen to 52,6% (a 51,2% improvement). The number of students at Level 1 had shrunk to only six; and nineteen students had passed with 50+%. That is almost an exact reversal of performance compared to the results of the diagnostic test. (Refer to p. 113, Chapter 4) Thirteen students had improved by between 22% and 50,5%, and only two students lost ground in their June examination. (Refer to Figures 4.16 and 4.17., p. 121.)

For the Numeracy questions in the formal September assessment, the class average had dropped back by 5,6%. Eight students could not achieve at more than Level 1; eleven students had passed with 50+%; and altogether sixteen students had still managed to hold their own and achieve above their original February results. Possible reasons for the drop in marks have been discussed in Chapter 4. Nevertheless, despite the drop-back in September, the general improvement in the class average of 12,2 percentage points between February and September is still a noteworthy achievement and motivates me to develop and refine the set of interventions for application beyond the confines of our Foundation Course.

(b) Findings regarding the qualitative data

I did not separate the qualitative data of Year B from those of Year A. The data were generated from different activities, as opportunities arose that allowed for discussions and/or written reflections. The recent methods of data collection were more focused in that I made a purposive selection of students whom I approached for interviews, the filling out of a questionnaire, as well as communication via WhatsApp. My aim here was to come to a better understanding of what had influenced some students to excel (after having done poorly in the diagnostic test), and why in the case of other students the interventions did not produce the desired improvement in the Numeracy results.

The picture which emerged leads me to conclude the following:

(i) The lectures and videos clips on the brain and its neuronal networks made the most profound and lasting impression on the students. That the brain has an inexhaustible capacity for learning, and that we can increase our cognitive powers (our ‘intelligence’) at will, came as a surprise to the students. Those who had never experienced problems with Mathematics were as interested to learn about their brain power as were those who had struggled with the subject all their life. Some of the students with a low sense of self-efficacy in “maths” commented that they felt more positive about engaging with Numeracy, and some

told me that, since having been 'introduced' to their own brain power, they were more hopeful about their academic future, in general, than they had been before. Furthermore, this intervention was clearly remembered – in detail! – four years later. Considering that these students had had strenuous academic years and had already spent varying lengths of time in industry, this testifies to the lasting impression which the intervention had made on them.

(ii) The lectures on the memory systems, and especially the working memory, were also received with much interest. What brought these lectures to life were the anecdotes which I could relate – typical scenarios from school with which the students identified immediately. These anecdotes and the memory games we played as part of the lectures convinced the students of the very serious message at the core of the intervention. A fair number of comments reflected on the opportunities missed at school because the students had not known about the effective use of the brain's memory systems. And, again, four years later the students with whom I communicated could still remember vividly the content of the lectures.

(iii) The intervention regarding Kolb's experiential and reflective learning cycle was not as successful. Taking individual students through this cycle with regard to personal or situational challenges bore fruit. However, despite our applying the cycle to academic obstacles, the students did not seem to be able to do so on their own. My personal observations of those who struggled most to orientate themselves in this transition period from high school to university and who had come to the course, already suffering from a sense of low control, led me to believe that they were – and remained – too disorientated and 'out of control' to attempt a purposeful analysis of their academic situation. Some of them resorted to various kinds of avoidance tactics, and some dropped either out of both theory subjects (mine being one of the two) or out of the course altogether. It is also interesting to note that, except for two students, those whom I contacted more recently felt that they had not *consciously* applied this reflective learning cycle in their academic work. However, they did wonder whether they had internalised this meta-cognitive skill to a point at which they were not aware of applying it anymore.

(iv) The notion of threshold concepts was the most difficult intervention for the students to gain from, academically speaking. They could identify with the idea of troublesome knowledge when I gave certain examples from their school background. From the reactions and comments in class I could clearly deduce that many of them were relieved at the idea that the impasse between them and their teachers over certain difficult concepts in school subjects was not to be attributed to their intellectual inability to understand such concepts; that it was not 'their fault'; that it could also have been the teacher's inadvertent 'fault' for not realising that the obstacle at hand was *transparent knowledge* to them as teachers, but *troublesome knowledge* to their scholars.

However, the students found it very difficult to identify such threshold concepts in their academic work. Judging from the reflections of the few students who felt that they had profited greatly from this intervention, it seems that students who started out with a healthy sense of self-efficacy and control were most able to identify core principles in their study material as threshold concepts. Once they

> knew what they were facing, they decided consciously to work through these principles; they became true agents of their own success. For this reason I contend that scholars and students alike, as well as teachers and lecturers, should be familiar with the idea of threshold concepts.

It is also of interest to note the following feedback which emerged from the questionnaire completed in Year B. I wanted to gauge whether my own communication methods and style were effective in carrying across my objectives for the class and my concern for every student. Thus I had asked them to sum up what they perceived my teaching mission to have been. Those who answered this particular question noted three objectives: (a) that I wanted them to become academically more self-confident, (b) that I wanted them to understand Numeracy better, and (c) that I was preparing them for their next year of studying – and even for their careers and life! Judging by their comments and the way in which some phrased their responses it is clear that they felt my mission had been successful.

5.3. Further general reflections

Next I shall reflect on my research in relation to similar studies done into similar problems in the international arena of education in maths-related fields of study. To what degree did the mixed-methods inquiry fit the purpose of my research? Will this modified and extended attribution retraining programme contribute meaningfully to the pedagogical discussion of the world-wide underperformance in Mathematics of scholars and students, and to the research into attribution retraining in particular? Will my observations and findings support and add to the theories concerning the explicit teaching of cognitive and meta-cognitive skills, especially with regard to Mathematics?

5.3.1. Methodological reflections

Opting for a mixed-methods research design has its advantages and disadvantages.

(a) Advantages

My objectives for introducing the extended attribution retraining programme have been discussed in Chapter 4. They can be summed up in two major objectives: (a) inspiring the students to make the paradigm shift from a fixed mindset to a

growth mindset in order to lift their self-efficacy beliefs and offer them hope for academic survival and success, and (b) to reduce their aversion to “maths” and, together with explicitly teaching them meta-cognitive skills, set them on a path to satisfactory progress in Numeracy.

The mixed-method design offered valuable perspectives on “What happened in those two years, and why?” - the main research question. The quantitative data cast light on “what happened…” by sketching a picture of the progress of the classes as a whole, as well as of individual students, with regard to the Numeracy component of the subject. They indicate a ‘shift’ in the marks and provide tangible proof of the students’ willingness to work hard and employ more effective strategies - or of their capitulation to their own misgivings regarding their mathematical ability.

The qualitative data offer insight into the “Why” and the “to what degree” aspects – the sub-questions of the research question: Why and to what degree were the interventions effective or not? These data speak of the paradigm shift in the students.

Both types of data have their drawbacks and showed up gaps. However, analysing them concurrently created a more detailed picture of what happened in those two years in that they often – though not always! - corroborated each other, each augmenting the information which the other presented. Where the quantitative data could be read easily and objectively, the qualitative data were rich in that they spoke of deeper, personal, more nuanced experiences of and reactions to the interventions, as well as subsequent personal growth.

(b) Limitations

(i) Because both implementation cycles of the intervention programme were quasi-experiments with data collection happening in a predominantly unstructured manner, not all students offered feedback at any given opportunity. No set of data is, therefore, complete – not even the quantitative data, as some students elected to stay away from classes and formal assessments.

(ii) As noted in Chapter 3, neither type of data is considered completely realistic and reliable. The quantitative data must be seen as the lowest level of every student’s intellectual competency in Numeracy. Every student is capable of certain other numerical computations that were not required in the given tasks or examination. Personal stressors or situational distracters could have played a negative role at the time of the

formal assessment. Furthermore, language proficiency also plays an integral role in assessment performance.

(iii) The qualitative data were studied with an overlay of the following considerations: to what degree were verbal and written feedback coloured by temporary affects at the time of collecting the feedback? (This consideration does not apply to the recently gathered data.) What role did the language barrier play in both the students' grasp of what I was asking of them, and in their ability to express themselves adequately? How did they interpret my motives for inviting feedback? Did they feel free to be completely honest in their assessment of the interventions? At the same time I needed to be aware of my own personal involvement with the class and my interpretation of their interpretations of the interventions.

(iv) Finally, it was not possible to link any one particular intervention to any particular student's (or the entire class's) progress in Numeracy. I must, therefore, accept that the outcome of my study can present only a 'graph of best fit'.

In the section below entitled *Further development and refinement of the intervention programme* I shall reflect on the above-mentioned limitations.

5.3.2. Substantive reflections

For a clear, summative comparison between existing attribution retraining treatments and my adapted and extended intervention programme, I have opted to present the features of both versions in the form of a table. The purpose of this table is to summarise and highlight the similarities and differences between both versions of attribution retraining. Both have profound value, having made a significant difference in students' academic self-image and achievements. However, the typical profile of students in need of each type of support differs considerably. Thus the two versions should not be considered interchangeable.

Table 5.1.: Comparison between conventional attribution retraining treatments and the extended attribution retraining programme

AR treatment as described in the literature	My extended attribution retraining programme
Duration: once-off treatment of +/- 30 minutes maximum;	Duration: lectures of 1-1½ hrs offered intermittently over the course of 6 months;
Aim: increased motivation, more effective study strategies, increased perseverance;	Aim: paradigm shift from a fixed mindset to a growth mindset; improved academic self-image; cognitive and meta-cognitive skills; decrease in maths anxiety and improvement in Numeracy performance;
Subjects for treatment: predominantly at-risk students who had performed well at school and had developed a temporary sense of low control due to the transition period from school to university; ('performed well at school' based on remarks made by researchers with regard to students' *disappointment* at having fared poorly in initial assessments, as well as comments re very strict selection criteria for admission to university)	No *selected* subjects: interventions offered as integral part of Professional Business Practices subject; students predominantly with problematic history of Mathematics at school and, therefore, with a sense of low academic control; school system failed to prepare students adequately;
Background of subjects: No mention of subjects' school background in the literature studied for this thesis, and apparently no discussion with subjects regarding their previous academic experiences at school;	Background of subjects: School background of students discussed with them to identify the causes (causal attribution) of their difficulties with "Maths". Some research done into the national schooling system and its effect on scholars;
Challenges of transition to university: no mention in AR literature of taking cognizance of freshmen's *situational* and *personal* issues;	Challenges of transition to university: first-time students often faced with academically and emotionally debilitating *personal* and *situational* problems which need to be taken into consideration in an intervention programme;
Content of treatment: questionnaire, video of senior students discussing their freshman year challenges and how they surmounted them, Psychology lecturer relating his own early student experiences, subsequent discussions among students plus follow-up tasks or tests (any combination of these elements); possibly some implicit teaching of cognitive and meta-cognitive skills;	Content of programme: lectures on the plasticity of the brain, the memory systems, Kolb's experiential and reflective learning cycle, as well as the notion of threshold concepts; general class discussions on the lectures; regular reference to the material taught for further consolidation; explicit teaching of cognitive and meta-cognitive skills;

Scientific experiments: According to the literature studied, the administering of AR treatments was done and researched under strictly experimental conditions with control groups of students with varying characteristics.	Quasi-experimental research: I had not control groups and no strict laboratory-style conditions under which the students were taught and tested. I could also not administer repeat assessments. Every assessment needed to test new skills, dictated by the studio subjects.
Results: good and lasting results with students with *temporary* perception of low academic and personal control (+/- 10% increase in end-of-year results);	Results: good to excellent results (up to 48% in-crease for *highly* motivated students with temporary loss of personal and academic control); average improvement for students with relatively low sense of control; drop in results for some students who were overwhelmed by this transition period; class average up by 8.8% in June of Year A, and up by 20.4% in June of Year B; September (Year B) average down by 5% from June results;
End-of-year outcomes: Because in the AR treatment cases which I have studied there have been control groups, end-of-year results could be compared across the board. Researchers concluded that AR treatments were of great value to underperforming students, as their end-of-year assessment outcomes improved across all subjects and the entire year (USA GPAs).	End-of-year outcomes: Because I had no control groups, I could not judge the final end-of-year results against those of another no-AR group. Also, the combination of subjects in this course does not lend itself to the calculation of an overall symbol, equivalent to the USA GPAs. I can, therefore, not establish to what degree my intervention programme influenced the students' chances at promotion to their first-year proper of the Design programme for which they had registered at the beginning of their Foundation year.

Similarly, my recommendations have focused on adaptations to policies and practices in the South African context. I have tailored them to the particular needs of our educators and students at all levels of the educational arena, at the same time keeping in mind what international institutes, such as UNESCO and the PISA 2012 report have put forward.

My recommendations resonate very much with Dweck's recommendations (2008) regarding the use of mindset changing interventions to improve mathematical achievement among scholars. Consequently, I shall present a brief tabulated comparison between our suggestions.

Table 5.2.: Comparison between Dweck's recommendations and those made in this study

Dweck's (2008) recommendations for improving mathematical achievement among scholars and students	**My recommendations for improving Maths teaching and learning**
Brain plasticity: teaching scholars/students about the brain's plasticity in order to facilitate a growth mindset	*Brain plasticity*: intervention which teaches students about the brain's plasticity to foster in them a sense of intellectual abundance (growth mindset)
Process praise: emphasis on the benefits of challenges and effort, rather than praise for good performance, to foster learning goals instead of performance goals in scholars/students	*Reflection on progress*: regular encouragement of students to reflect on their progress throughout the year – not just in my subject, but also in their studio subjects to foster pride in their incremental progress.
Teacher-training curricula: "teacher-training curricula in schools of education ……to include (a) the latest findings in brain plasticity and their implications for all children's potential to learn….."(2008:14), as well as (b) the concepts of fixed versus growth mindset, (c) the importance of emphasising "process praise" rather than performance praise, and (d) the value of demanding reasonably challenging work from scholars and students	*Teacher-training curricula*: modules to be introduced which teach the interventions which constitute my attribution retraining programme; This to be done * at teacher-training colleges for primary school teachers, * at diploma courses for training high school teachers, * in teaching development programmes for lecturers.
In-service training: "continuing education programs for existing teachers" (2008:14) so that teachers can offer "environmental support" and design their teaching material from a perspective of the growth mindset (2008:7).	*In-service training:* workshops for teaching staff at their various schools with the aim of: * creating a school atmosphere which embraces the concept of a growth mindset, * sensitising teachers to scholars' personal cognitive difficulties with Mathematics/Maths Literacy – and teaching accordingly, * hopefully slowing down the migration from Mathematics to Maths Literacy.

The above comparison illustrates that underachievement in Mathematics and maths-related subjects and careers, both nationally and internationally, is wide-spread and deep-rooted; so much so that entire educational institutions need to be retrained and educational policies revised.

5.3.3. Scientific reflections

As stated in Chapter 3, the purpose of my research is one of transformation and advocacy. If this dissertation on my extended intervention programme can initiate transformation in the manner in which Mathematics is taught at school (from primary schools upwards), then a multitude of scholars who have hitherto been

relegated to a second-rate existence (Jansen, 2012) because they are - falsely so! - considered incapable of doing Mathematics, will be allowed a 'place in the societal and economic sun'. My advocacy is, therefore, for equal opportunities for young people to become quantitatively literate and thus "functional and critical citizens" (Frith et al., 2010).

Consequently, the positive shift noticed in the marks, as well as in the minds, of the students, renders this research worthwhile for the following reasons: (a) to support the call for explicitly teaching cognitive and meta-cognitive skills in any field of study, (b) to demonstrate the value of implementing an extended attribution retraining programme with the aim of reducing students' maths anxiety, enhancing their experience of Mathematics and related subjects, as well as improving their performance in such subjects, and (c) to contribute to the research into and discussion of attribution retraining itself, particularly with regard to a "new form of AR" (Ruthig et al., 2004:727) interventions. According to Koles and Boyle (2013), a cognitive-behavioural approach would be very effective.

(a) Explicit teaching of cognitive and meta-cognitive strategies

Cornford (2004:2) speaks of "learning-to-learn" skills which are necessary in an age of constant change and burgeoning bodies of knowledge, and in which lifelong learning is indispensable to economic survival. Well-developed and refined cognitive and meta-cognitive strategies are "foundational elements" of such a survival kit (Cornford, 2004:2). Such skills need to be taught explicitly (Flavell, 1979; Their, 2002; Cornford, 2004; Tanner, 2012) to both scholars and students. Cornford (2004:8) notes with concern that few teachers instruct their pupils/students in these skills, and few researchers write about the explicit teaching of such skills when they discuss lifelong learning.

My contention has always been that both scholars and students need to "learn [how] to learn", and this has been the premise from which I proceeded in the development of my extended attribution retraining programme. Judging by the qualitative data, most students were very receptive to the interventions that dealt with cognitive skills; some reflected on opportunities missed at school because of a lack of these skills. Students who had grasped the nature and meaning of threshold concepts had employed them purposefully and successfully in their further studies.

I, therefore, conclude that my intervention programme has added support to the call for purposeful and explicit teaching of cognitive and meta-cognitive skills - especially in the domain of Mathematics and maths-related subjects.

(b) Revised attribution retraining programmes in the South African context

The vast majority of South African school leavers who wish to study cannot be compared with the first-time students discussed by international researchers of attribution retraining treatments. As mentioned in Chapter 2, Ruthig et al. (2004:713) quote Perry and his colleagues (2001) who speak of the "paradox of failure, in which bright enthusiastic high school students often are unable to adjust to the increased demand for self-initiative and autonomy" at university. Haynes et al. (2008:204) also speak of students' reaction to "unexpected failure". The average South African student is very accustomed to failure - specifically in Mathematics. According to Brombacher (NSTF, 2009, 2010), far too many South African schools are disadvantaged and/or dysfunctional. The majority of our South African students would, therefore, have found it difficult to be "bright" and "enthusiastic" against such an educational background. To compound matters, the selection criteria at South African universities of technology are far beneath those at, for instance, traditional universities in the U.S.A.

It is, therefore, to be expected that many of our first-time students arrive at university with a deep-seated perception of low academic control – which then drops still further when such students are faced with the complexities of the transition from school to university. Consequently, Wilson and Linville's (1982:374-375) conclusion, namely, that a "brief, one-time exposure" to attribution retraining treatments will have a lasting and positive effect on students (the two researchers speak of a "dramatic" effect), and which has been confirmed by more recent experiments with similar treatments, cannot apply to the South African scenario. This has been demonstrated by the drop in the September results - after the promising improvement in the June results! - of the students in Year B.

Researchers' findings point to an improved perception of control in students who felt that they had *temporarily* lost control and had then been exposed to the customary attribution retraining treatments. Unfortunately, many of our students arrive at university with a perception of very low personal and academic control

already in place. If our brains' neuronal networks can be altered over time and with regular positive input, then it should be possible to affect a turn-around in the downward spiral of disappointment and de-motivation in such students. However, this would necessitate a much longer and more intensive kind of attribution retraining programme – which is what this study recommends.

(c) A "new form of AR": a cognitive-behavioural approach

Although Koles and Boyle (2013) discuss scholars with learning difficulties, they suggest that attribution and cognitive-behavioural theories are akin to each other, and that combining the two in one type of intervention "appears to be a compelling option to increase the motivation and perseverance of those with learning difficulties." Haynes et al. (2008:198) take this suggestion one step further by considering that the solution to stemming "the downward spiral of low motivation and poor academic performance among first year college students … may be Attributional Retraining (AR), a psychotherapeutic cognitive treatment that is gaining ground in the area of higher education." It is with respect to this approach to attribution retraining that I wish my research to stimulate further discussion.

5.4. Recommendations

I base, in part, my recommendations on the findings, analyses and recommendations of the PISA 2012 report. The international reservations regarding PISA testing have been noted in Chapter 1. Therefore, in order to substantiate why I draw upon its report, I shall quote from Gurria's introduction to this report.

The Programme for International Student Assessment (PISA), introduced by the Organisation for Economic Co-operation and Development (OECD), has been "evaluating the quality, equity and efficiency of school systems" (PISA, 2012:2) for over ten years. Gurria (PISA, 2012:2) states that the "central preoccupation of [educational] policy makers" should be to create a school system which will provide scholars with the necessary skills to "achieve their full potential, participate in an increasingly interconnected global economy, and ultimately convert better jobs into better lives". Gurria continues by enumerating the benefits which such skills will have for both the individual citizen and society as a whole of any nation.

> "Beyond better outcomes for the individual, skills also provide the vital glue for resilient communities and well-functioning societies, by strengthening inclusiveness, tolerance, trust, ethics, responsibility, environmental awareness, collaboration and effective democratic processes."

The deduction to be made is that, internationally, among experts in the fields of global economy and societies' sustainability with all its ramifications, a sound understanding of basic mathematics is considered to be a cornerstone to said economic and societal well-being. This encapsulate the purposes of my attribution retraining interventions and this study: namely, advocacy for a better future for our youth through transformation of the teaching and learning of Mathematics/Maths Literacy, as well as transformation of young people's intellectual self-concept.

I wish to consider recommendations which should bear fruit in the short- and medium-term, and then put forward recommendations for the long-term. I am convinced that improvement in the domains of the STEM subjects is possible, and this is echoed by the PISA's findings, when it compares its 2012 to its 2003 results, namely, that "improvement is possible, whatever the starting point for students, schools and education systems" (2012:8).

At the centre of my recommendations lies the need to alter society's perception of mathematics, and I wish to suggest that attribution retraining should have the widest possible reach into all strata of society. Consequently, I note here that this objective necessitates adapting the interventions programme to the various contexts in which it is to be implemented: from primary school to university level, from reducing maths anxiety in students (at the receiving end of the retraining programme) to teaching educators how to implement this programme.

5.4.1. Recommendations for short- and medium-term policies and practices

Haynes et al., in their comprehensive review of attribution retraining over the past two to three decades, have come to the conclusion that this treatment should not be reserved for a selected group of academically vulnerable students in a laboratory setting. They maintain that it can and should be rolled out into the college classrooms (2009:256-257). However, they make the proviso that the

implementers who would administer the treatments should be well-grounded in causal attribution theory, and that the effectiveness of the treatments would depend on the teaching skills of the implementers. I fully support these considerations and add that the attribution retraining programme I have put forward here should be implemented at school level as well.

For short- to medium-term results through the implementation of the programme, I advocate a two-pronged approach at school level. Teachers who are entrusted with Arithmetic/ Mathematics/Maths Literacy instruction should be targeted at the same time as pupils in certain grades.

Concurrently, this intervention programme should also be offered to first-time students, particularly those in Foundation/Bridging/Extended Curriculum Programmes offered at universities of technology.

(a) Workshops for primary school Arithmetic teachers and high school Mathematics/Maths Literacy teachers

In Chapter 2, I reported on the research done into primary school teachers' complex relationship with mathematics (Hembree, 1990; Peker, 2009). Their apprehension and self-doubt in the Arithmetic lesson is transferred to their pupils (Steele, 1997; Brady & Bowd, 2005). According to Brombacher (NSTF, 2009:16), these pupils are then already "lost to Mathematics by the time they reach Grade 4".

An adapted attribution retraining workshop for primary school teachers of Arithmetic, based on the interventions regarding the plasticity of the brain, the information processing mechanism of the working memory, introduced by and interspersed with both unstructured and focused free-writing, should be mandatory. In the case of adults who subscribe to a fixed mindset and believe that they are, by nature, numerically handicapped, one may well expect their neuronal networks, which carry this maladjusted causal belief, to be firmly established. However, Zull (2002) would argue that even adults are able, over time, to "silence" such networks and develop and strengthen new positive networks regarding their cognitive ability to become quantitatively literate. Furthermore, one assumes that teachers, being motivated professionals with a commitment to educating young minds, would find it compelling and, therefore,

easier to grasp and internalise the information presented – and would then apply it in their classrooms.

The above project might be considered a first front of 'infiltration' (rather than 'attack'). The next such front would be Mathematics and Maths Literacy teachers at high school level.

Both interventions mentioned above should be presented to these teachers as well – for different reasons, though. Where primary school teachers need to conquer their own misgivings regarding their mathematical abilities, high school teachers, having studied Mathematics at university, should be unfamiliar with such doubts. However, it is very tempting for them to categorise their scholars as either being mathematically 'capable' or not - which translates into advising their scholars to choose Maths Literacy if 'pure' Mathematics seems to be beyond their grasp. Accepting Zull's (2002) notion of "changing the brain" of their scholars could pave the way to more meaningful and transformative teaching at both the 'pure' Maths and the Maths Literacy levels.

Furthermore, Brombacher (NSTF, 2009:15-16) speaks of the 'mathematical knowledge for teaching" - "the knowledge of how to teach the subject ... so that teachers know how children learn a particular subject." Introducing Mathematics/Maths Literacy teachers to the idea of threshold concepts should create in them an awareness of such concepts in their syllabi. They may develop greater patience in the face of their scholars' difficulties with grasping these concepts, and this would result in more purposeful and constructive communication between teachers and scholars.

Finally, both primary and secondary school teachers would benefit from applying Kolb's experiential and reflective learning cycle to their experiences as Arithmetic/Mathematics teachers. Firstly, they would be able to apply in a very focused and systematic manner this basic, analytical cycle to the issues they face in their teaching experience. Secondly, they would be able to take their pupils through this cycle as well – as an exercise in teaching a meta-cognitive skill explicitly to make the scholars' learning experience more constructive.

(b) Attribution retraining intervention programmes for scholars

The most vulnerable scholars in the high school phase are those in Grades 8, 10 and 12. Grades 8 and 10 are transition periods. If one wanted to effect an improvement in the learning of Mathematics/Maths Literacy as soon as possible, one would have to address these two grades as a matter of urgency.

In Chapter 2, I analysed the academic and situational complexities of the transition from primary school to high school. These are further compounded by pupils' personal transition from a more protected and dependent childhood phase to that of the emerging adolescent who asks questions about him-/herself and develops a self-image. Many such pupils will have had less than happy experiences with Arithmetic at primary school and will be apprehensive about the new Mathematics material that needs to be mastered at high school (See interview transcript No. 4). Being taught – explicitly! – the cognitive and meta-cognitive skills embedded in the attribution retraining programme should make orientation and adjustment to high school easier.

Grade 10 scholars experience a similar, though not as pronounced and disorientating, transition from the junior high school phase to the senior phase. This I have observed during 30 years of teaching at high school level and across all grades, including Mathematics to Grade 10 scholars. Because Grade 10s are entering a final school phase, with syllabi that are more advanced and demanding, teaching them the cognitive and meta-cognitive skills contained in my programme of interventions would be of great benefit to them.

The PISA 2012 report mentions that "the relationship between performance and students' attitudes towards learning" (2012:9) is an important factor in the striving for academic excellence. If students could be persuaded, by means of the attribution retraining programme under discussion, that such excellence is, potentially, within their reach, then that should provide them with the impetus to adjust their attitude towards learning, engage more meaningfully with their subjects, work more diligently and apply better study strategies (PISA, 2012:18, 23).

Finally, Grade 12s are studying towards their National Senior Certificate examination. A series of workshops at the beginning of the year should contribute positively to their endeavours at preparing constructively for this examination. Although the intervention programme may appear to come too late in their school

career, one should keep in mind that my students of Years A and B profited from the interventions within three to four months. Grade 12s would be given the opportunity to fare better in their final examination and would be better equipped to cope with the major transition period from school to university.

(c) Further considerations regarding schools

Obviously, the intervention programme's format and the complexity of its content would have to be tailored to the intellectual level of the various groups of pupils.

At high school level, teaching these cognitive and meta-cognitive skills explicitly should be a collaborative venture between Life Orientation, Biology/Physiology and Mathematics/Maths Literacy teachers. Life Orientation teachers would offer a generic programme in conjunction with Biology/Physiology teachers who would fill in basic neuro-scientific facts about the brain and its neuronal pathways (which certainly is part of their syllabus!). Mathematics/Maths Literacy teachers would instruct their classes, constantly aware of the way in which their scholars need to assimilate knowledge, aware of possible threshold concepts, and regularly 'weaving' references to the cognitive and meta-cognitive skills acquired in the Life Orientation classes into their own teaching programme.

Lastly, Dweck (2008:7) notes that scholars, especially those who struggle academically and have a poor academic self-image, need time and constant reinforcement of the above-mentioned interventions to make the paradigm shift from a fixed to a growth mindset – and subsequently improve their academic grades. This corroborates the research into the "silencing" versus growing and strengthening of neuronal networks (Hebb, 1949; Diamond, 2001; Zull, 2002; Schlaug, 2005; Kleim & Jones, 2008). The drop in the September results compared to the June results of my Year B group of students is an example of students needing sustained support for the paradigm shift to become a lasting one. Ideally, therefore, the entire staff of a school should be involved in attribution retraining workshops so that scholars are alerted to these skills in more subjects than just Mathematics and Maths Literacy.

(d) Which schools should be targeted?

The PISA 2012 report notes the following:

(i) Socio-economically advantaged students are almost an entire year's mathematics schooling ahead of their more disadvantaged peers.

(ii) Schools in socio-economically disadvantaged areas are often disadvantaged themselves. According to the report, "in many countries, schools tend to reproduce existing patterns of socio-economic advantage" (2012:13) - or, in this case, disadvantage. Consequently, many students are negatively affected by both personal and environmental, as well as educational, shortcomings (2012:14).

(iii) At the same time "policies and practices have an impact on both equity and performance" among schools and their scholars (2012:13), despite the above-mentioned disadvantages.

(iv) Education systems in some countries successfully targeted either underperforming scholars in schools, or entire schools which showed poor results in the subjects on which PISA focused.

(v) Some countries concentrated on their above-average performing scholars with the aim of growing a highly-skilled workforce which would boost their national productivity and, therefore, their economy.

It is reasonable to state that, in South Africa, serious consideration needs to be given to policies which would improve academic performance in maths-related fields at both the base and the tip of the pyramid, as will be explained below.

South Africa has a broad base of socio-economically disadvantaged communities and schools which display all the hallmarks that lead to underachievement. This broad base needs and deserves immediate attention and a concerted effort on the part of the Department of Basic Education to uplift it by means of more constructive schooling. That this is attainable has been proved by countries abroad (PISA, 2012:8). I would, thus, recommend that an attribution retraining programme should be rolled out at such schools. It would benefit both the scholars and teachers who are - through no fault of their own! - often ill-equipped to teach their subjects.

At the same time, South Africa is short of STEM-related professionals (the tip of the pyramid) who would drive its innovative resourcefulness, its productivity and, therefore, its competitiveness in the global market. This has been discussed in Chapter 2. Consequently, it would be advisable to take the extended attribution retraining programme to top-end schools as well to give scholars the best possible chance to perform optimally in maths-related subjects.

(e) Attribution retraining programmes at university

In Chapter 2, I discussed the national concern regarding inadequately prepared first-year students in the Mathematics and Science fields. The 2009 National Benchmark Test Project established that only 25% of first-year students were proficient in Maths Literacy, and only 7% of first-year students were proficient enough in Mathematics to study this subject (NSTF, 2009:15).

Students who have registered for courses in which a sound understanding of basic mathematical concepts is a prerequisite (especially at universities of technology) would, therefore, benefit from attending an intervention programme such as the one presented and analysed in this research. Moreover, the cognitive and meta-cognitive skills, which form the core of the interventions, would not only turn the tide for students who struggle with Mathematics, but would also be of value to every other student in his or her endeavour to succeed academically.

The interventions I have discussed are, in themselves, of a generic nature. They can, therefore, easily be contextualised to support students in different courses and should be offered at first-year and at Foundation/Bridging/Extended Curriculum Programme levels.

5.4.2. Recommendations for long-term policies and practices

If being quantitatively literate is considered world-wide to be an important prerequisite for personal advancement and fulfilment in more than just the job market (UNESCO, 2012); if the well-being of society and its economy hinges on its citizens being productive, adaptable and reasoning individuals (World Economic Forum, 2014), as discussed in Chapter 1, then a basic Mathematics (or Quantitative Literacy) course, contextualised according to the faculty and programmes in which it is offered, should be compulsory for first-year students at any university, but especially at universities of technology. These institutions are more vocation orientated - and have considerably lower admission requirements in general, as well as in Mathematics/Maths Literacy, than traditional universities, as discussed in Chapter 2.

However, this would mean that no students could escape the reality of a first-year basic Mathematics or Quantitative Literacy subject. Consequently, long-term policies and practices would have to be put in place which would aim at changing an entire society's understanding of and appreciation for the role of mathematical

literacy. Only a paradigm shift from believing that “maths” is for a selected few to accepting that everyone has the cognitive ability to grasp basic mathematical principles would pave the way for a general willingness to engage with this subject.

In order to bring about the realignment of the public’s attitude to everything mathematical, educational policies would have to be reconsidered.

(a) Adaptation of curricula in teacher-training diploma courses

According to the UNESCO report (2012:71) “the quality of mathematics teacher education is the key issue for ensuring quality mathematics education for all.” The same has been stated by South African educationists and educational reports (NSTF, 2009, 2010; Department of Basic Education, 2014).

(i) *Training of primary school teachers*. Universities which offer study courses for primary school teaching should raise their admission requirements with regard to Mathematics/Maths Literacy. This is advocated by the PISA report (2012:16) as well.

Students in training programmes for primary school teachers should be offered a module (perhaps in Educational Psychology, Curriculum Didactics or Mathematics Education) which teaches them the cognitive and meta-cognitive skills embedded in my intervention programme. Besides reducing their own possible maths fears it would also allow them to teach their pupils these skills at a very elementary level. In this way pupils may enter high school with a more positive self-concept regarding Mathematics and very basic cognitive and meta-cognitive skills already in place.

(ii) *Training of high school teachers*. The same programme that should be offered to student-teachers preparing for primary school teaching should be part of Educational Psychology, or Mathematics/Maths Literacy Didactics, for students training to become high school teachers. They would be able to teach more purposefully and effectively, if they understood the underlying causes for their scholars’ negative attitude towards Mathematics – and their consequent cognitive and affective barriers regarding the subject.

(b) Training of lecturers in higher education institutions

Lecturers involved in Foundation/Bridging/Extended Curriculum Programmes should be offered a workshop which introduces them to the cognitive and meta-cognitive skills dealt with in the interventions. At universities of technology, lecturers are often drawn from industry as they are experts in their professional fields. However, the gap between their vast knowledge of and experience in a particular career and the academic deficits experienced by the students they

teach often resembles an abyss rather than just a gap. Teaching staff are often not aware of the debilitating affective and cognitive impact which personal, situational and academic issues have on a student's ability to apply him-/herself whole-heartedly to their studies. This observation is based on ten years of interacting with lecturers at such a university of technology. Universities do offer a certificate in teaching in higher education (the Teaching Development Programme), and it should be standard practice that a module in this course should deal with cognitive and meta-cognitive skills, either as presented in the intervention programme discussed in this dissertation, though modified, or expanded to include further skills and strategies which they themselves might employ in their lectures and share with their students.

(c) Extension of a one-year Bridging or Foundation Course

That time constraints played an important role in hampering our attempt at consolidating and sustaining the impact which the attribution retraining programme should have had on the students is illustrated by the September test results of Year B discussed here below.

I concluded the Numeracy module by the end of the first semester of Year B. The average for the class was as follows: 34,8% for the diagnostic test and 52,6% for the summative assessment in June. In this year, though, the students also answered numeracy questions in their summative September assessment. The class average dropped back by 5,6%. This happened despite the fact that the September assessment tested the same mathematical competencies as the June assessment. The only difference was that I had not been able to spend class time on Numeracy in the third term, and that the pressure exerted by the studio subjects had increased.

The above pattern was repeated in a later year when the assessment outcomes were as follows.

diagnostic test in February: class average - 36,2%
summative June assessment: class average – 49,0%
summative November assessment: class average - 43,4%

My interpretation of this pattern is that, even at a post-school level, students with a long negative history in mathematics-related subjects, especially if

accompanied by debilitating emotions (Zull, 2004; Weiner, 1985), take longer to overcome their doubts and fears. It will take more than four months of intermittent Numeracy classes and references to the implemented interventions to 'silence' the firmly established neuronal networks and stimulate - as well as strengthen! - new and positive ones.

My contention that the Numeracy module should be continued right through the year, along with regular reminders and application of the taught cognitive and meta-cognitive skills, is perhaps best illustrated by the following incident regarding a student who found it difficult to overcome her deep-seated struggle to believe in herself.

She had passed her Physics and Chemistry in matric, but had obtained very unsatisfactory symbols. She decided to rewrite the two subjects in March of the year spent in our Foundation Course. Her symbols for the two subjects met her expectations. This indicates that she certainly was comfortable with mathematical computations pertaining to the sciences. In addition, she had experienced my attribution retraining programme, as well as my Numeracy classes. Yet, in the third term she approached me one day during one of our very rare revision sessions and asked whether she was right to think that there are 1000mm in 1 metre. This student had also admitted that "I do not trust my brain at all when it comes to theory work…". In the end, however, she commented that "I now believe I can do anything I put my mind to…". The student is now successfully completing her final year in Product design, a programme which relies heavily on basic mathematical principles.

I am, therefore, convinced that the most profound way of rendering the attribution retraining programme effective would be to extend the curriculum of the entire Foundation Course over two years and become the basis for all design programmes. Not only would the students stand a better chance at becoming qualitatively literate, but the interventions, if regularly woven into the fabric of the syllabi, would afford the students the opportunity to understand and internalise the cognitive and meta-cognitive skills at a more meaningful pace. In turn, a better understanding and sustained application of these skills would render them more readily transferable to other subjects. This is advocated by UNESCO (2012:57) as well. The pressure of the crowded curricula for the eight studio subjects, the History of Design subject, as well as the Professional Business

Practice subject could thus be reduced. Each teaching component in the latter subject could be dealt with at greater length and in greater depth.

5.5. Recommendations for further research

There is much room for further investigation, and relevant questions to be raised and answered.

5.5.1. Repeats of the present intervention programme

Considering that this research has studied data generated by a very loosely compiled quasi-experimental project, it stands to reason that more structured repeats of this project should be implemented and analysed. I do not suggest strictly laboratory-based research, as it is removed from the realities of the first-time student's experiences at a tertiary institution, as well as his or her new and complex lifestyle. However, both quantitative and qualitative data should be collected at more regular intervals and at strategic stages of the implementation of the programme and the teaching of the Numeracy syllabus. Students might also be drawn into becoming 'co-researchers', and thus more aware of the aims of the project and of their own progress, both in making the necessary paradigm shift and in developing greater proficiency in Numeracy. Involving the students in this manner may also lead to more introspective feedback from them. More students may want to take part in this research, and thus a larger body of comprehensive data would be available.

5.5.2. Isolating negative factors in the South African context

Haynes et al. (2009:262) ask which variables, other than the hitherto used ones, might be employed to identify at-risk students and offer them attribution retraining treatments. I would suggest that research be done into which specific factors in the South African context have the most profound – and negative! – effect on our scholars and students. The contextualisation of the interventions which I offer might then be more focused on particular causes which hamper students' progress in Numeracy - and which are *not* stable and uncontrollable. The following questions point to such variables.

(a) Does gender stereotyping play a role among African girls?

(b) To what degree does a lack of English language proficiency form a barrier to understanding the interventions? Would the content of the

programme become more accessible if it were translated into African languages? Such a translation would have to be done in the more commonly used, informal versions of the languages, as many students shy away from the elevated registers of their mother-tongues.

(c) To what degree do scholars and students consider a socio-economically disadvantaged background, as well as having attended a disadvantaged and/or dysfunctional school, a stigma? Is there a sense of negative stereotyping among these scholars and students? The PISA report states that socio-economically privileged students are a year ahead of their less privileged peers in their mathematical competencies. Consequently, there might be a blurring in the disadvantaged student's mind of causal attribution to an innate lack of cognitive ability (internal, stable and uncontrollable) regarding Mathematics based on his or her background (external, unstable and controllable).

(d) What are students' daily stressors, both the situational ones and those related to the academic environment? Research into this aspect of a student's experience of the transition from secondary to tertiary level would be of profound value. The intervention based on Kolb's experiential and reflective learning cycle would assist students in alleviating the situational stressors; the intervention explaining the information processing mechanisms of the working memory would alert them to the fact that interferences and attentional distracters compromise their working memory capacity and, therefore, need to be minimised at all costs.

5.5.3. Researching the impact of each intervention separately

In order to gain better insight into the effect which the various interventions have on a scholar's ability to break down the barrier to epistemological access to Mathematics/Numeracy, I would suggest the following research project. Each one of the four interventions is implemented in a particular class at a school, and one control group, taught by the same Mathematics teacher, is earmarked. Throughout an entire semester, both quantitative data (the assessment outcomes) and qualitative data (free-writing and verbal/written feedback with respect to the scholars' experiences in the Maths lessons) of the several classes are gathered and compared. This should bring to light whether and to what degree each intervention has an impact on the scholars' sense of academic control, on their self-efficacy beliefs and on their assessment scores. For the sake of fairness, the proviso should be made that the control group is offered the interventions at a later stage, if the latter proved to have a positive effect on the research groups of scholars.

The same experiment should be implemented at university level to establish whether and to what degree young adults are receptive to each of these interventions separately.

5.5.4. Longitudinal studies

At-risk students who had been offered the conventional attribution retraining treatments had been monitored over the course of two years and were found to have made promising progress; the majority of them had not deregistered from subjects which had challenged them in their freshman year, and had also not dropped out of their courses altogether (Haynes et al., 2009:260).

It would, therefore, be of value to launch such longitudinal studies in South Africa as well. I would recommend the following such studies:

(a) research into the effect which the suggested attribution retraining programme has on student-teachers training for primary school teaching: their sense of mathematical proficiency, their confidence to teach Arithmetic, and the progress which their pupils make right through to Grade 8 in high school;

(b) a similar study into the progress which Grade 8 and Grade 10 scholars make, having been offered the intervention programme and being taught by Mathematics/Maths Literacy teachers who collaborate in this project and incorporate the concepts taught in the programme into their own teaching methods;

(c) an equally worthwhile study into the effect which the programme has on Grade 12s who are preparing for their National Senior Certificate examination. There are two issues to be investigated: (i) Did the intervention programme make a substantial difference - even so late in the scholars' school career! - keeping in mind their various types of backgrounds? In particular: Could scholars from socio-economically disadvantaged backgrounds still benefit from such an intervention programme in their final year at school? (ii) How do matriculants who have experienced this programme adapt to their first year at university - especially in mathematics-related courses, but also with regard to the complexities of this transition period?

(d) Finally, returning to the high school phase of a scholar, it would be interesting to study the effect of the intervention programme on scholars' performance in all their subjects. Ruthig et al. (2004:723) note that the conventional attribution retraining treatments had a positive effect across all subjects taken by freshmen. Would the same apply to South African scholars? Brombacher (NSTF, 2009) contends that Grade 8 scholars who perform well in Mathematics, do well in their other subjects, too, and perform well in their National Senior Certificate examination. Again, of special concern would be an investigation into the effect which the programme has on scholars'

general experience of school and performance in all subjects, particularly with respect to scholars from less-advantaged backgrounds. PISA 12 speaks of “resilient” scholars who “beat the socio-economic odds against them and exceed expectations” (2012:12). The ultimate aim of my extended attribution retraining programme being transformation and advocacy, I consider such a longitudinal study of particular interest.

5.6. Further development in the extended attribution retraining programme

The intervention programme, as I implemented it, certainly can be improved upon. As stated above, it was loosely compiled and only a component of a larger subject. Its interventions were slotted into the teaching programme as time permitted; lack of punctuality and absenteeism on the students’ part exerted a negative impact on their chance to gain optimal benefit from the programme; some interventions were more accessible to the students than others. I would, therefore, consider developing certain aspects of the programme to deepen and consolidate its influence on the students’ sense of self-efficacy, on their proficiency in Numeracy in particular, and on their academic performance in general.

5.6.1. Reflections on the limitations regarding data

(a) *Incomplete sets of research data.* As lecturer, one does not have any control over this limitation for three reasons. (i) Students have the freedom of choice not to attend classes. (ii) Their situational circumstances – transport, finances, family responsibilities - are often unpredictable and hinder them from being punctual in more respects than one. (iii) They have the choice not to participate in any research activities. The only remedy for the lecturer is to render the interventions as interesting as possible (see *Best practices* below) and draw the students into the programme at as deep a level as possible.

(b) *Lack of reliable quantitative and qualitative data*. If I may play a word game for a moment: the data may be *realistic* in that they accurately present the precise situation of the students at the moment the data were generated. However, this does not mean that they are *reliable* in their portrayal of the students’ actual competencies and their innermost response to the interventions. Both sets of data are coloured by internal and external factors which influenced the students at the time, as well as my interpretation of the data in retrospect.

(c) *Language barrier*. As far as a possible language barrier in assessment tasks is concerned, the lecturer should be encouraged to take the students through briefs and formal assessments to make sure that they understand what is asked of them. As far as language barriers to qualitative data collection are concerned, I would suggest that (i) the

better the rapport between lecturer and students, the more comfortable the students will be to express themselves as best they can; (ii) the more regularly students are invited to reflect on their personal and academic progress, the easier introspection will become – as well as the verbalisation of such reflections; (iii) with regular remedial support from a language instructor, students should eventually find 'their own voice'.

(d) *Link between interventions and numeracy outcomes*. Gauging the effect which individual interventions have on scholars' or students' progress in Mathematics or Numeracy is discussed under the heading of *Researching the impact of each intervention separately* (# 5.5.3. above).

5.6.2. Further development of the programme

(a) The programme itself needs to be consolidated; its interventions need to be singled out as belonging to a series of lectures on cognitive and meta-cognitive skills. Although I have always explained the meaning of cognition and meta-cognition and have referred to these concepts regularly, they would have to be highlighted and taught explicitly as an introduction to the programme.

(b) The interventions regarding the plasticity of the brain and the memory systems have been very successful, as was noted in Chapter 4. However, improvement is always possible, and these two interventions should be given more lecture time for optimal effect, if one considers that they are expected to initiate the paradigm shift in the students from a fixed to a growth mindset.

(c) The modified and simplified version of Kolb's experiential and reflective learning cycle needs to be emphasised, made more memorable and employed more regularly, both to solve students' circumstantial issues, as well as their academic challenges.

(d) Meyer and Land's notion of threshold concepts, although it is the more important of the two meta-cognitive skills, was the most elusive. As explained in Chapter 4, students appreciated the idea of threshold concepts, but most of them were not able to identify such concepts in their studies. This intervention needs to be reformulated to make it more accessible, and lecturers in other subjects should be brought on board and asked to identify such concepts in their own syllabi – and then to help students recognise them and work through them.

(e) Lastly, as noted in the introduction to the recommendations, different versions of the intervention programme need to be developed, aimed at the cognitive levels of the various targeted age groups. In the development of such programmes, one must also distinguish carefully between those participants who, one wishes, will make a paradigm shift and develop greater intellectual self-confidence (pupils, scholars and students), and those participants (the teachers and lecturers) who need to facilitate such a change of mind in others.

5.6.3. Best practices under the circumstances

Having reflected, both then and now, on the circumstances under which I implemented my attribution retraining programme, I came to the following conclusion.

As long as the time constraints and the pressure of the studio subjects were unavoidable, I had to resign myself to very limited class time for each intervention. I could do no more than present the students with the information in the most accessible manner possible, and then leave to the students the choice of accepting and engaging with this information or passing it over.

My experience tells me that 'the most accessible manner possible' would involve the following strategies:

(a) Using visual material wisely

I do not believe that visual material should constitute the bulk of one's teaching material. However, it is a very powerful and memorable teaching tool. The video clips on the neuronal networks made a profound impression on the students. In this case animated images were more effective than any number of descriptive and explanatory words would have been - and took less time than working through texts would have taken. Visual material also empowers students who may be handicapped by language barriers - and for many of our students English is a second, if not third, language.

The flow diagramme for Kolb's reflective learning cycle was a visually very clear and useful pattern which we applied repeatedly to various situational and academic challenges. Students recognised it immediately, even two to three years later.

Using images of stained glass windows taken both from inside as well as outside a building (such as a church) to demonstrate 'transparent' and 'troublesome' knowledge was very effective. Although the students found it difficult to comprehend threshold concepts as a whole, they easily understood the difference between a teacher's experience of such concepts ('transparent knowledge') and a student's experience of the same concepts ('troublesome knowledge') when these were likened to the images of stained-glass windows.

Therefore, as long as teaching time remains an issue, I would incorporate visual material wherever and whenever helpful to render access to information more immediate.

(b) Linking the attribution retraining programme to students' prior experiences

Being able to draw upon years of classroom experience is a valuable asset for any lecturer involved with Foundation or Extended Curriculum Programmes. The tertiary environment and academic discourse is a novel and often bewildering experience for first-time students. Consequently, if the lecturer is familiar with students' prior school discourses and can sketch scenarios which every scholar would have witnessed, s/he can open channels for meaningful communication, as well as create opportunities for comparison and contrast between the two differing worlds of education. This is especially helpful in the case of the latter two interventions (Kolb's experiential and reflective learning cycle and threshold concepts) which deal with concepts that students find difficult to pinpoint in their personal engagement with academic work.

(c) Free-writing

Free-writing is an excellent tool for various reasons. One student wrote the following:

> "Being able to write down my feelings really helped me to open up and get to know myself more."

The above comment was in response to my initial invitation that they free-write about their experiences with Mathematics/Maths Literacy at school.

Being able to revisit their free-writing from the perspective of how the memory systems work was an illuminating experience for many of them. This is reflected in the following comments:

> "I am able to understand problems, situations, effects and experiences much better. For example, why I did not do too well at school in Maths."

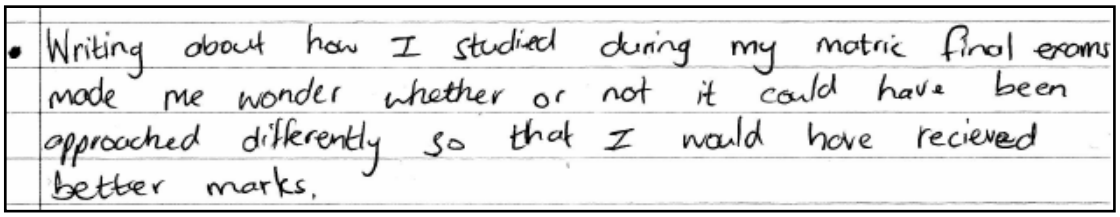


Figure 5.1.: Student's reflection on ineffective study methods at school

> "Writing about how I studied during my matric final exams made me wonder whether or not it could have been approached differently so that I would have received better marks."

Regular directed free-writing in response to feedback given with regard to assignments would also be a worthwhile exercise. It would allow students to reflect upon the underlying reasons for their successes and failures, and this, in turn, should allow them to employ Kolb's reflective learning cycle more successfully.

Finally, asking students to write down what they thought they knew about a certain topic, in this case topics related to the attribution retraining programme, and then asking them to write about the same topic again once I had concluded a certain intervention, would be a very valuable exercise. It would reveal to them their 'before' and 'after' understanding of certain concepts, and simultaneously demonstrate to them in a more tangible manner the notion of their own expanding neuronal networks and, therefore, their growing intellectual capacity.

5.7. Conclusion

In conclusion then, I would like to quote the following from UNESCO's report (2012:43) regarding quality mathematics (or then numeracy) education:

> "Such a project will only succeed if everyone – mathematicians, teachers, teacher educators, educationists, specialists, teachers of other disciplines and decision-makers – works together to take up this challenge and if regional and international cooperation and solidarity are strengthened. The potential for achieving this does exist, even in the most disadvantaged areas. "

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APPENDIX A : Matrix of Mixed Methods Research Design

Matrix for Mixed Methods Research (Creswell, Clark, Gutmann, Hanson, 2003)

	Implementation	Priority	Integration	Theoretical perspective	Purpose	Strengths	Weaknesses
1. Sequential Expalanatory Design (interpret'g relationships)	1. collect + analyse quan. data 2. collect + analyse qual. data	QUAN - qual QUAL - quan	interpretation phase	not necessarily	**To explain unexpected quan results;** used to **"characterise students along certain traits - for purposeful sampling"**	* report in 2 phases * final discussion combines the 2 * gd for further quan. Research	*length of time for collection of data
2. Sequential Exploratory Design (to explore phenomenon)	1. collect + analyse qual data 2. collect + analyse quan data	QUAL - quan	interpretation phase: am using qual data to explain quan data	not necessarily	* use quan data to interpret qual findings * for test'g elements of emerging theory result'g from qual phase; **used to generalise qual findings to diff. samples** * used **when researcher develops & tests an instrument**	**useful if researcher is build'g new instrument** (for what? Teaching or researching?)	requires length of time
3. Sequential transformative design	* collect + analyse quan data *collect + analyse qual data (or vice versa)	QUAL - quan (QUAN - qual)	interpretative phase	**theoretical perspective - more NB in guid'g study than methods alone**	* employ methods which will BEST serve theo. perspective/ give voice to diverse perspectives/**better advocate for participants/better understand phenomenon or process that is changing as result of being studied**	places mixed methods research within a transformative frame-work	little guidance on how to use transformative vision to guide the methods; unclear how to move from analysis of 1st phase to data collection of 2nd phase
4. Concurrent Triangulation Design	2 types of data collection concurrent	ideally QUAN/QUAL (vice versa) OR: QUAL/quan in my case	**interpretation** phase; will note convergence of findings or needs to explain lack of convergence **OR:** during **analysis** phase which means transform'g data from one type to the other		**uses 2 diff. methods to confirm, cross-validate, corroborate findings within 1 study**	*can result in well-validated + substantiated findings	problem study'g phenomenon with 2 diff. methods + using data of diff. forms; how to resolve discrepancies that arise from results

5. Concurrent Nested Design (multilevel design)	2 types of data collection concurrent	1 method embedded in more dominant method; MAY mean that methods are seek'g info for diff. questions OR seek info from diff. levels	data from both methods mixed at analysis phase	can have guiding theoretical perspective	may gain broader perspectives from using 2 methods; "qual data can escribe an aspect of a quan study that can't be quantified"	1. gives advantages of both kinds of data **2. researcher gains diff. perspectives**	1. transform data at analysis phase 2. how to resolve discrepencies between two types of data
6. Concurrent Transformative Design	both types of data collected concurrently	may be equal or unequal: Qual - quan	most often during analysis phase OR possibly during interpretation phase	**theoretical framework: reflected in purpose of research question; guides methodological choices (cf p. 185)**	triangulation of both data to best converge information	all the advantages of (4) and (5) as well as: positions mixed methods research within transformative frame-work	ditto (4) and (5)
Mine: (sequential transform-ative)	* quan & qual data * collected within 6mths (quan & qual) + then 2 yrs later (qual)	QUAL + quant	analysis phase (?) : analysing QUAL data and supporting results with quant. data (?) to estab. degree of relationship	definitely theoretical framework and advocacy objective	1. explain unexpected quan results 2. choose specific students (purposive) 3. for develop'g new instru-ment 4. will process (programme) change as result of study? 5. 2 methods confirm, cross-validate, corroborate findings 6. gain broader perspective	1. useful for bldg new teaching & learning instrument 2. possibly well-validated + substantiated findings (?) 3. gives different perspectives	how to resolve discrepencies between two types of data

1. I summarised the basic types of mixed methods researches and coded in green the elements which I identified in my study.
2. then blocked in blue No. 3 because I think that should be my research design.
3. then summarised (blue band at bottom) with green elements which, I think, definitely fit my design, PLUS bold blue/purple/orange elements which are important to me.

APPENDIX B: Year B – Spreadsheet with Numeracy marks

Foundation Course - Professional Business Practice													
YEAR B	Diagnostic test			Summative June assessment									
	Total		Performance level	Metric conversions	Area/Vol. composite shape	Costing & percentages	Areas: complex shapes	Total		Performance level	Percentage increase	Percentage decrease
	45	%		8	5	9	13	35	%		%	%
	8	17.8	1	4	2	3	3	12	34.3	2	16.5	
	8	16.7	1	3	0	0	4	7	20.0	1	3.3	
	35	77.8	6	8	5	6	9	28	80.0	7	2.2	
	12	26.7	1	3	1	3.5	3	10.5	30.0	2	3.3	
	5	11.1	1	1	0	2.5	4	7.5	21.4	1	10.3	
	10	22.2	1	5	3	6	3	17	48.6	3	26.3	
	12	26.7	1	5	0	4	3	12	34.3	2	7.6	
	9	18.9	1	4	5	6	8	23	65.7	5	46.8	
	15	32.2	2	6	0	5	8.5	19.5	55.7	4	23.5	
	15	33.3	2	7	2	5.5	5	19.5	55.7	4	22.4	
	33	73.3	6	6	5	6	4	21	60.0	5		-13.3
	8	16.7	1	8	4	0.5	7	19.5	55.7	4	39.0	
	6	13.3	1	2	5	1	3	11	31.4	2	18.1	
	20	44.4	3	8	5	6	6	25	71.4	6	27.0	
	25	55.6	4	7	5	4	13	29	82.9	7	27.3	
	9	20.0	1	3	5	2.5	7	17.5	50.0	4	30.0	
	9	20.0	1	3	2	0	0	5	14.3	1		-5.7
	9	20.0	1	4	1	3	2	10	28.6	1	8.6	
	13	27.8	1	4.5	4.5	7	5.5	21.5	61.4	5	33.7	
	19	42.2	3	5	5	8	8	26	74.3	6	32.1	
	13	27.8	1	0	2	3.5	4	9.5	27.1	1		-0.6
	15	32.2	2	7	3.5	7	7	24.5	70.0	6	37.8	
	19	41.1	3	8	2	6.5	8	24.5	70.0	6	28.9	
	11	23.3	1	4	0	4	5.5	13.5	38.6	2	15.2	
	20	44.4	3	8	5	8	9	30	85.7	7	41.3	
	38	83.3	7	7	5	8	12	32	91.4	7	8.1	
	34	75.6	6	7	5	5	3	20	57.1	4		-18.4
	8	16.7	1	1	1	1	4	7	20.0	1	3.3	
	15	33.3	2	6	3	6	5	20	57.1	4	23.8	
	31	67.8	5	8	5	9	5	27	77.1	6	9.4	
	12	25.6	1	5	2	3	3	13	37.1	2	11.6	
	12	26.7	1	7	5	7	8	27	77.1	6	50.5	
TOTAL		1114.4		165	98	148	180		1684.3		607.9	-38.0
AVE.		34.8		5.1	3.1	4.6	5.6		52.6		21.7	-9.5
%		34.8		64.3	61.3	51.2	43.1		52.6		21.7	-9.5

APPENDIX C: Questionnaire: Reflections on my brain

In the past, how much did I know / think about my brain? _____

_____

_____

_____

How did I judge my brain's ability to learn? Did I trust my brain to understand and retain what I needed to learn and know tests and exams? Did I worry about forgetting information?

_____

_____

_____

_____

_____

Did I trust the standard of education at my high school? (I do not want to know WHERE you went to school and who taught you.) _____

WHY? _____

_____

_____

_____

Have the notes and videos on the brain affected my attitude to my ability to learn and cope with tertiary work? _____

HOW? _____

_____

_____

_____

_____

_____

APPENDIX D: End of course year questionnaire

Some deep questions regarding what you discovered this year in the Prof. Bus. Prac. subject.

How have you grown this year in your understanding of university life and academic requirements?

How did any of the notes/classes/discussions help you find your feet in this course?

Compare how you feel now about your strengths/abilities to your understanding of yourself when you arrived here in January? (What were your doubts/fears then? And have you changed your mind in the course of the year?)

How have any of the PBP classes helped you find your strong points/quieten your fears?

Whether you were good at Maths or not before you joined us, did any of my interventions help? How?

Explain what you understand threshold concepts to be:

If you could give me some advice on how I could improve my subject, what would it be?

Think about what and how I taught you: What, do you think, was my attitude and purpose towards the subject and you as a group? I.o.w., what was my mission?

Anything else you would like to add? Anything that stood out? Changed your mind? Made you feel better about yourself? Gave you hope?

APPENDIX E: Recent questionnaire in preparation for interviews

Cape Peninsula University of Technology
Faculty of Informatics & Design
Research for Master's dissertation
(by Monika Rohlwink)
Information given to prospective participants in my research

Name: _____ Design programme: _____

Contact No.: _____ Email address: _____

My contact: 072-242-1236 Email address: mrohlwink@cybersmart.co.za

Topic: Attribution retraining in the reduction of maths anxiety experienced by first-time design students at a South African university of technology.

Many students come to university with a history of failure and frustration in their Mathematics / Maths Literacy school subject. They believe firmly that they cannot achieve success in any tasks that involve working with numbers. However, being comfortable with numbers is necessary in life and in one's career - especially in Design! My belief, based on international research done over the past few decades, is that a healthy brain can learn the **basics** of any subject – also Maths! This is so because one of the very important functions of the brain is to learn, and it is beautifully designed for this purpose. With this questionnaire I am trying to …

… find out why you had certain experiences (good ones or bad ones!) with Maths (or Maths Lit.) at school,
… understand what effect these experiences had on you and your self-image,
… understand what effect (if any) my lectures had on your understanding of your own brain power,
… establish whether my lectures helped you change your attitude towards Numeracy and towards your own ability to cope with this module,
… establish whether my interventions helped you cope with other subjects during the following years of study.

I also would like your critique:

1. What did you find interesting and helpful in my lectures which were supposed to prepare you for Numeracy?

2. What did not work well for you? What could I have done differently to help you lose your fear of Maths / Numeracy and give it another try? How could I have convinced you of your brain power?

In order to prepare you for the Numeracy classes I covered the following with you ….

the brain and neuronal networks,
the memory systems (sensory, working and long-term memories),
what distracts you from learning,

Kolb's reflective learning cycle,
threshold concepts,

I also …

… asked you do to free-writing about your past experiences with Maths,
… taught you the basics of Numeracy step by step,
… gave you regular tests to gauge your progress,
… asked you to reflect on your progress in Numeracy in our Foundation Course.

If this study should prove that, with the right attitude and guidance, students can experience success in Numeracy / Mathematics, then the same method could be applied to the teaching of and learning in other subjects. This would be of great value to both students and lecturers country-wide.

Therefore, I am inviting you to participate in an interview during which I would like to ask you to reflect on your experiences in my classes as far as the above-mentioned strategies are concerned. If you are willing to participate in my research, please sign the accompanying consent form.

Here are the questions which I would like you to reflect upon and answer during the interview. The questions are obviously geared more towards those of you who struggled with Maths / Maths Lit. But I also need to know how those of you, who had had neutral or good experiences with this subject at school, reacted to the fact that you had to do Numeracy in my course. and what effect my method of preparing you and teaching you Numeracy had on you and your attitude towards everything to do with numbers. Therefore, please consider the questions below.

NB: You need to answer the questions HONESTLY and not worry about whether you are criticising me and my teaching methods.

Your experiences with Maths / Maths Lit. at school:

How did you fare in Maths / Maths Lit. at school?

Your marks during the course of your high school career: _____

Your attitude towards your own ability to do Maths / Maths Lit.: _____

_____

_____

If you struggled with the subject, did you become emotional about it? Angry? Depressed? Afraid? Despondent? Panicky?

_____

To what or whom did you ascribe your good/average/poor results? (i.o.w., did anything or anybody have a positive or negative influence on you and your ability to fail/cope/do well in this subject?)

_____

_____

Your experience with Numeracy at CPUT:

How did you instinctively react when I announced that we would be starting with Numeracy?

_____

Why?

_____

_____

_____

What was your inner self-talk (what thoughts went through your mind) when you were faced
with Numeracy tasks?

_____

_____

_____

How did you feel when you realised you would have to do Numeracy?

_____

Did your first few sets of marks confirm what you expected to obtain? _____

How did you react to my interventions?

The information on the brain? The neuronal networks!

_____

_____

_____

The information on the memory systems (sensory, working and long-term memories)?

_____

_____

_____

Kolb's reflective learning cycle?

_____

_____

Threshold concepts?

_____

_____

My slow and step-by-step explanations of the numeracy calculations?

_____

Did you at any stage start changing your mind (positively OR negatively) about your ability to do basic Numeracy? _____

Why?

_____

_____

Could you accept the information I gave you about the brain and how it works? (i.o.w. did you trust that the information was really genuine/true/or even just possible?)

_____

_____

Could you then step away from years of not feeling good about Maths and give yourself another chance? Or did you think your situation was beyond rescue?)

_____

_____

If you did change your mind about your own ability to do Maths, was the time span we had at our disposal enough for you to feel the difference, become calmer when we worked with numbers, obtain better marks? _____

What was your emotional reaction to my interventions? Did they give you hope? Motivate you to try again? Did they free you from the feeling that you are simply not 'wired' for Maths (or "dumb" when it comes to Maths ☹)? Or did you turn your back on the entire situation?

_____

_____

_____

Why?

_____

_____

Your studies after the Foundation Course

Are you still using any of the strategies I taught you? _____

The reflective learning cycle? _____

The idea of threshold concepts? _____

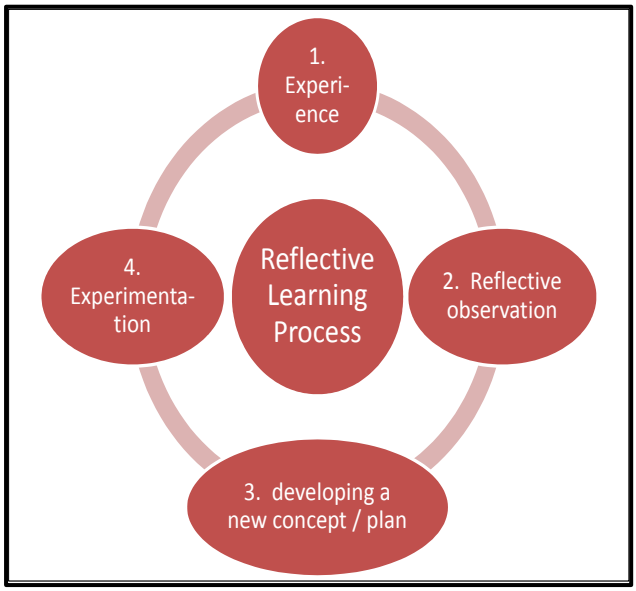
The breaking down of calculations / tasks into small manageable steps?_____

Did you ever sit back and say to yourself: I CAN do this! My brain has the natural ability

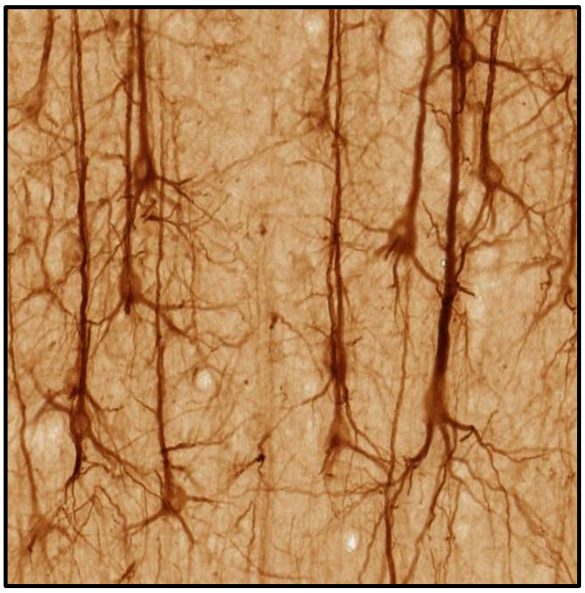
to understand at least the basics of this. _____

Most importantly:

Have you ever thought of applying / or did you apply what you learned in my subject regarding meta-cognitive skills (do you remember that term? Watching oneself learn and monitoring one's own learning process) to **other** subjects, other situations – even situations outside your studies? (i.o.w., did your understanding of the brain, how it learns, the memory systems and how they work, the reflective learning cycle, the threshold concepts help you cope or do well in other challenging situations?) Please elaborate briefly.



Kolb's experiential and reflective learning cycle (Atherton, 2009)



Stained neuronal networks in the cerebral cortex (Wikipedia)

APPENDIX F: Consent form

I.....agree to participate in Monika Rohlwink's research study.

The purpose and nature of the study has been explained to me.

I am participating voluntarily.

I give permission for my interview with Monika Rohlwink to be recorded.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within two weeks of the interview, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up by disguising my identity if I choose it to be done.

I understand that extracts from my interview may be quoted in the dissertation and any subsequent publications if I give permission below:

(Please tick one box:)

☐ I agree to quotation/publication of extracts from my interview

☐ I do not agree to quotation/publication of extracts from my interview

Signed..... Date.....

APPENDIX G: Diagnostic Numeracy test (February)

Faculty of Informatics & Design
Numeracy: Diagnostic Test
Lecturer: M. Rohlwink

Name: _____

Student number: _____

/ 45

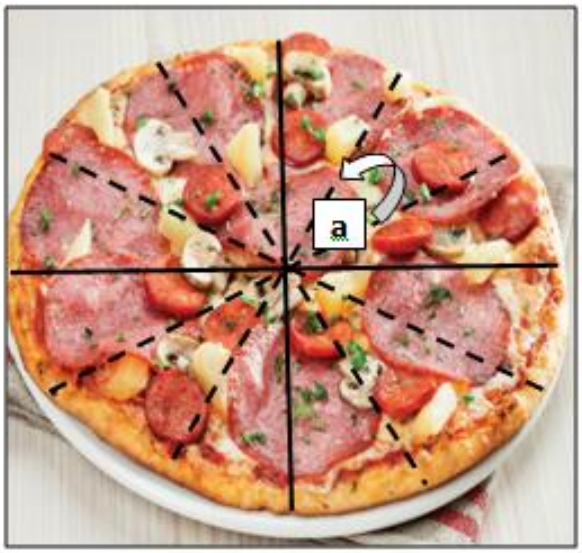


Image 1: Panarotti's Pizza (advertisement)

Exercise 1:

In the images on the left, indicate the following:
NB: In some images the item you have to identify is portrayed at an angle, and you have to turn the image somewhat in your mind's eye. (Visual literacy!!)

a. A radius
b. An equilateral triangle (gelyksydige driehoek)
c. A diameter
d. An isosceles triangle (gelykbenige driehoek)
e. a right angle
f. one pair of parallel lines

[6]

Image 2: (Photo: M. Rohlwink)

Exercise 2:

2.1. If all slices are equally sized, give the size of angle A. (3)

2.2. If the diameter of this pizza is 30cm, give the diameter in mm. (1)

2.3. If of pizza have you eaten? (4)

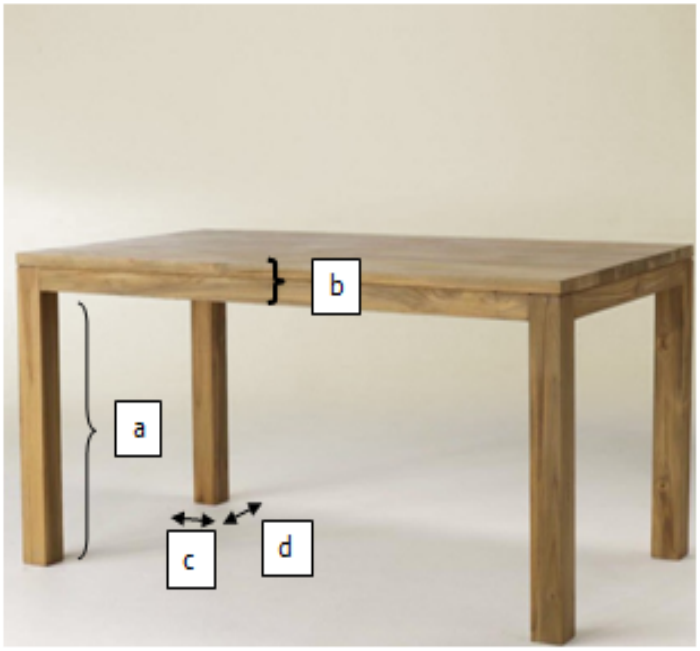
2.4. How many mm^2 would that be? (2)

2.5. If this was a 'crammed crust' pizza (with sausage wrapped around the edge of the pizza) how many cm of sausage would they need for each pizza? (3)

[13]

Image 3: Toblerone

Page 1



Dimensions of the table:

Tabletop: 1400mm x 1000mm

a : 670mm b : 70mm (thickness of tabletop)
c : 70mm d : 70mm

Exercise 3:

Study Image 4. It is a table made from very expensive yellowwood with the dimensions given below.

3.1. Calculate the volume of wood (in cm^3) used to create the table. (5)

3.2. If the wood for the table cost R25 000, what is the value of 1 cm^3 of yellowwood? (2)

3.3. What, then, is the value of 1 m^3 ? (3)

[10]

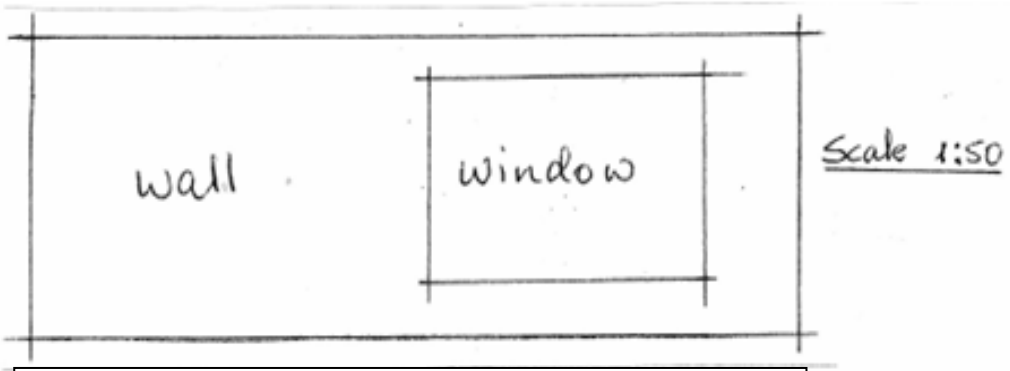
Exercise 4:

A client asks you to redecorate her lounge. She would like to have one wall (diagram given below) treated with a beautiful, important wallpaper, available at *Wall Coverings Inc.* (145 Sir Lowry Rd, Cape Town; www.wallcoverings.co.za).

NB: The diagram is an accurate representation of the wall and its window; the measurements are given in mm, and the scale is 1:50.

4.1. How many square metres of wall need to be covered with wallpaper? (5)

4.2. How many metres of wall paper do you need if the wallpaper is sold from rolls 50cm wide? (2)



NB: In this image of the actual test the dimensions of the wall and window are not accurate.

Exercise 4 (cont.)

4.3. The lady has already chosen a wallpaper called 'beauty-ruby' for her bedroom, which has a surface area of 30m². If each roll of wallpaper (50cm wide) has 10m of wallpaper on it, and the price per roll is R795 (excluding VAT), calculate the price (excl. VAT) for the number of rolls needed. (3)

4.4. Now add 14% VAT to the price you calculated in 4.3. above. (2)

4.5. She has also engaged an architect to design a new family room for her home. He is charging her R 5600 for his services. If she pays him within 7 days of completion of his work, he will give her a 15% discount. How much will she have to pay? (2)

4.6. The entire alterations to this lady's new home in Cape Town add up to R 125 500. She is still living in France, though, and needs to know how much this amount will be in Euros. If, at the moment, the exchange rate is R1: € 0,076, what is the total cost of these alterations in Euros? (2)

[16]

TOTAL: 45

APPENDIX H: Year A – June Numeracy Assessment

Cape Peninsula University of Technology

FACULTY OF INFORMATICS AND DESIGN

FOUNDATION COURSE

SUBJECT : Professional Business Practice

DATE :

MARKS : 50

TIME : 1 ½ hours

EXAMINER : M. Rohlwink

NAME OF STUDENT:_____

STUDENT NUMBER: _____

Question 1 : Conversions

275 mm^2 = _____ cm^2 b. 0,45 m^3 = _____ cm^3

c. 4,5 km = _____ m d. 0,28 m^2 = _____ cm^2

e. 25 000 mm^2 = _____ m^2 f. 1000 mm^3 = _____ cm^3

/6/

Question 2 : Volume and Area

2.1. You have a wooden board from which you want to cut little cubes in order to create play blocks for little children.

How many such blocks (5cm x 5cm x 5cm) can you produce from one wooden board?

_____ (3)

2.2. You are building a basic log cabin (7m x 11m) on stilts at a water's edge. A verandah 1,5m wide runs around the entire cabin.

a. The floor of the cabin and verandah is constructed from strong boards (300mm x 1500mm). How many boards (to the nearest whole one) do you need for the floor?

_____

_____ (4)

b. The height of the verandah is 1,5m above the ground/water level, and you want to build a ramp instead of steps. If the gradient needs to be 1:12 in metres) how long must the ramp be?

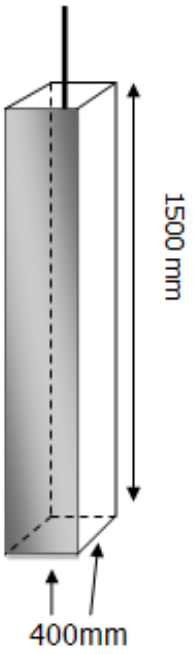
_____ (2)

/9/

Question 3 : Prisms and total surface area

3.1. You have designed decorative lights like the one on the right. They are open at the top, are covered on all sides and the base with silver mosaic pieces which reflect light, and are suspended from the ceiling.

Calculate the total surface area which needs to be covered with the mosaic pieces. **(in mm²)**



_____

_____ (3)

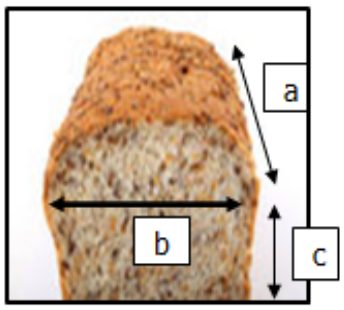
If the mosaic pieces are 20mm long and 20mm wide, how many will you need for one such light.

_____

_____ (3)

3.2. One of you industrial designers has been asked to design a bread prop from fibreglass for the **Blue Ribbon** bakery who are planning a television advertisement. The advert is for a 'high-rise' loaf. (a) length of loaf = 250mm (b) width = 120mm © height (without the 'high-rise' bit) = 100mm.

NB: We shall consider the top section of the front view of this loaf to be a semi-circle.



Calculate the total surface area which would to be formed using fiberglass **(in cm²)**.

_____

_____

_____

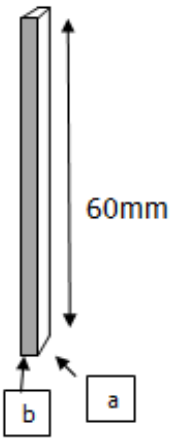
_____

_____ (7)

/13/

Question 4 : Volume of prisms

4.1. You are manufacturing a very plain, but elegant, earring from silver. Its length is 60mm, and it has a square base [(a) and (b) both = 2mm].



Calculate the volume of the earring in mm^3 :

_____ (1)

Convert the mm^3 into cm^3 : _____ (1)

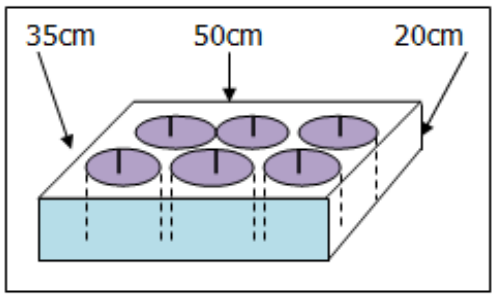
How many such earrings could you manufacture out of a block of silver 2,5cm x 1,5cm x 3cm?

_____ (2)

1 cm^3 of silver weighs 10,5g.

Now calculate the weight of one earring: _____ (1)

4.2. Your client asks you to design a decorative glass container to hold six candles. The space between the candles is filled with glass beads. The diameter of each candle is 10cm. Calculate the volume of glass beads which you need to buy. (For convenience, consider that the candles reach down to the floor of the container.)



_____

_____

_____

_____

_____ (6)

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Question 5 : Basic costing and percentages

5.1. You, a surface designer, have been commissioned to design a decorative clay tile. You are charging R 59,95 for one tile, but are offering an 8% discount if the client orders 30 tiles. How much would the client have to pay if she ordered 30 tiles?

_____

_____ (3)

5.2. One kilogram-bag of clay costs R24,00 and is enough for 6 tiles. The electricity for baking the tiles comes to R134,50, and you are also charging R 450 for the time it took to create the 30 tiles. Calculate the total price for the materials, electricity and the time.

_____

_____ (2)

5.3. Comparing the price the client paid to your expenditure (including the time you spent on the order), what percentage profit have you made on the entire order (to nearest full %) ?

_____

_____ (3)

5.4. The Michaelis School of Fine Art offers courses in pottery:

Course 1: Basic hand-building techniques in ceramics.....R 800,00
Course 2: Colour in ceramics .....R 880,00.

If you sign up for both courses, you pay only R 1500 in total. What percentage discount does the school give in this case (rounded up to one decimal place)?

_____

_____ (3)

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APPENDIX I: Year B – June Numeracy Assessment

Cape Peninsula University of Technology

FACULTY OF INFORMATICS AND DESIGN

FOUNDATION COURSE

SUBJECT	:	Professional Business Practice
DATE	:	
MARKS	:	60 **(Some questions did not deal with Numeracy.)**
TIME	:	2 hours
EXAMINER	:	M. Rohlwink

NAME OF STUDENT: _____

STUDENT NUMBER: _____

Question 1 - Conversions

1.1. 6800mm = _____ m

1.2. 0,4km = _____ m

1.3. 0,125m^2 = _____ cm^2

1.4. 2km^2 = _____ m^2

1.5. 650mm^3 = _____ cm^3 (5)

1.6. A fish tank holds 6000cm^3 of water. You are using a jug, which holds four standard cups of liquid, to fill the tank. If 1ml = 1cm^3, and a standard cup takes 250ml of water, how many jugs will fill the fish tank?

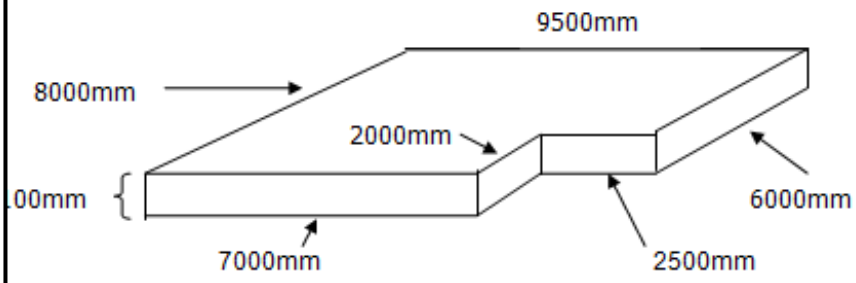
_____

_____ (3)

/8/

Question 2 – Area and Volume (Contextual)

Per Mertesacker is a centre defender in the national German soccer team. He likes Cape Town so much that he decides to buy a holiday home here and has asked your firm to undertake some alterations. He wants to have a family room added to the existing structure. The dimensions are as follows:



Per Mertesacker

A concrete slab (100mm thick) has to be laid as foundation for the room. Using the above measurements, calculate the volume of concrete needed for the foundation - **in m^3**. (Think of the various steps and do it one step at a time.)

_____

_____

_____

_____

/5/

Question 3 - Costing

Per asks you to source good quality porcelain tiles for the entire floor.

3.1. The tiles you suggest are 400mm x 400mm large. How many tiles, to the next whole tile, do you need for the floor? (Hint: use the relevant information which you have already calculated in 2.1.)

_____

_____ (3)

3.2. Now add 12% to the total for 3.1. to accommodate wastage of tiles. Again: Give your answer to the next complete tile.

_____ (2)

3.3. If the tiles come in boxes (8 tiles per box), how many boxes do you need to buy? (to next whole box)

_____ (1)

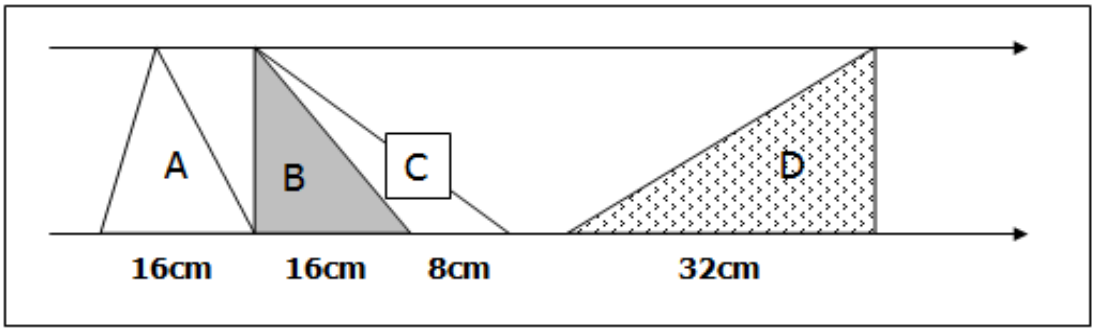
3.4. The price for the consignment of tiles is R36 225,00. If Mertesacker pays immediately, he will be given a discount of 15%. How much does he pay for the tiles?

_____ (3)

/9/

Question 4 - Areas

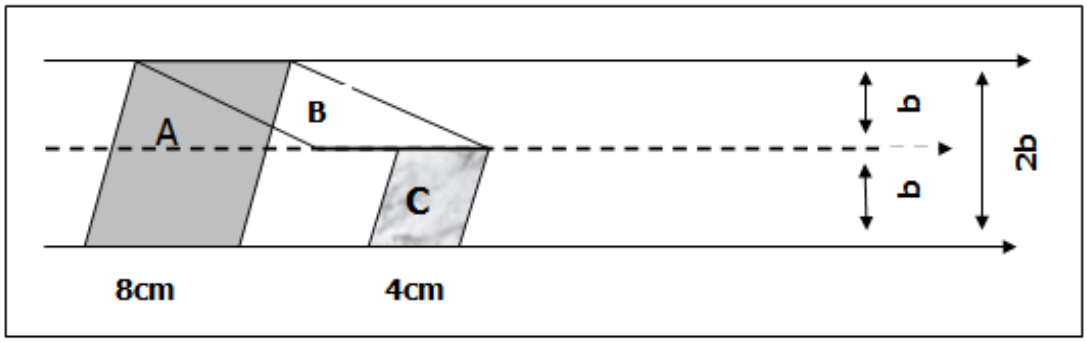
4.1. Consider the following triangles and give their areas.



The area of triangle A is 160cm^2.

B = _____ cm^2 C = _____ cm^2 D = _____ cm^2 (3)

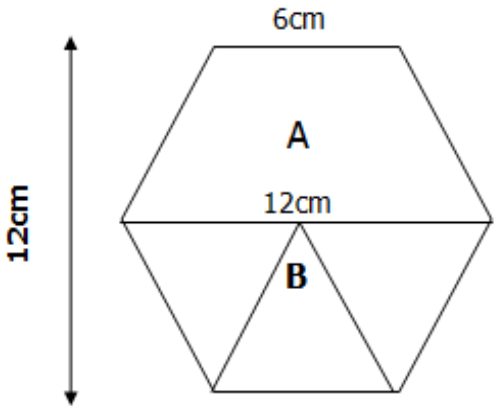
4.2. Consider the following parallelograms.



If the area of parallelogram A is 80cm^2, give the areas of parallelogram B and C.

B = _____ cm^2 C = _____ cm^2 (2)

4.3. The shape below is a regular hexagon. Calculate the areas of trapezium A and triangle B.



Area of Trapezium A:
Formula:

_____

_____

_____ (3)

Area of Triangle B:
Formula: _____

_____

_____ (3)

4.4.

Your client wants to have ten such hexagons distributed across her patio floor. You can order the variously coloured little triangles only in sets of 12. How many dozen do you need of each colour?

(**NB:** You will have some little triangles to spare.)

_____

_____ (2)

/13/