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A learning facilitation strategy for mathematics in a support course for first year engineering students at the University of Pretoria

by

Tobias M Steyn

Submitted in partial fulfillment of the requirements
for the degree of

Philosophiae Doctor

in the

Faculty of Education

at the

University of Pretoria

Supervisor: Professor JG Maree

January 2003

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Acknowledgements

The author wishes to acknowledge the following people for their contributions, directly or indirectly, to this dissertation.

Professor Kobus Maree for encouragement, unstinting support and help, constructive recommendations as to the improvement of my ideas and for always being an approachable and most dedicated supervisor.

The **first year engineering students** enrolled for the Professional Orientation Support Course during 2000, 2001 and 2002 who were key figures in the action research activities reported in this thesis.

The **students** enrolled for the Science Orientation course during 1999, and the **first year civil engineering students** of 1999 and 2000 who contributed to insights regarding the thinking style preferences of first year science and engineering students at the University of Pretoria.

Dr Ina du Plessis for encouragement, support and informative sessions during 2000-2002.

My former colleagues in the Faculty of Natural Sciences, **Mr Alan Carr**, **Dr Willem Greybe**, **Ms Deidre Breytenbach** and **Professor Johan van Staden** and the more than 1200 **mathematics students** whose contributions during 1993-1999 in the Gold Fields Computer Centre for Education led to the development of the software *Master Grapher for Windows* and the instructional model for mathematics practicals. These paved the way for the present study.

Ms Elana Mauer of the Department of Statistics, University of Pretoria, for processing of the data.

Ms Rina Owen and **Mr Jackie Grimbeeck** of the Department of Statistics, University of Pretoria, for help with the statistical analysis and interpretation of the data.

Ms Marie Swanepoel of the Academic Information Services, University of Pretoria, and **Mr James Kitching** of the UNISA library, for help on literature surveys and their prompt and expert service.

Ms Kim Zimmerman of Telematic Education, University of Pretoria for help with converting my designs and requests into graphics.

Ms Sharon Manley and **Ms Lee Johnson** for proofreading and final editing of this manuscript.

Friends and family for supportive enquiries as to the progress of the study, in particular a sincere thank you to:

Drs Mechiel and **Leona Venter** for spiritual support and prayers when I needed them most.

Ms Stefnie Scott, **Dr Enla Minnaar** and **Dr Annamari Grundlingh** for substantial and continuing support throughout the study.

Lodewyk for encouragement out of Cambridge, Massachusetts, as to the completion of the thesis.

Frederik for tolerating an academically oriented household.

Elet for enchanting laughs and joy amidst serious writing; generous support concerning household matters and constant reminders to physically 'sit up straight' during sustained hours at the computer.

Jasper for understanding the scope and intensity of academic commitment.

Love the Lord your God with all your heart and with all your soul and with all your mind and with all your strength. ... Love your neighbour as yourself. There is no commandment greater than these.

Mark 12:30-31

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List of Abbreviations

4YSP	Four Year Study Programme
5YSP	Five Year Study Programme
HBD	Herrmann Brain Dominance
HBDI	Herrmann Brain Dominance Instrument
ILS	Felder Solomon Index of Learning Styles
IP	Information processing
JPO110	First semester module code of the Professional Orientation Support Course
LAS	Lumsdaine and Lumsdaine Learning Activity Survey
MC	Mathematics confidence
POSC	Professional Orientation Support Course
PSB	Problem solving behaviour
SA	Study attitude
SE	Study environment
SH	Study habits
SOM	Study Orientation Questionnaire in Mathematics
SOMT	Study Orientation Questionnaire in Mathematics Tertiary
UP	University of Pretoria
WTW114	Module code of the standard first semester calculus module in 2000 and 2001
WTW158	Module code of the standard first semester calculus module in 2002

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Glossary of Terms

2000 POSC group	Students enrolled for the Professional Orientation Support Course during 2000
2001 POSC group	Students enrolled for the Professional Orientation Support Course during 2001
2002 POSC group	Students enrolled for the Professional Orientation Support Course during 2002
Five Year Study Programme	Extended study programme in engineering at the University of Pretoria.
Four Year Study Programme	Regular study programme in engineering at the University of Pretoria.
learning style	Refers to an individual's preferred way of learning that has developed from genetics (nature) and fostered through education (nurture). It is also closely related to an individual's thinking style.
mainstream module/course	Refers to a module/course presented to all students enrolled for the specific module/course; is used alternately with the term standard module/course.
M-score	Used at the University to Pretoria for admission requirements and is based on performance in the final school examination.
potential	Potential regarding a specific aspect is genetically given; is dependant on biological development as well as education; development of potential leads to competency in the specific aspect.
Professional Orientation Support Course	Course presented as part of the curriculum in the Five Year Study Programme, School of Engineering, University of Pretoria.
SOM	Study Orientation Questionnaire in Mathematics developed by Maree (1996) and statistically processed by Maree, Claassen and Prinsloo (1997). The SOM was used as a pre-intervention instrument during the 2000 and 2001 research.

SOMT	Study Orientation Questionnaire in Mathematics Tertiary. This term is used as a general term when referring to the study orientation questionnaire in a tertiary setting. This term is also used for the final version of the questionnaire presented in this thesis.
SOMT-1	Study Orientation Questionnaire in Mathematics Tertiary Version 1 which is the first edited version of the original SOM to portray a tertiary focus. Used in the 2001 research reported in this thesis.
SOMT-2	Study Orientation Questionnaire in Mathematics Tertiary Version 2 which is an edited version of the SOMT-1. Used in the 2002 research reported in this thesis
SOMT-3	Study Orientation Questionnaire in Mathematics Tertiary Version 3 which is an edited version of the SOMT-2 and represents the final edit as per this study. Used in the 2002 research reported in this thesis
standard module/course	Refers to a module/course presented to all students enrolled for the specific module/course; is used alternately with the term mainstream module/course
study orientation	Includes approaches to learning, motives for learning, styles of learning, elements of study methods and attitudes.
thinking style	Refers to an individual's preferred way of thinking that has developed from genetics (nature) and fostered through education (nurture). It is also closely related to an individual's learning style.
whole brain learning **whole brain learning facilitation**	Refers to the inclusion of different modes of learning (implying different thinking and learning preferences). On a physiological level different modes of learning are associated with cognitive activities in different parts of the brain.

Key terms	Sleutelterme
Action research	Aksienavorsing
Composite approach	Saamgestelde benadering
Graphical exploration in mathematics	Grafiese eksplorasie in wiskunde
Learning styles for mathematics	Leerstyle vir wiskunde
Learning facilitation strategy for mathematics	Leerfasiliteringstrategie vir wiskunde
Multifaceted approach	Veelfasettige benadering
Study orientation in mathematics	Studie-oriëntering in wiskunde
Tertiary mathematics education	Tersiêre wiskunde-onderrig
Thinking styles for mathematics	Denkstyle vir wiskunde
Whole brain learning	Heelbreinleer

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Summary

A learning facilitation strategy for mathematics in a support course for first year engineering students at the University of Pretoria

by

Tobias M Steyn

Supervisor: **Professor JG Maree**

Department: **Teaching and Training Studies**

Degree: **Philosophiae Doctor**

This thesis presents a conceptual framework for a learning facilitation strategy which is aimed at developing the mathematics potential of learners on an academic support programme. The study involved first year engineering students on an extended Five Year Study Programme in the School of Engineering at the University of Pretoria who were enrolled for the Professional Orientation Support Course during 2000-2002.

The learning facilitation strategy proposed and defined in this thesis originated in research conducted from 1993 to 1999 in the Faculty of Natural Sciences at the University of Pretoria. Insights gained through this research indicated that a combination of graphical exploration and analysis of graphical images could enhance students' understanding of fundamental mathematical concepts encountered in a first course in calculus. In the current study factors that appeared to contribute to this enhanced understanding were researched.

The strategy for learning facilitation of mathematics encompasses a multifaceted and composite approach. This includes a whole brain approach towards structuring the learning facilitation activities to accommodate and develop different modes of thinking and learning; to create in learners an awareness of the existence of thinking style and learning style preferences as well as an awareness of study orientation in mathematics, and to give learners insight into their own thinking and learning preferences and study orientation. Development of mathematics potential of learners is an important focus of this approach. Therefore, in addition to the above mentioned activities the mathematics potential of learners is also developed by facilitating their acquisition of appropriate learning and thinking skills and by structuring the learning environment to promote effective learning.

The proposed learning facilitation strategy for mathematics was implemented, monitored and assessed by way of action research studies during 2000-2002.

Results of the study indicate that the learners' thinking style and learning style preferences are diverse and represent a range of different preferences. Results also indicate that learners have a latent favourable study orientation towards mathematics. The effects of the proposed strategy's implementation on the learners' study orientation towards mathematics and on their performance in mathematics were investigated. The results indicate a significant improvement in the learners' study orientation towards mathematics. Their performance in the mainstream first semester calculus course confirmed their enhanced ability in mathematics. These results point towards efficacy that can be attributed to the implementation of the proposed learning facilitation strategy.

Results of this study also indicate that active involvement by both learners and facilitator in a multifaceted and composite approach to learning facilitation provides a suitable principle basis for structuring an academic support course. It provides for the development of learners and for the refining of course content to address the needs of the learners. It is envisaged that freshman students, other than those on an academic support programme, may benefit from a learning facilitation strategy for mathematics structured according to this multifaceted and composite approach.

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Opsomming

'n Fasiliteringstrategie vir die leer van wiskunde in 'n ondersteuningskursus vir eerstejaarstudente in ingenieurswese aan die Universiteit van Pretoria

deur

Tobias M Steyn

Promotor: **Professor JG Maree**

Departement: **Onderwys- en Opleidingskunde**

Graad: **Philosophiae Doctor**

In hierdie proefskrif word 'n konseptuele raamwerk vir 'n leerfasiliteringstrategie voorgestel wat gerig is daarop om die wiskundepotensiaal van leerders in 'n akademiese ondersteuningsprogram te ontwikkel. Eerstejaar ingenieurstudente op die Vyfjaar Studieprogram in die Skool vir Ingenieurswese aan die Universiteit van Pretoria wat gedurende 2000-2002 vir die Professionele Oriënteringkursus ingeskryf was, het deelgeneem aan die navorsingaktiwiteite wat gerapporteer word.

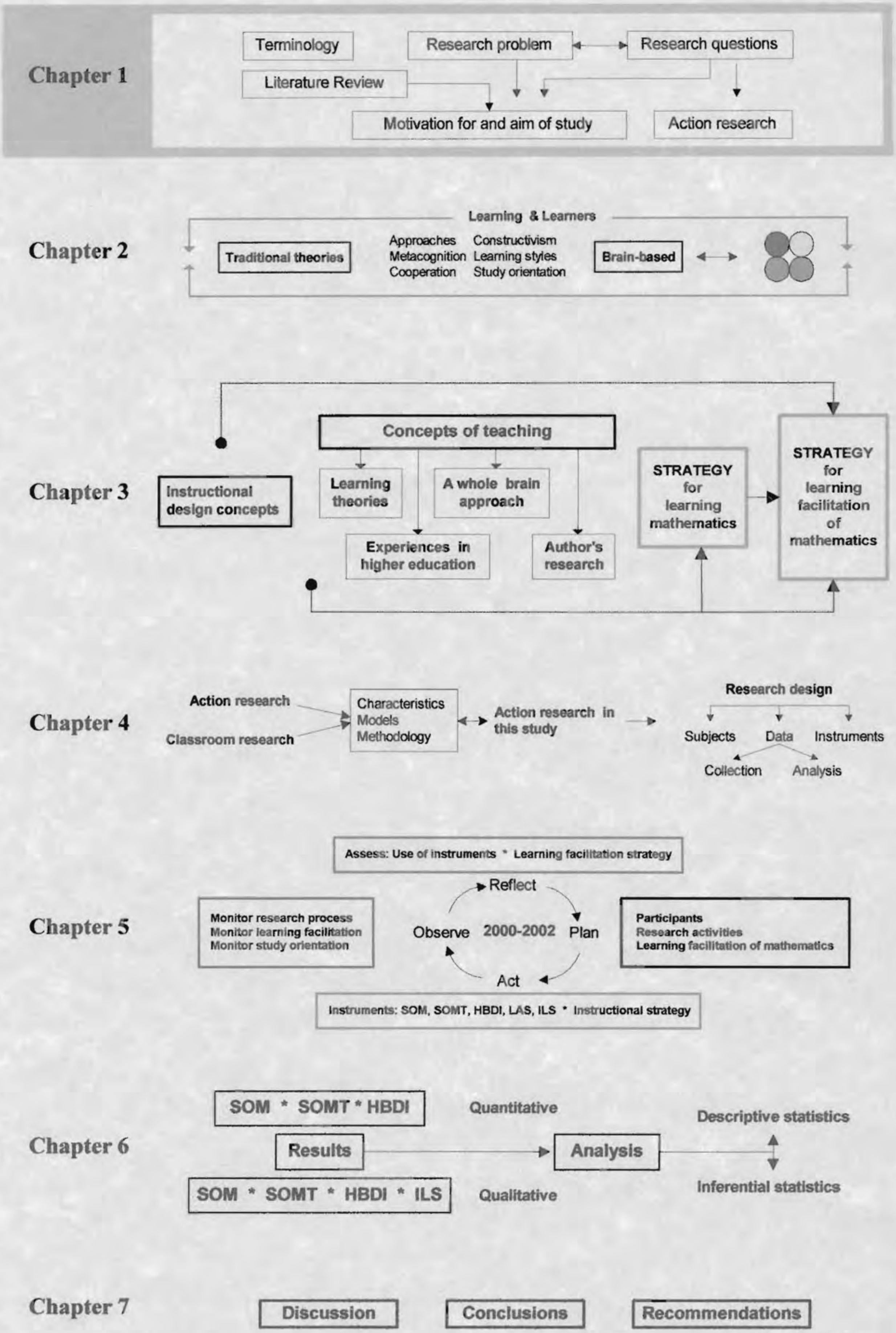
Die leerfasiliteringstrategie wat in hierdie proefskrif voorgestel en gedefinieer word, het sy oorsprong gehad in navorsing vanaf 1993 tot 1999 in die Fakulteit Natuurwetenskappe aan die Universiteit van Pretoria. Insigte verkry deur hierdie navorsing het daarop gedui dat 'n kombinasie van grafiese eksplorasie en die analisering van grafiese beelde leerders se begrip bevorder van fundamentele wiskundebegrippe wat nodig is in 'n eerste kursus in calculus. In die studie van hierdie proefskrif word faktore ondersoek wat waarskynlik tot hierdie verbeterde begrip kan bydra.

Die strategie vir leerfasilitering van wiskunde behels 'n veelfasettige en saamgestelde benadering. Dit sluit in 'n heelbrein benadering tot die strukturering van leerfasiliteringaktiwiteite om verskillende denk- en leerstyle te akkommodeer en te ontwikkel; om leerders bewus te maak van hulle eie denk- en leerstylvoorkeure en om hulle bewus te maak van hulle studie-oriëntering in wiskunde, en ook om leerders insig te gee in hulle eie voorkeure en studie-oriëntering. Die ontwikkeling van die wiskundepotensiaal van leerders is 'n belangrike fokus in hierdie benadering. Bykomend tot die genoemde aktiwiteite, word die wiskundepotensiaal van leerders ook ontwikkel deur fasilitering van hulle verwerwing van toepaslike leer- en denkvaardighede en deurdat die leeromgewing gestruktureer word om effektiewe leer te bevorder.

Die voorgestelde leerfasiliteringstrategie vir wiskunde is by wyse van aksienavorsing gedurende 2000-2002 geïmplementeer, gemonitor en geassesseer.

Resultate van die studie dui aan dat die leerders se denk- en leerstylvoorkeure uiteenlopend is en 'n verskeidenheid van verskillende voorkeure insluit. Resultate dui ook daarop dat leerders 'n latente gunstige studie-oriëntering teenoor wiskunde het. Die moontlike effek van die voorgestelde leerfasiliteringstrategie op leerders se studie-oriëntering in wiskunde en op hulle prestasie in wiskunde is ook bepaal. Die resultate dui op 'n betekenisvolle verbetering in die leerders se studieoriëntering in wiskunde. Hulle prestasie in die hoofstroom eerstesemester kursus in calculus het hulle verbeterde vermoë in wiskunde bevestig. Hierdie resultate dui op gunstige uitkomste wat toegeskryf kan word aan die implementering van die voorgestelde leerfasiliteringstrategie.

Resultate van die studie dui ook daarop dat die aktiewe betrokkenheid van beide leerders en fasiliteerder in 'n veelfasettige en saamgestelde benadering tot leerfasilitering, 'n sinvolle beginselbasis bied vir die strukturering van 'n akademiese ondersteuningskursus. Dit bevorder die ontwikkeling van leerders en rig verfyning van kursusinhoud om in die behoeftes van die leerders te voorsien. Dit word voorsien dat nuweling eerstejaarstudente, benewens dié in 'n akademiese ondersteuningsprogram, sal kan baat by 'n leerfasiliteringstrategie vir wiskunde volgens hierdie veelfasettige en saamgestelde benadering.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Chapter 1

Orientation

1. Introduction

The state of mathematics learning and teaching in South Africa cannot be regarded as adequate if the results obtained from the Third International Mathematics and Science Study (TIMSS) in 1995 are considered. In this study South African learners were rated last amongst the 42 countries that participated in the study (Gray, 1997:v). In 1998 a further study, the TIMSS-Repeat (TIMSS-R) was done. South African pupils again performed poorly when compared to other countries. The score of 284 points out of a possible 800 for South Africa is well below the international average of 487 for the 38 countries that participated in the TIMSS-R (Howie, 2001:2). Results like these not only portray a bleak picture of the mathematical competence level of South African students entering tertiary study but also compel educators of mathematics to rethink the learning facilitation of mathematics at all levels including tertiary education.

Statistics made available by the Bureau for Institutional Research and Planning (2001) at the University of Pretoria (UP) on the pass rate for mathematics in the South African matriculation exams during 1997-1999 indicate that less than 40% of students who write mathematics on higher grade pass. In 2000 fewer students wrote mathematics on higher grade and 50.2% passed. The trend for 1997-2000 seems to be that about 19 000 students per year passed mathematics on higher grade.

Furthermore, statistics reflecting on the pass rates of engineering students at the UP in the early 1990s indicate that only one out of every four freshman enrolments completed the degree programme in the scheduled four years and one out of every three students left the university without obtaining any qualification.

These figures are not encouraging for a developing country like South Africa in the early 2000s where increased scientific and technological expertise is needed. The success of prospective students, who have the potential to enter tertiary study to pursue careers in the natural sciences, may be seriously at risk if they come from an educational background deficient in high-quality mathematics instruction. These students can benefit from support, other than remedial measures, in the learning facilitation of mathematics. The focus in this study is thus on the learning facilitation of mathematics of first year engineering students at the UP who have passed the admission test assessing their ability to succeed at engineering studies but who are academically still at risk because of deficiencies in their educational background.

The regular university engineering programme in South Africa requires four years of full time study as regulated by the Engineering Council of South Africa (ECSA). In 1994 the School of Engineering at the UP instituted an extended study programme, the Five Year Study Programme (5YSP). This programme increases the duration of the regular engineering study from four years to five years and is structured in such a way that the academic courses of the first two years of the regular four year study programme are spread over the first three years of the 5YSP.

The purpose of the 5YSP is to create an opportunity for students who have the potential to become engineers but who do not meet the entrance requirements for the regular four year programme and/or are academically at risk of not completing their studies through the regular four year study programme. All the students on the 5YSP are given extensive academic support in their first year engineering courses through tutoring given by senior (engineering) students. Due to varying levels of educational competency in schools and a lack of exposure and access to technology that some students on the 5YSP experienced in their high school years, an additional two-semester credit-bearing course, the Professional Orientation Support Course (POSC), is offered during the first year of study. The course comprises of a conceptual mathematics component, the development of personal skills, communication skills and skills in information technology. The course content provides a broad academic background to mainly black students who are presently an underrepresented minority in engineering study in South Africa.

This thesis reports on the learning facilitation strategy for mathematics that was followed in the POSC during 2000, 2001 and 2002.

1.1 Motivation for the study

In November 1999 the author joined the 5YSP in the School of Engineering as lecturer responsible for the POSC. This posed the opportunity to implement the experiences and results gained during the author's involvement with students in the Faculty of Natural Sciences since 1991 and action research conducted during 1993-1999 in the Faculty of Natural Sciences with students on an extended study programme in the Faculty of Natural Sciences.

Experiences during the 1993-1999 studies indicated that the use of a computer graphing tool can enhance mathematical conceptualisation of two dimensional functions (Steyn, 1998). The 1998 and 1999 studies also added, among other things, the following possible dimensions to the facilitation of mathematics at introductory calculus level. Firstly the 1998 study showed that first year tertiary students on a support course can benefit from training in study skills and mind mapping as one such skill could successfully be used as a study tool in mathematics (Steyn & De Boer, 1998). Secondly the 1999 study showed that a group of tertiary learners in mathematics displays an array of thinking and learning style preferences and it was envisaged that instructional approaches in mathematics should take cognisance of these when planning learning facilitation (De Boer & Steyn, 1999).

Although some data pertaining to students' experience of mathematics at school and in the calculus course of the extended programme was qualitatively analysed during the 1996-1998 studies (Steyn & Maree, 2002), no quantitative analysis was done. Moreover the mentioned research did not address the students' study orientation in mathematics.

The research during 2000-2002 was undertaken to implement the experiences, gained with first year science students on a support course, in the learning facilitation of mathematics for first year engineering students on the POSC. In this way a strategy for the learning facilitation of mathematics for first year engineering students on a support course could be developed. In addition, a profile of these students' study orientation in mathematics and their thinking and learning preferences could be compiled.

1.2 Explanation of the title and definition of the terminology

An explanation of the title, namely, *A learning facilitation strategy for mathematics in a support course for first year engineering students at the University of Pretoria*, will explain the meaning of the terminology involved as it is applied within the context of this study. Other terms used in this study will be defined as they occur.

1.2.1 Learning

> *No one definition of learning is universally accepted by educational theorists, researchers, and practitioners. Definitions of learning are numerous and varied*...(Schunk, 1996:2).

As a universally accepted definition for human learning does not exist, the following views on learning give an indication of the essential aspects that describe learning as it is viewed in this study.

The concept "learning" is defined by Thompson (1995:774) as *to gain knowledge of or skill in by study, experience, or being taught and also to acquire or develop a particular ability*. Woolf (1977:654) defines "learning" as *knowledge or skill acquired by instruction or study*. Knowles (1990:147) points out that *to learn is to change*.

Gagné (1977:4) views learning as follows:

> *Learning is a change in human disposition or capability, which persists over a period of time, and which is not simply ascribable to processes of growth. .... The change must have more than momentary permanence; it must be capable of being retained over some period of time ... it must be distinguishable from the kind of change that is attributive to growth.*

Kolb (in Zuber-Skerritt, 1992a:105) defines learning as

> *The process whereby knowledge is created through the transformation of experience.*

Shuell (in Schunk, 1996:2) defines learning as

> *Learning is an enduring change in behavior, or in the capacity to behave in a given fashion, which results from practice or other forms of experience.*

Herrmann (1998) summarises his views on learning as follows:

- Learning is a mental process.
- Learning occurs when intended information can be recalled from memory for independent applications.
- Learning involves the establishment of neural circuits, which provide pathways for mental processing. These neural circuits developed through learning are interconnected to the specialised long-term memory sites storing the learned information.

In 1999 the Committee on the Developments in the Science of Learning of the National Research Council in the United States of America (USA) published a contemporary account of principles of learning (Bransford, Brown & Cocking, 1999). Instead of restricting learning to a single definition of a *basic, adaptive function of humans* (Bransford *et al.*, 1999:xi), it is noted that

> *A scientific understanding of learning includes understanding about learning processes, learning environments, teaching, sociocultural processes, and many other factors that contribute to learning.*
> (Bransford *et al.*, 1999:221).

The latter description of learning gives an indication of the extent of the context of human learning and this view is endorsed by the author of this thesis. In Chapter 2 an epistemological overview of learning and learners relevant to the focus of this study is given and in Chapter 3 the facilitation of learning is discussed.

1.2.2 Facilitation

Crowther (1995:414) and Woolf (1977:410) define the term "facilitate" as *to make an action or a process easier*. Gove (1961:812) gives the same definition and adds that the term also implies the acts of *assisting* or to *aiding*. The relevance of the concept "facilitation" for education is endorsed by comparing the meaning of "facilitate" to that of "instruct". Gove (1961:1172) defines the term "instruct" as *to give skill or special knowledge or information*. Woolf (1977:599) defines "instruct" as *to direct authoritatively and on the basis of informed awareness* and Thompson (1995:706) also defines it as *to direct or to command*. These definitions highlight the difference between facilitation and instruction as approaches to teaching.

1.2.3 Learning facilitation

In this study the combined term "learning facilitation" is defined as *assistance in the process of knowledge creation and behavioural change that occur over a period of time.*

1.2.4 Strategy

Crowther (1995:1179) defines "strategy" as *a plan designed for a particular purpose* and Thompson (1995:1377) defines it as *a plan of action.* Woolf (1977:1150) defines it as a *careful plan or method.*

For the purpose of this study "strategy" is defined as a *careful plan of action designed for a particular purpose.*

1.2.5 Mathematics

Howsen (in Maree, 1997:14) distinguishes between the following perspectives in defining the term "mathematics":

> *[Mathematics is] an abstract structure with seemingly miraculous inter-relationships, [or] a collection of interesting and potentially useful methods and results, [or] an activity that relies upon the participant's ability to conjecture, prove, generalize, model, apply, define.*

Steen (1988a) regards the science of patterns as an integral part of the concept "mathematics" and defines it as follows:

> *Mathematics is often defined as the science of space and number, as the discipline rooted in geometry and arithmetic. Although the diversity of modern mathematics has always exceeded this definition, it was not until the recent resonance of computers and mathematics that a more apt definition became fully evident. Mathematics is the science of patterns ... it begins with the search for pattern in data ... Generalization leads to abstraction, to patterns in the mind. Theories emerge as patterns of patterns, and significance is measured by the degree to which patterns in one area link to patterns in other areas. Subtle patterns with the great explanatory power become the deepest results, forming the foundation for entire subdisciplines.* (Steen 1988a:616).

The term "pattern" is defined by Thompson (1995:1002) as *a regular or logical form, order or arrangement of parts.*

Gove (1961:1393) defines "mathematics" as a *science that deals with the relationship and symbolism of numbers and magnitudes and that includes quantitative operations and the solutions of quantitative problems.*

Lakoff (in English, 1997:3) defines "mathematics" as the *study of the structures that we use to understand and reason about our experience - structures that are inherent in our preconceptual bodily experience and that we make abstract via metaphor.*

Thompson (1995:840) defines the concept "mathematics" as the *abstract science of number, quantity and space studied in its own right.*

Dubinsky (1994:228) views mathematical knowledge and its acquisition as follows:

> *A person's mathematical knowledge is her or his tendency to respond to certain kinds of perceived problem situations by constructing, reconstructing, and organizing mental processes and objects to use in dealing with the situations.*

According to Dubinsky (1994:228) the "tendency to respond" refers to the fact that a person may respond *in different ways at different times and in different* places and that the existence of a certain kind of knowledge does not imply that a person will exhibit that knowledge all the time. The "perceived problem situation" suggests that if a question is asked, *there is no guarantee that this perception of the question is the same as that of the person who posed it* (Dubinsky, 1994:228). The terms "constructing" and "reconstructing" indicate that a person's knowledge is not static.

Maree (1997:14) states that an etymological and semantical analysis of the word "mathematics" brings to light that the subject cannot be mastered without (almost every day) effort, learning, experience, practice, understanding, the will to learn, responsibility, self-discipline and perseverance.

For the purpose of this thesis mathematics is seen as a combination of the viewpoints above, namely, that **mathematics is a science of structures (patterns) and deals with relationships and symbolism, and that a person's interaction with mathematics is dynamic**.

1.2.6 Support course

Crowther (1995:1200) defines the term "support" as *help or encouragement given to somebody especially in a difficult situation*. Thompson (1995:1400) gives different meanings of the term "support", all of which can be applicable to this study, namely, *keep from failing; encourage; give help; assist.*

1.2.7 First year engineering students

The phrase "first year engineering student" refers to any freshman who is enrolled for the first academic year of engineering study.

1.2.8 Additional terminology

The definitions of the following terms, used throughout this thesis, are briefly stated. The terms "higher education" and "tertiary education" are used interchangeably. In the South African context, these terms refer to formal education at universities, post-school academic institutions and technical colleges. The phrase "tertiary learner" refers to any learner at an institution for higher education.

1.3 The main research problem

The research problem addressed in the current study focuses on the development of the mathematics potential of a learner with specific reference to the relationship between a learner's study orientation towards mathematics, a learner's academic performance in the first semester course in calculus and a learner's awareness of cognitive processing modes and thinking style preferences. This relationship presumably constitutes a profile of a learner's study orientation and thinking preferences towards mathematics. In the current study this relationship is viewed against the background of the learning facilitation strategy proposed and followed in the POSC.

1.4 The main research questions

With regard to the students enrolled for the POSC, the aspects that constitute the relationship between study orientation in mathematics, performance in mathematics, thinking style preferences and a whole brain learning facilitation strategy will be addressed in this thesis in an attempt to answer the following questions.

1. What is the study orientation towards mathematics of the students enrolled for the POSC?

2. Does the learning facilitation strategy followed in the POSC have an effect on the students' study orientation in mathematics? In particular, is there an improvement in the students' study orientation towards mathematics?

3. Does the learning facilitation strategy for mathematics followed in the POSC have an effect on students' academic performance in the standard first semester calculus course?

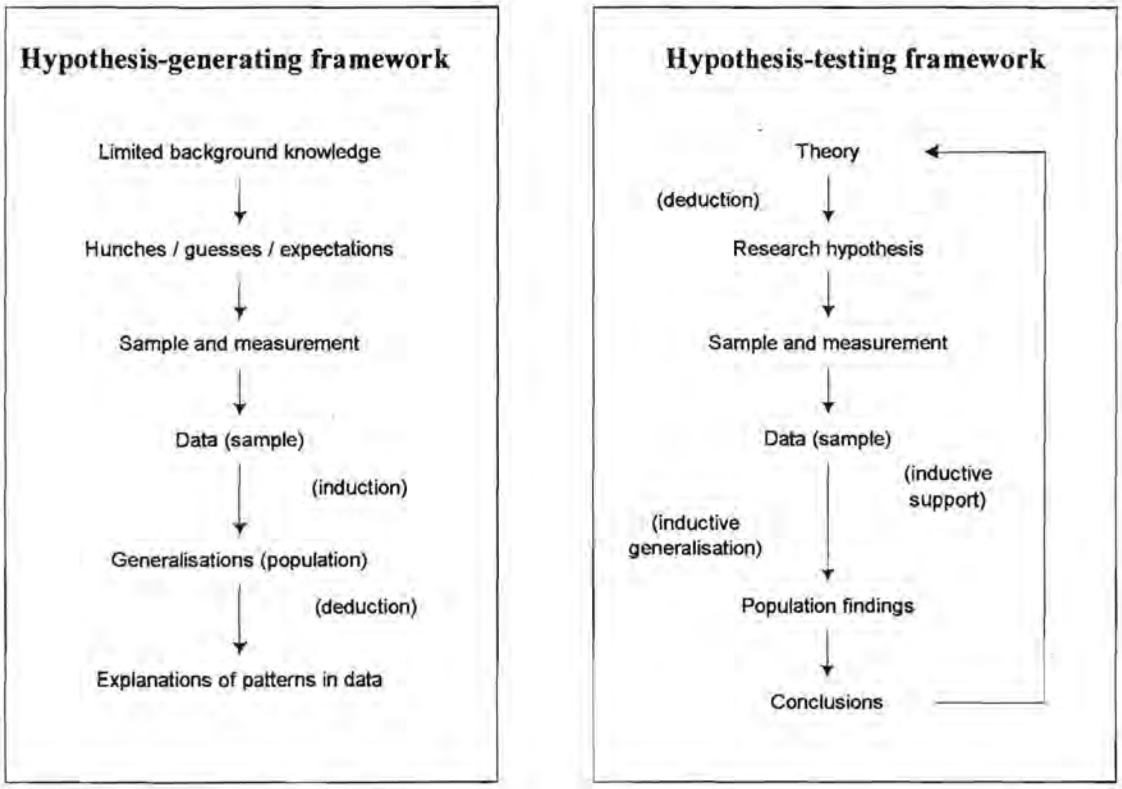
4. What are the thinking style preferences of first year engineering students enrolled for the POSC?

1.5 Research hypotheses

The research undertaken in the present study is twofold in nature. On the one hand the research is of an exploratory nature aimed at developing new hypotheses and on the other it is of a validation nature aimed at testing these hypotheses. The difference between a hypothesis-generating study and a hypothesis-testing study is illustrated in Figure 1-1. Mouton (1996) remarks that in a hypothesis-testing framework a research hypothesis is derived from an existing theory. A sample is identified and the hypothesis is tested. In a hypothesis-generating framework data is collected from a sample of cases and findings are generalized to the target population and patterns in the data are explained. Light, Singer and Willett (1990) also point out that data should be used not only to test theory but also to develop theory.

In the present study the research questions can be regarded as of a hypotheses-generating nature. These questions are aimed at determining the study orientation towards mathematics of the students enrolled for the POSC, their thinking style preferences and the effect that learning facilitation strategy for mathematics followed in the POSC have on academic performance in the first semester course in calculus. Once generated, these hypotheses are investigated and evaluated with the participants[1] in the study.

Figure 1-1 Hypothesis-generating and hypothesis-testing frameworks

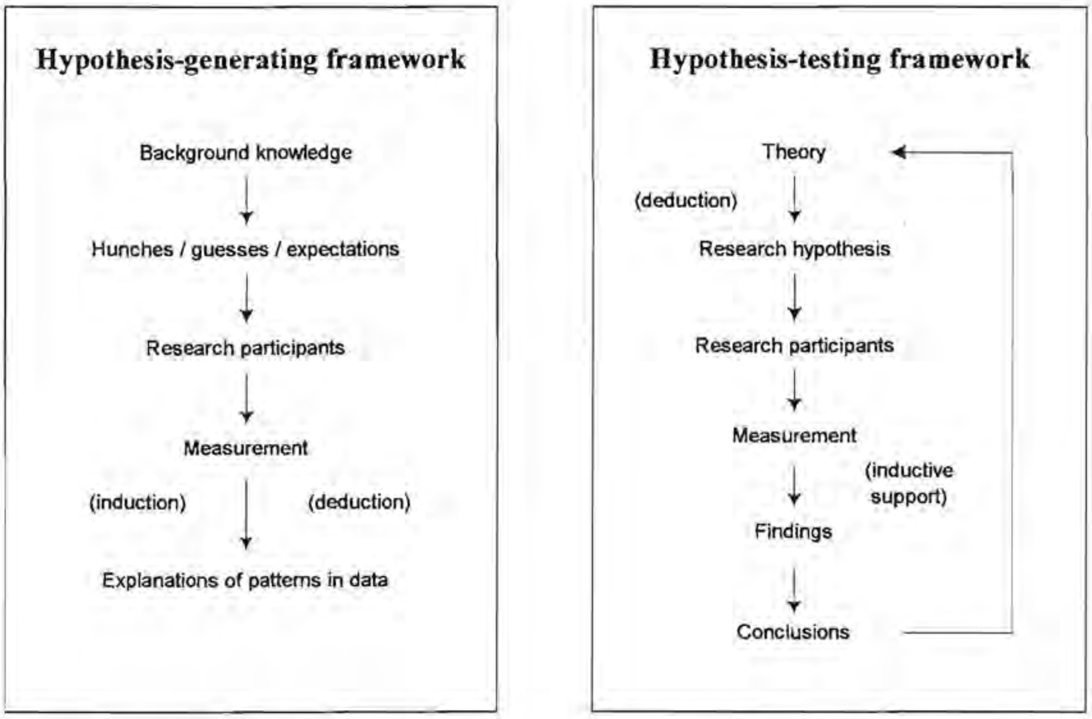


Adapted from Mouton (1996:82)

Mouton's framework as in Figure 1-1 above represents a view regarding social research in general. By the very nature of the action research approach followed in the present study where the focus is on particular participants in a specific situation, the aim with the research is not to generalise findings to a population. However, it may be possible to explain patterns in the data that could be of significance to a broader population. The framework in Figure 1-2 is a more probable representation of the hypothesis-generating and hypothesis-testing frameworks in the present study.

[1] The traditional notion of 'subjects' in a study is substituted with 'participants' as the latter term conveys one of the core aspects of an action research approach.

Figure 1-2 Hypothesis-generating and hypothesis-testing frameworks in the present study



Adaptation of Figure 1-1 for the present study by the author of this thesis

Concerning the **hypothesis-generating** aspect in the present study and according to the framework in Figure 1-2 the action research activities of the author during 1993-1999 form the 'background knowledge' from which 'hunches'/'guesses'/'expectations' are deduced. In the study reported in this thesis these 'hunches'/'guesses'/'expectations' are investigated with 'participants', relevant aspects are 'measured' and 'patterns in the data are explained'.

Concerning the **hypothesis-testing** aspect in the present study and according to the framework in Figure 1-2 the results of the action research activities during 2000 and 2001 generated hypotheses that could be regarded as 'theory'. Following from this 'theory', 'research hypotheses' could be formulated and again investigated with 'research participants'. The hypotheses could then be tested, the 'findings' reported and 'conclusions' drawn.

1.6 Research design overview

Mouton (1996:175) states that the objective of research design is to *plan, structure and execute the relevant project in such a way that the validity of the findings is maximized.* For the research design of this thesis the following aspects are specified, namely the

- aim of the research
- research approach
- participants in the study
- data collection methods and instruments
- methods of data analysis
- ways in which the reliability, validity and objectivity of collecting the data have been controlled.

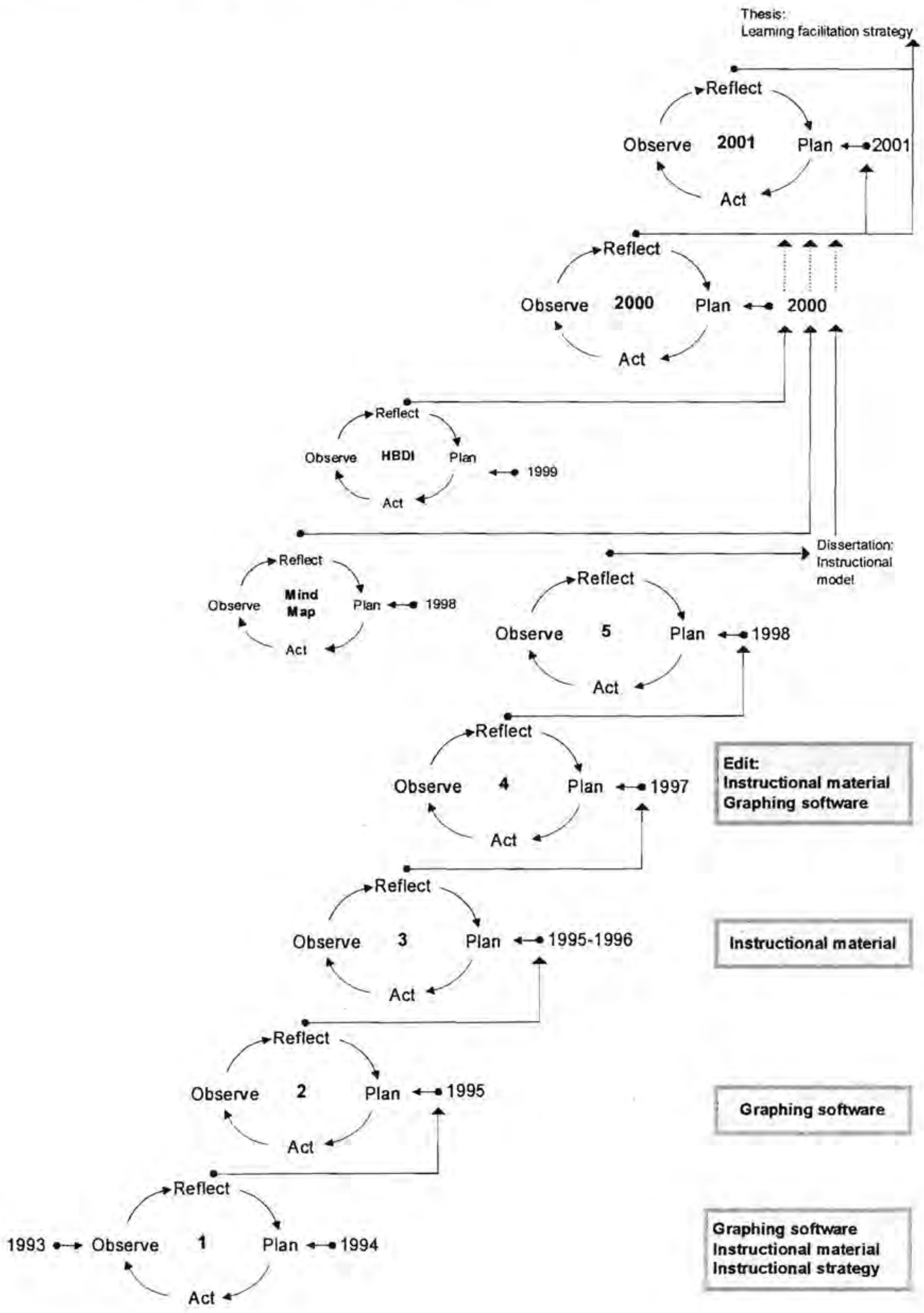
1.6.1 Aim of the research

The primary objective of the research is to propose a strategy for the learning facilitation of mathematics in a support course for first year engineering students, to define the aspects that constitute such a strategy and to determine the possible effects of the strategy on learners' study orientation towards mathematics and on their performance in mathematics.

1.6.2 Research approach

The main research approach adopted for the study described in this thesis is action research. Cohen and Manion (1994:186, 192) define action research as a *small-scale intervention in the functioning of the real world and a close examination of the effects of such intervention.* The research approach in the present study also displays the core principles of *Classroom Research* as postulated by Angelo and Cross (1993) and Cross and Steadman (1996). In the opinion of the author of this thesis the principles underpinning an action research approach in education are similar to those proposed in the classroom research approach. In Chapter 4 the characteristics of these two approaches are given and the research model and methodologies of the present study are discussed. Figure 1-3 gives an outline of the action research activities of the present study as well as those that preceded and contributed to the current research.

Figure 1-3 Action research activities 1993-2001



Compiled by the author of this thesis

1.6.3 Participants in the study

In each of the two action research cycles during 2000 and 2001 that is reported in this study there are different groups of participants and categories of data that contribute to the findings of the study. The action research cycle during 2002 only involved one group of participants.

The main participatory groups consist of the first year students enrolled for the POSC during 2000-2002.

With regard to data pertaining to thinking style preferences, a group of first year civil engineering students also participated in the study during 2000. The results of a previous study (De Boer & Steyn, 1999) regarding the thinking style preferences of science students on a support course are also used to compare the thinking style preferences of first year engineering students and first year science students.

In addition to data regarding the mathematics performance of the POSC groups, the data of two other comparative[2] groups are also considered. The comparative groups comprise two groups of freshman engineering students. The one group consists of freshman students registered for the 5YSP but who are not enrolled for the POSC. The other comparative group includes freshman students registered for the regular four year study programme (4YSP). In Table 1-1 a summary of the data categories and participating groups are given.

Table 1-1 Data categories and participants in the study

	Contributing participants						
Data	**POSC 2000**	**POSC 2001**	**POSC 2002**	**First Year Civ Eng**	**Science Students**	**4YSP**	**Other 5YSP**
Thinking style preferences	✓			✓	✓		
Study orientation	✓	✓	✓				
Mathematics performance	✓	✓	✓			✓	✓

Compiled by the author of this thesis

[2] The traditional notion of 'control' group is substituted with 'comparative' group to indicate data that is compared to that of the participatory group.

1.6.4 Data collection and analysis

The collection of data pertaining to the participatory group formed part of the formal activities of the POSC. The data concerning the mathematics grades was obtained from the official records of the university.

Qualitative and quantitative methods and instruments were used with the participatory groups so that the effects of the learning facilitation strategy of the support course could be observed and monitored. The qualitative means by which the data was collected included questionnaires, observations and interviews. The quantitative means included questionnaires and official student records.

1.6.5 Validity of action research

Zuber-Skerrit (2001) argues that validity of research in the social sciences has a different meaning in different paradigms and is relative with regard to a researcher's philosophical assumptions and epistemological framework. She points out that within the social sciences, there are two main competing paradigms, namely the positivist and the phenomenological. The traditional positivist paradigm uses methods that are predominantly quantitative and in the alternative phenomenological paradigm (of which action research is an exponent) the methods are predominantly qualitative although both these methods are used in both approaches.

Furthermore, an investigator's philosophical assumptions and epistemological framework will not only determine the research approach but also the process and methods that are chosen. Zuber-Skerrit points out that the concept "validity" in the traditional (positivist) approach to research *is recognised as assured when knowledge is generalisable and when the study is conducted in controlled conditions, using rigorous methods of data collection, analysis and interpretation* (Zuber-Skerrit, 2001: in press).

On the other hand, Zuber-Skerrit argues that from the phenomenological paradigm (as in action research) the researcher's role is to describe and explain the situation or case as truthfully as possible. She continues to say that the aim is *not to establish generalisable laws for multiple contexts, but to know, understand, improve or change a particular social situation or context for the benefit of the people who are also the participants (not just* *subjects) in the inquiry and who are affected by the results and solutions* (Zuber-Skerrit, 2001: in press).

For Zuber-Skerrit validity in the phenomenological paradigm is more *personal and interpersonal than methodological, and should be based on interactive dialectic logic* rather than on a dichotomy of subjective or objective truth. She concludes that the action researcher is *interested in perspectives, rather than truth per se, and in giving an honest account of how the participants in the project view themselves and their experiences* (Zuber-Skerrit, 2001: in press).

Ebbutt and Elliot (1985:11) mention that an action research study can be

> *... judged to be internally valid if the author demonstrates that the changes indicated by his/her analysis of a problem constitute an improvement. Such an account would therefore need to contain not only an analysis of the problem but an evaluation of the action undertaken. An account can be judged to be externally valid if the insights it contains can be generalised beyond the situation(s) studied. An account can be internally valid but have no external validity, i.e. it can be judged as 'true' but entirely unique.*

In line with Zuber-Skerrit (2001), Feldman (1994) strongly argues that the focus for teacher-research[3] is shifted as the teacher as researcher is not attempting to measure outcomes or prove causality that should lead to generalisations, but to effect a change in the way that results in learners looking at the world in different ways. He continues and points out that this shift in focus alters the question of validity in action research. Specifically, Feldman (1994:97) notes that

> *The validity of teachers' self-developmental action research arises from their discourses with their educational situations that leads to a change in their understanding of those situations. ... The teachers are coming to know the reality in order to transform it.*

Bransford *et al*. (1999:188) point out that *forms of validity that are appropriate to research in the practical domain, as in the case of action research, need to be acknowledged.*

The mentioned views on validity inevitably also touch on the notion of validity in qualitative research. In this regard Maxwell (in Cohen, Manion & Morisson, 2000:106) argues for the *need to replace the positivist notions of validity in qualitative research with*

[3] In this regard teacher-research is viewed as action research in an educational setting.

the notion of authenticity and points out that *understanding* is a more suitable term than *validity*. Maxwell (in Cohen *et al.*, 2000:107) proposes five kinds of validity in qualitative methods that define his views on "understanding", namely:

1. **Descriptive validity** refers to the factual accuracy of what happened in the research.
2. **Interpretive validity** refers to the ability of the research to interpret the meaning that the data has for the participants themselves.
3. **Theoretical validity** is the extent to which the research explains phenomena.
4. **Generalisability** here refers to generalising within specific groups and to specific outsider groups. In this regard internal validity has greater significance than external validity[4].
5. **Evaluative validity** is the application of an evaluative framework and is judgemental of what is being researched.

With regard to the research reported in this thesis, it should be stressed that this study in essence reflects on a specific group of learners in particular circumstances. Furthermore, by the very nature of the developmental trend of the intervention, it cannot be assumed that the possible outcomes (awareness of thinking styles, changes in study orientation and successful grades) can solely be attributed to the specifics of the learning facilitation intervention of the support course. A developmental approach would fall very short of its aim if development was seen as restricted to a specific course strategy and outcomes. Therefore, personal and academic maturation of the learners is also a projected outcome of the learning facilitation strategy reported in this study. These are changes in learners that cannot be measured by questionnaires or tests as the latter only focuses on particular aspects of the learners' situations.

1.7 Research ethics

The matter of ethics is an important consideration in the present study[5]. The researcher accepts the assertion that research contributes to scientific knowledge and that human and technological advances are based on this knowledge. In particular, it is accepted that

[4] Internal and external validity are treated in Chapter 4, section 4.4.
[5] Ethical considerations with regard to research design are adressed in Chapter 4, section 4.3.

educational research should contribute to better the scholarship of teaching and the development of the learner. The researcher agrees with Mouton (2001:243) that

> *Where research involves the acquisition of material and information provided on the basis of mutual trust, it is essential that the rights, interests and sensitivities of those studied must be protected.*

Due to the action research approach followed in this study, the students were viewed as essential participants in the research and not as merely 'experimental subjects'. Furthermore, the action research activities during 2000, 2001 and 2002 that are reported in this study were conducted as an integral part of the instructional approach followed in the POSC. Where the research methodology required the completion of questionnaires, this was treated as an integrated part of the course activities. Furthermore, the completion of the questionnaires was not compulsory and the students were assured that data would be treated anonymously and confidentially. In all, the researcher strongly honours each participant's right not to be harmed in any manner, physically, psychologically or emotionally.

Formal written permission for the research and the use and publication of the research data was obtained from the ethics committees of the School of Engineering and the School of Natural Sciences. Copies of these are given in Appendix A.

1.8 Overview and structure of the thesis

In Chapter 1 a brief background is given of the domain in which the research for this thesis was done. The title is explained, the research approach followed in the study is outlined and the researcher's view on ethical considerations is highlighted.

Chapter 2 gives an epistemological overview of learning. The concept of brain-based learning and whole brain utilisation is viewed as a possible paradigm for elucidating learning in a support course in tertiary mathematics. Aspects of learning including meta-cognition, cooperative learning, constructivism, thinking styles, study orientation in mathematics and dimensions of intelligence are also discussed.

In Chapter 3 a theoretical basis for instructional design is given. Aspects of teaching derived from learning theories as well as from experiences in higher education are discussed. A brain-based model for learning mathematics is proposed incorporating the aspects concerning learning discussed in Chapter 2. This model is taken as point of departure to design the learning facilitation strategy of mathematics for first year engineering students on a support course. It is suggested that teachers in higher education should take cognisance of the fact that instructional principles in higher education are increasingly being deduced from experiences based on concepts related to student learning as well as from research results which indicate that neuroscience and the functioning of the brain can contribute to insights in the facilitation of learning. The strategy for the learning facilitation followed in the Professional Orientation Support Course (POSC) is discussed.

Chapter 4 gives an overview of action research and the research design of this thesis. The validity and applicability of action research for the study are discussed. The data collection methods, procedures and instruments used in the study are discussed as well as the data processing procedures.

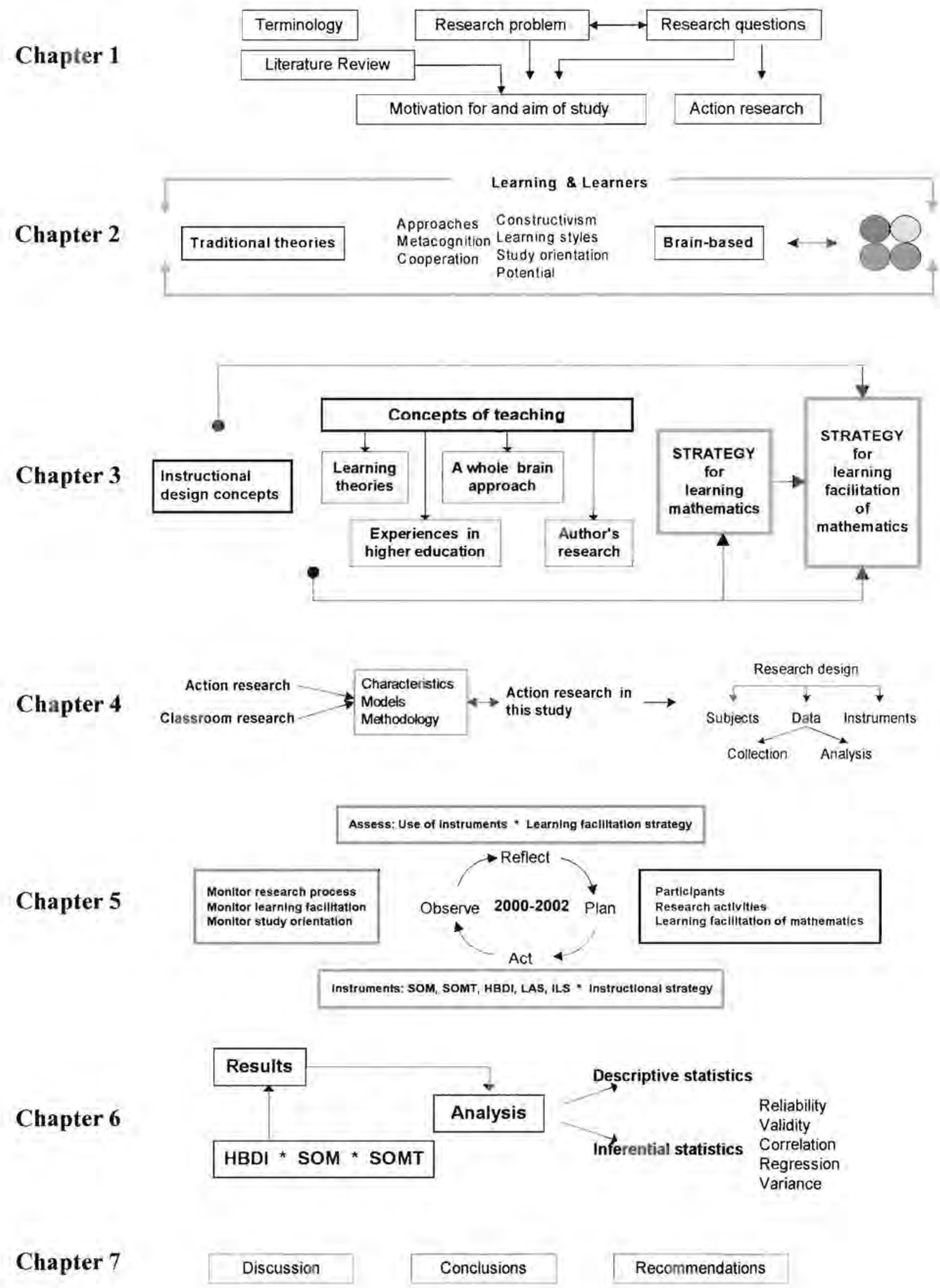
In Chapter 5 a detailed description is given of the action research cycles during 2000, 2001 and 2002 that were done in the School of Engineering at UP and which form the main focus of this thesis.

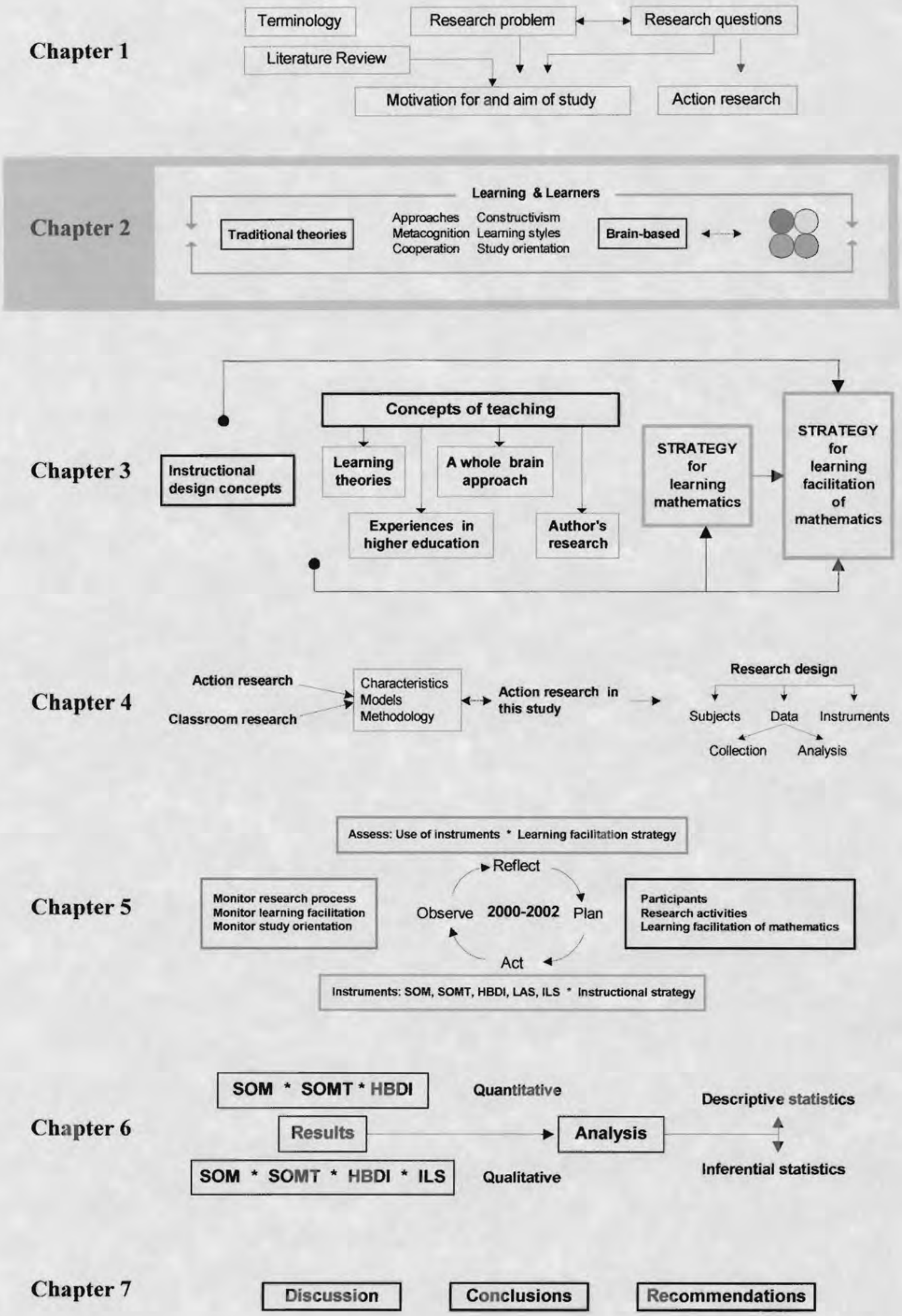
In Chapter 6 a quantitative and qualitative analysis of the research results of the 2000, 2001 and 2002 research studies are given.

In Chapter 7 the focus is on determining whether the aim of the research has been met. The proposed learning facilitation strategy is summarised, the results presented in Chapter 6 are discussed and the effects of the implementation of the learning facilitation strategy on study orientation and mathematics performance are discussed. Insights gained during the study are summarised and possible areas for further research are identified

Figure 1-4 on the following page gives an overview of the thesis and the structure thereof.

Figure 1-4 Overview and structure of the thesis




Chapter 1
Terminology
Research problem
Research questions
Literature Review
Motivation for and aim of study
Action research
Chapter 2
Learning & Learners
Traditional theories
Approaches
Metacognition
Cooperation
Constructivism
Learning styles
Study orientation
Brain-based
Chapter 3
Concepts of teaching
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A whole brain approach
Experiences in higher education
Author's research
STRATEGY for learning mathematics
STRATEGY for learning facilitation of mathematics
Chapter 4
Action research
Classroom research
Characteristics
Models
Methodology
Action research in this study
Research design
Subjects
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Instruments
Collection
Analysis
Chapter 5
Assess: Use of instruments * Learning facilitation strategy
Monitor research process
Monitor learning facilitation
Monitor study orientation
Reflect
Observe
2000-2002
Plan
Act
Participants
Research activities
Learning facilitation of mathematics
Instruments: SOM, SOMT, HBDI, LAS, ILS * Instructional strategy
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Results
Analysis
Descriptive statistics
Inferential statistics
SOM * SOMT * HBDI * ILS
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Discussion
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Recommendations

Perspectives on learning and learners: an epistemological overview

- **2.1 Overview of traditional views on learning and learners relevant to tertiary mathematics education**
  - 2.1.1 Behaviourism: S-R
  - 2.1.2 Neobehaviourist theory of Gagné
  - 2.1.3 Gestalt learning theory
  - 2.1.4 Cognitive learning theories
    - Constructivism - Piaget's model
    - Kelly's personal construct theory
    - Leontiev's cognitive theory of action
    - Information and knowledge
  - 2.1.5 Kolb's experiential learning theory
  - 2.1.6 Adult learning
- **2.2 Further aspects of learning**
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- **2.3 Brain-based learning**
  - 2.3.1 Brain basics
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- **2.4 Recent views on learning and learners**
- **2.5 Learning styles**
  - 2.5.1 Herrmann model
  - 2.5.2 Lumsdaine & Lumsdaine model
  - 2.5.3 Felder Silverman model
  - 2.5.3 Dominance profiles
- **2.6 Profile of a learner**
- **2.7 Summary**

Chapter 2

Perspectives on learning and learners: an epistemological overview

2. Introduction

According to Sylwester (1995) the dominant theory of human behaviour and resulting educational paradigms during the 1950s and 1960s came from the doctrines of Skinner. Sylwester further points out that, based on these paradigms, educators focused on visible and measurable manifestations of cognition rather than on cognitive mechanisms and processes. Educators learned to manipulate learners' environments to achieve the behaviour they desired and educators became a profession of behaviourists (Sylwester, 1995). Knowles (1990) points out that most of the 'scientific' theories of learning have been derived from studies focusing on learning by animals and children. The author feels that these learning theories cannot, as such, be applied to the learning of first year tertiary students. However, research since the 1960s on the functioning of the human brain has paved the way for educators to rethink the way their students learn and how learning should be facilitated. Sylwester (1995) argues that, in a certain sense, the increasing knowledge on the functioning of the human brain changed the paradigm for describing learning from psychology to biology.

In pursuing a theory of learning, the following views are noteworthy. If a theory is considered as a *system of ideas explaining something* (Crowther, 1995:1446) or *a set of principles* (Smit, 1995:3), a theory should not be regarded as an end in itself, but that a specific theory can serve as a frame of reference for a research question. Zuber-Skerritt, (1992a:57) remarks that

> *All theories are hypotheses created by people; they may be valid at any particular time, but may suddenly be invalid in some unforeseeable respect and replaced by a better theory.*

Reporting on new trends in undergraduate mathematics education, Kaput, Schoenfeld and Dubinsky (1996:215) rightly ask

> *Are learning theories transferable across cultural and subject matter boundaries? Can they be applied to different topics and different groups of students in different countries?*

Maree (1997) remarks that a final and conclusive theory on the learning of mathematics has not been formulated and that it probably cannot be done.

In the current study, only examples of those theories that are seemingly significant for the discussions in the study have been considered. Furthermore, the approach in this study is in accordance with the opinion of Maree (1997) who emphasises a holistic[6] approach to any research that reflects on learners in mathematics.

Following on Sylwester's line of thought, this chapter starts with an overview of traditional theories of learning relevant for tertiary mathematics education in a support course, followed by current views on learners and aspects of learning. The aspects of learning treated here include learning strategies, metacognition, cooperative learning, constuctivism, study orientation, learning styles and learning and intelligence. The discussion then focuses on brain-based learning and overviews the left-right brain hemisphere model of Sperry, the triune model of MacLean and the four-quadrant whole brain model of Herrmann. The chapter concludes with examples of thinking and learning styles that are relevant for the present study.

2.1 Overview of traditional views on learning and learners relevant to tertiary mathematics education

In this section, the possible significance that the traditional theories of learning may have for tertiary mathematics learning in a support course will be discussed.

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[6] In this study the term "holistic" refers to the totality of possible factors that may be of significance with regard to a learner. The learner is viewed as a person within a (complex) situation. Aspects of this complexity are discussed in Chapter 3.

2.1.1 Behaviourism: The stimulus response (S-R) formula

Knowles (1990:147) points out that *to learn is to change* and that the scheme most commonly proposed for explaining how learning-change takes place is the **S** (**stimulus**) and **R** (**response**) formula or **some variation** thereof.

Behaviourists oversimplified the highly complex nature of human learning by defining it as a response to external stimuli. Although they extrapolated human behaviour from observation and experiments with animals, they ought to be credited for noting that change (learning) takes place following (external) stimuli. In spite of the criticism against traditional behaviourism, its underlying principles have influenced, either consciously or unconsciously, teaching to a great extent.

It seems as if the **S-R** model is a fairly good description of learning as long as it is confined to simple kinds of learning (Knowles, 1990). When learning is more complex (as in higher education) and the learner is more mature (as with tertiary students), the physical properties of the stimulus are insufficient to account for individual differences in responses. In order to describe more complex learning, Knowles (1990:147) defined an *intervening variable* as the **person** (**O**) and extended the **S-R** model to a **S-O-R** model. All other models of learning may simplistically be related to this distinct **S-O-R** model.

It should be pointed out that Knowles's **S-O-R** model is not merely an extended behaviourist model, but a descriptive model for learning and that the **intervening variable O** implies the **totality of a learner**. This totality should further be interpreted by taking **all** aspects relating to human learning into account.

2.1.2 The neobehaviourist learning theory of Gagné

Maree (1997) points out that in spite of Gagné's strong behaviourist preferences, he acknowledged and described a learner's accountability, attitude, intentions and creativity. Gagné (1977:6) remarks that change brought about by learning is *an increased capability for some type of performance ... an altered disposition of the sort called "attitude" or "interest" or "value".*

Gagné (1977, 1985) distinguishes five categories which form the core of his views on learning. He regards these categories as learning outcomes, as learner characteristics and as descriptive of possible different kinds of human performance. These five characteristics are:

- **Intellectual skills** (1977:28; 1985:47). Gagné points out that these skills enable individuals to interact with their environment in terms of symbols or conceptualisations. It thus implies a learner's knowledge and use thereof.
- **Cognitive strategies** (1977:35; 1985:48). which Gagné regards as the capabilities that governs an individual's own learning, remembering and thinking.
- **Verbal information** (1977:38; 1985:48) is information that an individual can recall in verbatim, paraphrased or summarised form.
- **Motor skills** (1977:42; 1985:48) refer to basic (physical) abilities.
- **Attitudes** (1977:44; 1985:48) constitute a persistent state that modifies the individual's choices of action.

Gagné (1985) classified all learning (including mathematics) as hierarchical, from 'signal learning' (which corresponds with the behaviourist stimulus-reaction concept) to the more difficult 'problem solving'.

Although the ideas of Gagné may be viewed in relation to tertiary mathematics education, the fundamental premise of an integrated brain-based approach proposed in this study, differs from Gagné's hierarchical structure of learning.

2.1.3 The gestalt learning theory

Although the learning theory of Köhler was based on his observations of chimpanzees, the resulting idea of *gestalt* correlates with later research findings on the functioning of the brain and the identification of *gestalt* as a (right) brain function. Köhler should be credited for his insight into the concept of wholeness that he noted long before the research evidence on the functioning of the brain. Köhler described 'learning with insight' as the formation of a whole (*gestalt*) which is constituted by the separate parts (Maree, 1997).

Kruger (in Hodgkinson, 1998:66) states that the *crux of gestalt theory is that the whole is prior to the parts*. Crowther (1995:568) defines *gestalt* as *an organised whole that is* *perceived as more than the sum of its parts*. These definitions of *gestalt* have particular significance for the learning (and teaching) of mathematics at all levels.

Maree (1992) points out that educators cannot assume that learners, who have mastered separate elements of mathematical content, have also acquired *gestalt* cognition. Maree notes further that learning achievement includes a totality of learning operations such as *the integration of visualisation and concrete representation* (Maree, 1992:55).

In the subsequent sections of this chapter on brain-based learning as well as in Chapter 3, it is pointed out that the right brain function of *gestalt* can and should be utilised in the learning (and teaching) of mathematics.

2.1.4 Cognitive learning theories: the learner as a constructor of knowledge

Where behaviourists focus mainly on the **outcome** of learning, the cognitive theorists focus on the **process** of learning. Cognitive theories of learning emphasise that learners are ultimately responsible for their own understanding through active construction of meaning (Cross *et al*., 1996). For the purposes of this study, aspects of cognitive theories relevant to the tertiary learner will be overviewed within the framework of a brain-based approach to learning. It should, however, be borne in mind that cognitive theorists formulated their theories on learning prior to the knowledge of brain functioning that emerged following the work of Sperry and others. Zuber-Skerritt (1992a:55) stresses that

> *The learner is not merely a passive consumer of accumulated knowledge, but an active producer and reproducer of knowledge and theory.*

2.1.4.1 Constructivism and Piaget's model of learning (1970)

According to Piaget (Copeland, 1979), learning results from a tension between two processes, the process of **assimilation** and the process of **accommodation**. Through **assimilation**, events and experiences from the world are integrated into a learner's existing concepts and experiences. Changes in a learner's existing cognitive structures are brought about by **accommodation**.

The four major stages of cognitive growth (Copeland, 1979) identified by Piaget are:

- The **sensorimotor stage** lasting from birth to approximately two years of age.
- The **pre-operational stage** lasting from two until approximately seven years of age.
- The **concrete operational stage** lasting from about seven to 11 or 12 years of age. In this stage logical thought is based in part on the physical manipulation of objects.
- The **formal operational stage** starts at about 12 years of age and is regarded as an adult level of thinking (Copeland, 1982). In this stage the child *reasons or hypothesis with symbols or ideas rather than needing objects in the physical world as a basis for his thinking* (Copeland, 1979:25). The mental structures in this stage include *the propositional combination of symbolic logic-implication (if–then), disjunction (either–or, or both), exclusion (either–or) [and] reciprocal implication* (Copeland, 1979:25).

Piaget's four stages of intellectual growth refer to children from birth to about the age of 11-12. They are therefore not directly applicable to tertiary learners. However, it could be expected that in a study such as this, involving first year tertiary students in mathematics, attention should be given to Piaget's fourth developmental stage, the **formal operational** stage. According to Piaget (Copeland, 1982), learners in this stage function on an abstract level that is an adult level of thinking and these learners are not bound by concrete experiences.

Copeland (1982) questions Piaget's view regarding abstract thinking without concrete experience and points out that children of age 11-12 still need experiences with concrete material. Copeland (1982) also points out that this is too young an age to accomplish this formal operational level. He refers to a study, done by Heron in 1975, which indicated that 50% of college freshmen in the USA were functioning completely at the concrete operational level. Fewer than 25% were fully formal operational in their thoughts (Copeland, 1982).

Piaget's postulate that cognitive function on an abstract level should be accomplished without concrete experience is also questionable within the framework of the principle of whole brain utilisation.[7] If the term "concrete" is defined as *existing in a form that can be touched, felt or seen* (Crowther, 1995:238), then the concept "concrete experience" can be viewed as a cognitive function associated with the global (right) hemisphere. This does not necessarily imply that a concrete cognitive activity remains focused on the concrete image.

[7] See Section 2.3.4.

The author feels that it is in the combination of image (global brain hemisphere function) and abstraction (linear brain hemisphere function) that knowledge is formed. This aspect is of special significance in support in tertiary mathematics education where the facilitation of fundamental mathematical concepts is a primary aim of instruction. Therefore, in the opinion of the author, the learners (freshmen students) in this study cannot be categorised in terms of Piaget's fourth development phase.

The following aspects of the cognitive learning theories of Kelly and Leontiev are of special interest to the practice of higher education.

2.1.4.2 Kelly's personal construct theory (1955)

Zuber-Skerritt (1992a) points out that Kelly's theory bridges the gap between traditional theorists on the one hand and practitioners (for example students and teachers) on the other. Kelly (in Zuber-Skerritt, 1992a) believes that everyone (students, teachers, counsellors, administrators) is a 'personal scientist' engaged in a process of observation, interpretation, prediction and control. Kelly regards learning as the active, creative, rational, emotional, intentional and pragmatic construction of reality. Therefore students should not be seen as the passive receivers of information but the active constructors (or self-instructors) and interpreters of their experiences.

Kelly's theory seems to be descriptive of tertiary students' learning. With regard to this study, it can readily be assumed that specialised brain functions should be utilised during 'active construction' and 'interpretation' in the learning facilitation strategy defined in this thesis. Kelly's theory is a holistic view of the learner and an elaboration of Knowles' **S-O-R** model. It could readily be linked to the functional whole brain model of Herrmann.[8]

2.1.4.3 Leontiev's cognitive theory of action (1977)

Action theories have evolved as a critical reaction to behaviourism. Action theorists regard cognition and conscious action as essential factors in human behaviour. They assume that mental processes, such as reasoning, problem-solving or decision making, as well as motor procedures, are dependent components of the macro unit 'action' (Zuber-Skerritt, 1992a).

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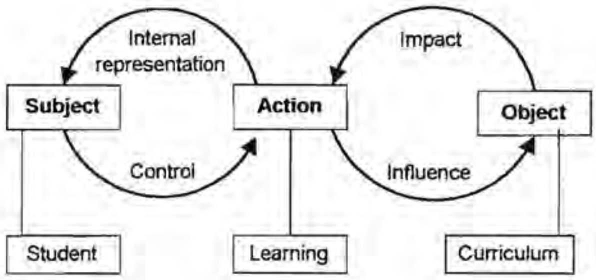
[8] See section 2.3.4.

Where Kelly emphasises individualism, Leontiev emphasises the adaptation of the human mind to social conditions. However, in both cases, the primary importance of action is useful for human cognition and for the creation of knowledge.

Heger was among the first to apply Leontiev's theory to higher education and to develop a model for the analysis of student learning. Figure 2-1 is a model for student learning adapted from Heger by Brandt and Sell (Zuber-Skerritt, 1992a).

Figure 2-1 A model of student learning after Leontiev



Zuber-Skerritt (1992a:75)

In the model in Figure 2-1:

- the **subject** is the holistic person (e.g. student/learner) and his/her consciousness. This includes intentions, motivations, cognitive aspects (thoughts, ideas, concepts) as well as effective aspects (emotions, feelings, anxiety);
- the **action** refers to actions of studying and learning and is influenced by the personality traits and external demands;
- the **object** refers to the context of studying (a task, a problem or that which is produced by the subject) as well as all given factors within the context and system of an institution.

Zuber-Skerritt (1992a) deduced the following four principles for learning and teaching (understood as facilitation[9]) from Leontiev's theory of action:

[9] The term "facilitation" is defined in Chapter 1, section 1.2.2.

1. **The action of learning should be as concrete and practical as possible in the early stages of studying a new area of knowledge in order to facilitate internal representation.** This principle correlates, for example, with the use of the specialised instructional media[10] that is used in the learning facilitation strategy proposed in Chapter 3 and discussed in Chapter 5 of this thesis.

If this principle is interpreted form the perspective of brain-based learning (discussed in section 2.3 and in Chapter 3), the following can be noted. The pictorial visualisation of symbolic mathematical data by way of a graphical representation using a computer graphing tool to generate the graphs of two-dimensional functions is a **concrete** learning activity. **Practicality** in this sense can then be interpreted as a physical action by the learner, using a tool (computer graphing software) to represent mathematical content. This implies **experiential** and **non-verbal** cognitive activity that mainly involves right brain hemisphere functions. The **facilitation** of **internal representation** can be associated with **graphical analysis** which is verbal and structured where internal representation mainly involves right brain hemisphere and graphical analysis left brain hemisphere functions. It can therefore be assumed that Leontiev's first principle can be correlated with whole brain cognitive activity in learning mathematics.

It should also be noted that this principle for learning, deduced from Leontiev's theory of action, to an extent contradicts Piaget's fourth developmental stage as discussed in section 2.1.4.1 above.

2. **The degree of consciousness and conceptualisation depends on the extent to which actions - whether practical/concrete or mental/abstract actions - are interiorised[11] in the learner. Important constituents of interiorisation are language, communication with others and active reflection.**

Zuber-Skerritt (1992a) points out that 'interiorisation' is not only meant as a mirror-effect of the action of learning on the learner but also as the student's own effective reaction to and reflective thinking about the content and processes of learning. Mere internalisation of action (i.e. storage of information or events and accumulating them in one's memory) is only the lowest level of thinking. In order to reach higher levels of abstraction,

[10] For example, graphical exploration and analysis of 2-D functions using the textbook by Greybe, Steyn & Carr (1998).

[11] The author feels that the term "interiorised" in this case is use synonymously with the term "internalise" which *make[-s] attitudes, behaviour, etc. part of one's nature by learning or unconscious assimilation* (Crowther, 1995:712).

generalisation and theory, thinking must become progressively active, reflective, critical, self-critical and creative. Zuber-Skerritt (1992a) also points out that an instrument to reach more and more advanced levels of theory is **language** in both **oral** and **written** forms. She elaborates on this aspect and adds that one can theorise better through discussions with others and through writing a report or paper than just through thinking on one's own.

This second principle is also reflected in the aspects of metacognition and cooperative learning. These aspects are elaborated on in section 2.2.

3. The third principle of learning (and teaching) derived from Leontiev's theory of action is that **students' existing knowledge should be utilised in action learning**.

Zuber-Skerritt (1992a) explains that action learning (e.g. by doing, experiencing, participating through discussion, problem-solving, project work, etc.) and metalearning are possible because of students' previous experience and existing knowledge in most areas of learning. The principle that learners of all ages bring with them existing pre-knowledge that influences learning has repeatedly and substantially been backed by research (Bransford *et al.*, 1999).

The author's experiences with first year mathematics students have brought to light that their existing pre-knowledge of graphical representation and interpretation of two-dimensional functions is often inadequate and prone to misconceptions. However, it has also been observed that the action of learning by way of doing, experiencing, participating through discussion and problem-solving as well as metalearning not only leads to the mastering of new knowledge but aids in rectifying existing misconceptions.

4. The fourth principle of learning and teaching deduced from Leontiev's theory of action relates to the **dialectical**[12] **relationship between institutional requirements and the needs of students in a fast changing world**.

Zuber-Skerritt (1992a) elucidates this principle:

- Active learning and metalearning may influence the curriculum and assessment (the 'influence' arrow in Figure 2-1 on page 28). This can be done through open discussions between lecturers and students and through student evaluation of courses and teaching.

[12] Dialectic refers to a view on something in context and in contradictions.

- Institutional conditions, requirements, expectations have a great impact on learning (the 'impact' arrow in Figure 2-1). Zuber-Skerritt (1992a) illustrates this point with an example that is applicable to the learning facilitation strategy defined in this study. An assessment system with only end-of-semester or end-of-term examinations is likely to encourage rote learning and to discourage active learning. These approaches to learning can also be categorised as a 'surface' approach and a 'deep meaning' approach (see section 2.2.1). Continual assessment forms an integral part of the learning facilitation strategy defined in this study. The author feels that this form of assessment contributes to active learning and an overall 'deep meaning approach' in a support course in tertiary mathematics. The principle of continual assessment is discussed in chapters three and five as an aspect of the learning facilitation strategy proposed in this study.

2.1.4.4 Information processing and knowledge construction

Cognitive views of learning contend that new information is more easily understood and retained when it can be related to existing information. The knowledge structures that organise and store information in a learner's memory are referred to as schemata. Cross *et al.* (1996) point out that schemata can be compared to networks of facts, ideas and associations formed around related concepts.

Maree (1997) describes schemata as distinct units of physical and cognitive actions that are often repeated. Learners have their own schemata available that continuously develop, change and become more complex. These schemata are the building blocks of cognitive structures.

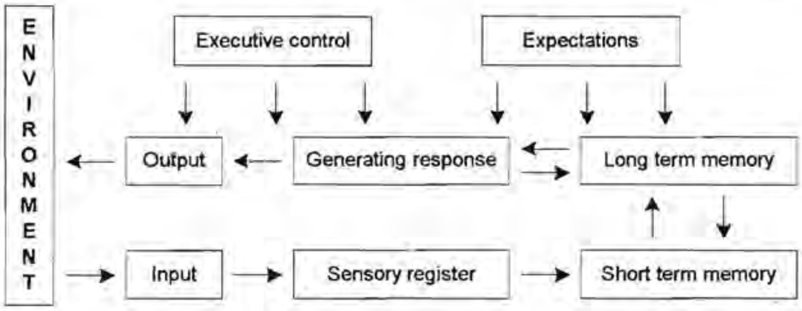
Crawford and Chaffin (1986) (in Cross *et al.*, 1996) summarise three assumptions about the way schemata work namely:

- People do not remember information exactly as they received it (mental representations are thus not 'copies' of original events).
- Schemata are generalised knowledge structures that provide the framework for and determine the nature of understanding.
- Schemata provide the learner with background knowledge from which to make deductions.

Gagné's (1983:8-10) view on information processing and knowledge construction is illustrated in Figure 2-2 and can be summarised as follows:

- The fundamental unit that is learned and stored in human memory is a 'semantic unit' which is inherently meaningful.
- The physical stimulation delivered to the senses is transformed into nerve impulses which can be viewed as 'intricate masses if information' that undergo several kinds of transformation sequentially, simultaneously or parallel.
- The kinds of transformation are called 'processes'.
- The learner has 'executive control' over the processes.
- Processing that turns external stimulation into 'learned information' is influenced by inputs from three sources, namely, the organisation of the external stimulus; the executive control processes that are available to and used by the learner and by what has previously been learned (contents of memory).

Figure 2-2 Information processing and structuring according to Gagné



Adapted from Gagné (1977:53; 1985:71)

Maree (1997) summarises the contemporary theories on information processing and points out that internal processes, which are influenced by the external organisation of stimuli, initiate the activities 'learning' and 'memory'. Learners together with their own available memory contents have control over these processes.

2.1.5 Kolb's experiential learning theory (1984)

Kolb defines learning as

> *the process whereby knowledge is created through the transformation of experience* (in Zuber-Skerritt, 1992a:105)

and Kolb's experiential learning theory suggests further a

> *holistic integrative perspective on learning that combines experience, perception, cognition and behaviour* (in Zuber-Skerritt, 1992a:100).

Although the learning of mathematics as described in this thesis is not experiential learning in the sense of learning in real-life situations, McKeachie (1999:154) points out that the criterion for experiential learning should be the *degree to which learning is transferable to other times and places.* In this sense, the learning and understanding of fundamental concepts underpinning calculus to be transferred to 'other times and places' is in essence a focus of the learning facilitation strategy described in this thesis.

Kolb has developed six major propositions that describe learning of which the following three are significant for the learning of mathematics as viewed in this thesis.

1. **Learning is best perceived as a process, not in term of outcomes** (Zuber-Skerritt, 1992a). Zuber-Skerritt points out that a process of learning will lead to an outcome, and outcomes of learning are the result of a process. She therefore rephrases Kolb's 'process proposition' as *learning is a process as well as an outcome* (Zuber-Skerritt, 1992a:103).

Kolb applies 'learning as a process' to suggest a shift away from the preoccupation with tests and examinations to a greater attention to the process of learning. He regards this to produce more personalised and lasting knowledge than the mere accumulation of knowledge in preparation for exams. This correlates with Leontiev's fourth principle mentioned above.

2. **Learning is a continuous process grounded in experience** (Zuber-Skerritt, 1992a). This proposition implies that a teacher's task is not only to expose learners to new ideas, but also to dispose of or modify old ones.

3. A further proposition of Kolb's experiential learning is that **learning is the process of creating knowledge** (Zuber-Skerritt, 1992a). According to Zuber-Skerrit, Kolb distinguishes social and personal knowledge.

The significance of these propositions of Kolb for learning activities associated with the learning facilitation of mathematics in a support course, as defined in the current study, can be summarised as follows:

- The facilitation of the mathematics component of the support course is not viewed solely in terms of outcomes. In accordance with the first proposition, it encompasses a **learning process** to enhance the conceptual understanding of mathematics and is also aimed at the development of the mathematics potential of the learner.
- In the learning facilitation of the mathematics component of the support course, computer-generated graphs of two-dimensional functions are used to explore concepts. In this way learners are exposed to **new mathematical content** and to **modify** misconceptions that may exist which underpins Kolb's second proposition of experiential learning.
- It may readily be assumed that mastered subject content knowledge, such as fundamental knowledge that underpin a study in calculus, can be related to Kolb's category of **personal knowledge**. Furthermore, an awareness of one's own thinking and learning preferences and the necessity to also utilise less preferred modes of thinking and doing contribute to social and personal knowledge and development.

2.1.6 Adult learning

Knowles (1990) distinguishes six categories to describe learners. For the purposes of this study these categories are summarised and comparatively stated for child learners and adult learners in Table 2-1 on page 36.

Knowles (1990) points out that (tertiary) educators have the responsibility to check which assumptions are realistic in a given situation, namely those reflecting on child learners or those of adult learners. Whichever strategy is realistic in a given situation for a particular (tertiary) learner with regard to a particular learning goal, should be viewed as an appropriate starting point, but **(tertiary) learners must take increasing responsibility for their own learning.**

The second assumption listed in Table 2-1, namely, a learner's self-concept is elaborated on by Knowles (1990:55) as follows

> *As individuals mature, their **need** and **capacity** to be self-directing, to utilise their experience in learning ... and to identify their own readiness to learn, increases steadily from infancy to pre-adolescence, and then increases rapidly during adolescence.*

This view has significant implications for higher education. **Tertiary learners** (as those in a support course for mathematics) should be recognised as **developing learners** and teaching initiatives should be structured accordingly.

The challenge for tertiary education in general, and with regard to learning facilitation (of mathematics) in a support course in particular, may be to think, to investigate and to write about the learners who are in transition form child learning to adult learning. It seems obvious that the learning of first year tertiary students on a support course would entail aspects of learning in both categories.

In chapter five it ought to become clear to what extent these aspects have been addressed in the learning facilitation strategy defined in this study.

Students need to be actively engaged in the learning facilitation process of mathematics. They must eventually take control of their own learning. Since understanding in mathematics is crucially important, students must learn to recognise when they understand and when they need more information or help to facilitate their understanding.

Table 2-1 A comparison between child learning and adult learning according to Knowles' assumptions

Assumption	Child learning	Adult learning[13]
1. The need to know	Learners only need to know that they must learn what the teacher teaches if they want to pass and get promoted.	Adults need to know why they need to learn something before undertaking to learn it. For the facilitator this implies, firstly, helping learners to become aware of the 'need to know' and secondly, the facilitation of experiences in which the learners discover for themselves the gaps between where they are and where they want to be.
2. (Self-) concept of learners	The teacher's concept of the learner is that of a dependent personality. The learner's self-concept remains that of a dependent person.	Adults have a self-concept of being responsible for their own decisions.
3. Role of experience	The experience that is predominant is that of the teacher, the textbook writer, and the audio-visual aids producer. Transmittal techniques, such as lectures, are the backbone of pedagogical methodology.	Adults come into educational activity with greater volume and different quality of experience, implying a wider range of individual differences. These necessitate: • individualisation of learning (and teaching) strategies; • greater emphasis on experiential learning and • acknowledgement of the learner's previous experiences as this enhances self-identity.

[13] From the viewpoint of learning, the psychological definition of adulthood is relevant: a self-concept of being responsible for one's own life and of being self-directing (Knowles, 1990:57).

4. Readiness to learn	Learners are ready to learn what the teacher tells them they must learn.	Adults are ready to learn those things they need to know and with which they will be able to cope with effectively in their real-life situations.
5. Orientation to learning	Learners have a subject-centred orientation to learning. Learning experiences are organised by the teacher according to the logic of the subject matter content.	Adults are task-centred or problem-centred.
6. Motivation	Learners are motivated to learn by external motivators – grades, the teacher's approval or disapproval as well as parental pressure.	Adults are responsive to some form of external motivators (better jobs, promotions, higher salaries, etc.). The most potent motivators for adults are internal pressures (the desire for increased job satisfaction, self-esteem, quality of life, etc.). Research by Thought (1979) (in Knowles, 1990) has indicated that all normal adults are motivated to keep growing and developing. This motivation can be blocked by barriers such as a negative self-concept (as a student) or by programmes that violate principles of adult learning.

Compiled from Knowles (1990:55-63)

2.2 Further aspects of learning

2.2.1 Learning strategies

A strategy (approach) to learning refers to the way in which cognitive skills are adapted to comply with a learning task. There are various perspectives that describe students' approaches to learning. These descriptions are not contradictory but rather complementary.

According to Du Plessis (1992) Hudson had already referred to a 'syllabus bound' and 'syllabus free' approach to learning in 1968. A student who is syllabus bound does not extend his study efforts beyond prescribed course content whereas a syllabus free student will engage in extending his focus wider than the prescribed course content.

Pask (1976) distinguishes between a 'serial' and a 'holistic' approach. A serial approach indicates a step-by-step approach whereas in a holistic approach a student first strives to get an overall view of the content. Pask points out that the most successful students are those who can adapt their strategy to the requirements of the learning task. Pask's view confirms an important principle of the learning model described in chapter three, namely the ability to utilise different cognitive modes when learning.

Marton and Säljö (1976) identify two approaches to learning, namely, a 'deep' or holistic approach and a 'surface' or atomistic approach. Marton and Säljö's categories have been widely used and adopted to describe approaches to learning. In Table 2-2 on the following page the identifying characteristics of a student who follows a 'deep' approach and of a student who follows a 'surface' approach to learning are compared.

Although deep approaches to learning are generally associated with more successful learners, Säljö (1984) (in Cross *et al.*, 1996) points out that a deep/surface distinction does not apply to all learning situations. For example, a deep approach will be more effective when reading scientific texts that present arguments, principles and constructs to be analysed whereas a surface approaches are entirely appropriate for leaning tasks that require nothing more than memorisation. Laurillard (1984, in Cross *et al.*, 1996) indicates that problem solving assignments such as word problems in algebra do not necessarily require deep approaches to learning because once students recognise that the problems follow a typical pattern (indicated by certain phrases), they may reproduce answers using formulas without thinking about underlying principles. The author of this thesis is of the opinion that this approach is not necessarily wrong because once a learner has mastered a concept, it becomes useable knowledge and is used as an automatism. Automatisms that are grounded in concepts form the base for further knowledge generation.

Table 2-2 Approaches to learning according to Marton and Säljö

A student who follows a deep approach:	A student who follows a surface approach:
• tries to understand the 'big picture';	• focuses on aspects and not on the 'big picture';
• tries to relate content in a broader context;	• sees the learning task as a short-term activity, for example, to pass a test;
• tries to synhesize aspects and integrate them within the 'big picture';	• cannot synthesize aspects and integrate them within the 'big picture';
• identifies core principles and distinguish detail;	• invariably masters content through memorization;
• seeks for the deeper meaning of course contents and	• is focused on time and the immediate completion of the task and not on a possible deeper meaning thereof and
• is committed to and enjoys the learning task.	• is not necessarily committed to the learning task or enjoyment of the process.

Compiled from Marton and Säljö (1976:20, 37, 48)

According to Entwistle and Ramsden (1983) students choose a specific learning strategy depending on their cognition of the learning task. A student may exhibit different approaches in different courses, depending on perceptions of what is expected for success. Gibbs (1981:76) refers to research by Laurillard where she states that *students will take a deep or surface approach to a task depending on the nature of the task*. It follows that students need to develop the ability to adapt their strategy to fit the learning task and content.

Entwistle and Ramsden (1983) also point out that students adapt their learning strategies through contact with other students. According to Pressley and McCormick (in McKeachie, 1999) teachers can influence the degree to which students use deep rather than surface strategies for learning through assessment that requires a deep understanding of the content.

Smith (2001) identifies course characteristics (in mathematics) that can encourage either a deep approach or a surface approach to learning. These characteristics are summarised in Table 2-3 below.

Table 2-3 Course characteristics that encourage a deep or surface approach to learning

A deep approach is encouraged by:	A surface approach is encouraged by:
• interaction – peers working in groups;	• excessive amount of material;
• well-structured knowledge base – connecting new concepts to prior experience and knowledge;	• lack of opportunity to pursue subjects in depth;
• motivational context – choice of control, sense of ownership;	• lack of choice over subjects and/or method of study;
• learner activity plus faculty connecting activity to abstract concept.	• threatening assessment system.

Compiled from Smith (2001:11)

2.2.2 Metacognition

According to Cross *et al.* (1996) metacognition implies both knowledge of cognition and control of cognition. Knowledge of cognition is an awareness of and reflection on one's own learning processes ('thinking about thinking'). The practice of observing oneself in the act of learning contributes to the ability to understand one's own learning process and to manage and control it. Biggs (1985) describes the managing of one's own learning as metalearning.

Flavell (in Maree, 1992:73) describes metacognition as follows:

> *Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything else related to them ... I am engaging in metacognition ... if I notice that I am having more trouble learning A than B; if it strikes me that I should double-check C before accepting it as a fact.*

Metacognition thus entails the planning, monitoring, controlling and evaluating of one's own learning. The ability to use metacognition as a way to improve learning is not necessarily part of a tertiary learner's frame of reference.

Flavell (1970, 1976, in Cross *et al.*, 1996) identified three main areas of knowledge about cognition that may help learners improve their learning process namely, knowledge about oneself; knowledge of the learning task and knowledge of strategies available to complete the task. The question arises if metacognition and learning strategies in mathematics (in a support course) can be developed through instruction.

Weinstein (1999:319) emphatically states that facilitators (lecturers) can have a *tremendous impact on helping students to develop a useful repertoire of learning strategies.* Students should have the opportunity to reflect on their learning (strategies) and teachers should not only ask students **what** they think but also **how** they think.

The author of this thesis strongly endorses the principle that students need to be given the opportunity to communicate in mathematics both orally and in writing. The principle of giving learners ample exercise in not only writing down mathematics but also writing down the reasoning behind it, is increasingly being implemented by mathematics educators who realise that there is more to understanding mathematics than mere performing correct calculations (Hubbard, 2001; Smith, 2001). The author of this thesis agrees that these activities promote metacognitive skills.

Metacognition refers to people's abilities to predict their performances on various tasks and to monitor their current level of mastery and understanding. Teaching practices congruent with a metacognitive approach to learning include those that focus on sense making, self assessment and reflection on what worked and what needs improving. (Schoenfeld, 1985; Bransford *et al.*, 1999). If this is true in general, it is certainly also true for the learning facilitation of mathematics.

2.2.3 Cooperative learning

Cooperative learning is generally regarded as an activity where learners work together in small groups. Davidson (in Maree 1997:77) defines cooperative learning as follows:

> *Cooperative learning involves more than just putting students together in small groups and giving them tasks. It also involves very careful thought and attention to various aspects of the group process.*

According to this definition, cooperative learning is a formal instructional methodology that implies organising groups and structuring tasks.

Davidson (1990) used cooperative learning with college level mathematics students and summarises his research findings as follows (Becker & Pence, 1994):

- students taught by small-group discovery method perform at least as well as those taught by more traditional lecture methods;
- students are actively involved;
- students have the opportunity to communicate mathematically;
- the classroom atmosphere is relaxed and informal;
- students have the freedom to ask questions;
- there is a closer student-teacher relationship;
- there is a high level of student interest;
- students' attitudes are more positive;
- students use the opportunity to pursue challenging mathematical situations.

Felder and Brent (1999) define "cooperative learning" as a subset of "collaborative learning". According to them, in collaborative learning students are interacting with one another while they learn actively and apply course material. In cooperative learning students work in groups on structured tasks under conditions that should meet the following criteria, namely:

- **Positive interdependence.** Team members must rely on one another to accomplish a goal.
- **Individual accountability.** Members are held accountable for doing their share of the work and mastering all material.
- **Face-to-face interaction.** Some or all work done by members working together.
- **Appropriate use of interpersonal skills.** Team members practise and receive instruction in leadership, decision-making, communication and conflict management.
- **Regular self-assessment of group functioning.** Teams periodically reflect on what they are doing well as a team, what they could improve, and what (if anything) they will do in future.

Felder *et al.* (1999) strongly states that cooperative learning is **not** students sitting around a table studying together or group projects with one or two students doing all the work.

2.2.4 Aspects of constructivism — a summary

Perspectives on learning and learners will fall short if the educational concept "constructivism" is not mentioned. The author views "constructivism" in contrast to "instructivism" and delineates the concepts according to the following definitions. Crowther (1995:247) and Thompson (1995:286) define "construct" as *to put or fit together*, and Woolf (1977:244) defines "forming a construct" as *mentally assembling and integrating sense-data.* Crowther (1995:619) defines "instruct" as *to teach somebody a skill* and Woolf (1977:599) defines it as *to give information.* Incorporating these definitions the author considers "instructivism" as more *teacher centred* whereas "constructivism" is more *learner centred.* Cross *et al.* (1996:43) remark that *learners are ultimately responsible for their own understanding through active construction of meaning.*

According to Maree (1997) the following aspects succinctly describe constructivism:

- Knowledge is **not passively received**.
- Learners are **active** participants in the learning process.
- **Assimilation** is the process whereby new, but recognisable, ideas are added to existing knowledge structures.
- **Accommodation** refers to the process whereby new and different ideas are incorporated to existing ideas.
- The incorporation of new ideas into existing ones presupposes the **consolidation** of previously acquired concepts.
- **Verbalisation** of concepts is a prerequisite for consolidation.
- Social constructivism focuses on **communication** between learners.
- Social constructivism is **group-based** and **process orientated**.
- Social constructivism supposes a **problem solving** and **investigatory** approach.
- Constructivist learning strategies are aimed at **understanding** subject contents in contrast to behaviourist drill and practise.
- Learners should take **charge** of their **own learning** experience.
- Learners **constitute** their world through their own experience.
- **Experiential** learning, **metalearning** and **problem-solving** are key aspects of the constructivist learning situation.
- Learning needs to be facilitated to incorporate **different** instructional approaches.

2.2.5 Study orientation in mathematics

According to Schmeck (1988:8) the term "orientation" refers to a *consistency in one's approach to learning in school and university setting* and the concept "approach" *stresses the relationship between intention, process and outcome within a specified context.* A person's orientation is thus the *result of a relation between person and environment* (Schmeck, 1988:10). Entwistle (1988) describes "orientation to studying" as the factor that summarises approaches, motives and styles and it includes elements of study methods and attitudes.

Several researchers have shown that there is a statistically significant association between aspects of study orientation in mathematics, such as anxiety, motivation, attitudes with regard to mathematics, the use of effective meta-cognitive strategies in mathematics, effective time management, concentration, the will to achieve in mathematics and the social, physical and experienced environment of learning mathematics on the one hand, and achievement in mathematics on the other (Reynolds & Wahlberg, 1992; Van Aardt & Van Wyk, 1994; Visser, 1988; Wong, 1992).

According to Maree (1997) little attention is given to pupils' (students') study orientation in mathematics when reasons for poor performance in mathematics are sought. Van Aardt and Van Wyk (1994) identify the harmful influence of inadequate study orientation among mathematics students and point out that evidence suggests that the use of effective learning and study strategies is important in determining (academic) success.

Maree (1992) points out that numerous aspects can affect study orientation in mathematics. The formation and acquisition of basic concepts is important because when conceptualisation is incomplete, problem solving in mathematics is inhibited. Students' emotions, their habits and attitudes regarding mathematics and the way in which they process mathematical information influence their study orientation in mathematics. The display of acquired, consistent and effective study methods and doing assignments form an important part of a student's study orientation in mathematics. Study attitude therefore culminates in certain study habits. A student's learning environment (social, physical and perceived), their feelings about mathematics and the way in which they experience their teachers (lecturers) all form an integrated part of a student's study orientation in mathematics.

Entwistle (1988:48) remarks that *by ensuring that students become aware of their own approaches, and the implications of adopting them, it may thus be possible to improve the quality of learning* outcomes. One of the aims of the research reported in chapters five and six of this thesis is to determine the study orientation in mathematics of a group of first year engineering students and to promote an awareness of the individual's own study orientation in mathematics.

2.2.6 Learning styles

In section 2.5 a selection of views on and definitions of styles of learning are discussed. The choice of the examples of those discussed include a selection that can be interpreted from the premise of brain-based learning as the researcher values this principle as point of departure for the learning facilitation strategy defined in this thesis.

2.2.7 Learning and intelligence

> *Intelligence boils down to your ability to know your own strengths and weaknesses and to capitalise on the strengths while compensating for the weaknesses.* (Sternberg in Jensen, 1996:175).

During the twentieth century Binet's model of intelligence dominated the educational world. This model was biased towards determining a fixed 'intelligence quotient' (IQ) that measured and quantified so-called verbal and non-verbal competencies and that was fixed for life. Gardner (1983) diverted from Binet's static model and defines human intelligences as an array comprising seven categories. He states that each individual has his/her own unique combination of these seven categories and that this combination can and does change over life. In Table 2-4 a summary of Gardner's categories for multiple intelligences is given as well as examples of indicators by which the different categories can be identified.

Table 2-4 Gardner's multiple intelligences

Intelligences	Identified by
Logical-mathematical	Strong mathematical and problem-solving skills. Sequential thinking. Handling of quantitative information.
Verbal-linguistic	Sensitivity to the meaning, sound, inflection and order of words. Enjoys reading and talking.
Musical-rhythmic	Appreciation of sounds; sensitivity to rhythm. Difference in interpretation of 'musical messages'.
Spatial	Visual and tactile ability to accurately perceive and act on objects and form in the environment. Strong imagination, read graphics, needs pictures to understand. Capacity to recognise forms, shapes and how they relate and interact. Sensitivity to the balance and composition of shapes.
Bodily-kinaesthetic[14]	Ability to handle objects skilfully, either fine or gross motor movements. Ability to control own movements for function or expression.
Intrapersonal	Enjoys working (being) alone. Has a good understanding of own strengths and weaknesses. Good at goal setting.
Interpersonal	Strong people skills.

Compiled from Sylwester (1995:108-114)

According to Sternberg (in Wiechers, 1993) intelligence and intelligent behaviour can be taught. Using this point of view and for the purposes of this study, the author of this thesis regards Gardner's dimensions of intelligence as **dimensions of potential** and defines dimensions of potential as follows:

- Potential is genetically given (based on nature).
- The development of potential is dependent on nature (physical care and maturation) and nurture (education).
- The development of given potential leads to functional competency.

[14] Sylwester (1995) remarks that bodily-kineasthetic involves the following brain structures: the basal ganglia (at the base of each hemisphere that coordinates the actions of the sensory and motor systems); the amygdala (limbic structures that provide the emotional trigger for movements); the motor cortex (narrow strips above the ears in each hemisphere) and the cerebellum (coordinates and fine-tunes automatic movement patterns). See Figure 2-7 on p 57.

- If an individual's full potential is developed, it implies 'intelligent behaviour' relevant to a specific task in a specific context.
- Intelligence in some dimension is potential that has developed to a functional state.

2.3 Brain-based learning

In this section recent views on learning from a brain-based perspective that emerged from research and insights on the functioning of the human brain are discussed. Sylwester (1995:vii) remarks:

> *Recent dramatic developments in the cognitive sciences are moving us closer to an understanding of our brain's development, organization, and operation. Increased understanding of the brain should lead to widespread discussions of the important issues that will arise out of these advances, and to the development of appropriate and effective educational applications of this knowledge.*

Key findings of research in neuroscience have indicated that *learning changes the physical structure of the brain* and *these structural changes alter the functional organisation of the brain* (Bransford *et al.*, 1999:103). Undoubtedly it can be stated that learning organises and reorganises the brain.

The strategy for learning facilitation of mathematics in a support course proposed in chapter three of the study proposes the principle of brain-based learning. Although it is beyond the scope of this study to give in-depth detail of the physiological functioning of the human brain, an overview is given of some basic structures and processes to provide a broad background for the definition of the mentioned strategy. However, the author endorses a remark by Vander, Sherman and Luciano (2001:358), namely that

> *Physiologists have only a beginning understanding of the brain mechanisms that give rise to mind or conscious experiences.*

2.3.1 Brain basics for education

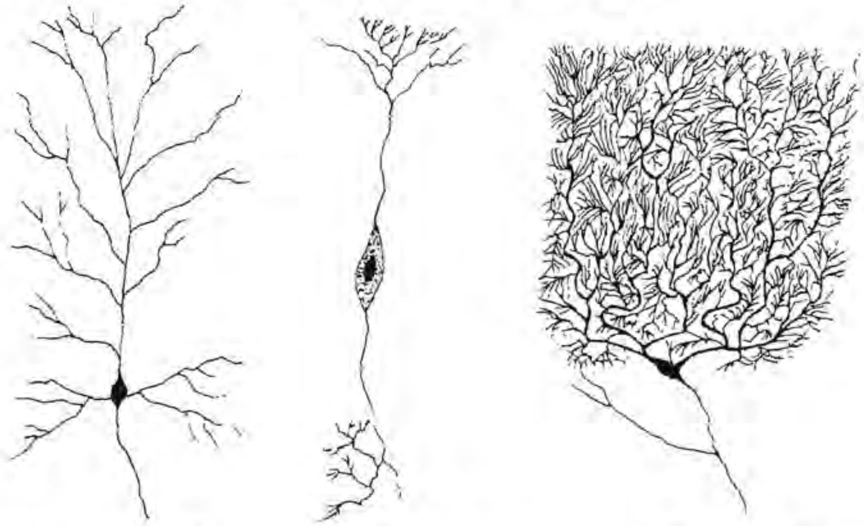
Hannaford (1995:18) points out that *learning proceeds as we interact with the world* and at a physiological level this interaction is communications among neurons. Sensory stimuli promote neurons to form dendrites to other neurons that bring the nerve cells into communication with these other neurons.

Neurons are viewed as the functional units in the brain and nervous system and are classified according to structure and function. Structurally there are three types namely, uni-polar; bi-polar and multi-polar of which the multi-polar type is the most common. In Figure 2-3 three examples of variations of multi-polar neurons in the brain are shown indicating the extensive occurrence of dendrites in some of the examples. Figure 2-4 on the following page illustrates a multi-polar neuron and the functions of the different parts. All of the structures in a neuron are involved in guiding and programming behaviour (Hannaford, 1995).

Functionally, neurons are classified as sensory, intermediate and motor. The sensory neurons bring sensory information to the brain and spinal chord from all over the body. The intermediate neurons form networks of neurons that relay information to other networks of neurons, process information and relay information via dendrites to motor neurons that carry messages from the brain and spinal chord to muscles and glands to activate their function.

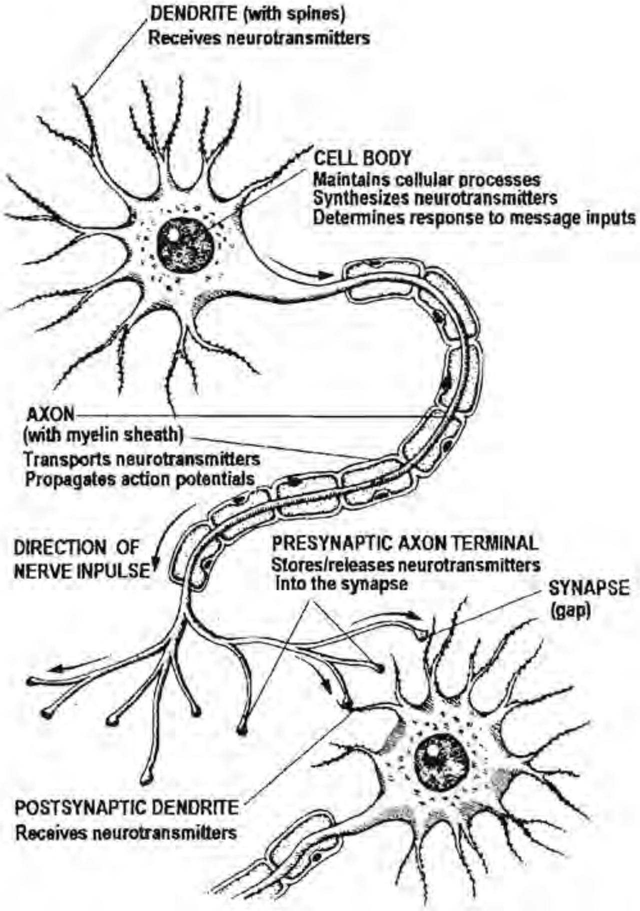
Hannaford (1995) points out that by learning, neurons are activated repeatedly and the more this occurs, the more myelin (see Figure 2-4 – myelin sheet occurs at the axon) is laid down. Impulses travel faster in highly myelinated neurons. It follows that the more practise, the more myelin and the faster the processing.

Figure 2-3 Examples of variations in neurons of the brain



Ornstein and Thompson (1984:62)

Figure 2-4 Functional model of a multi-polar neuron

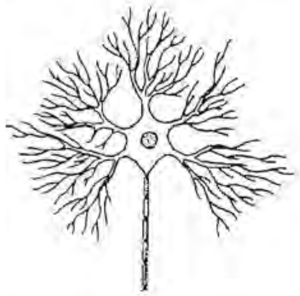


Sylwester (1995:31)

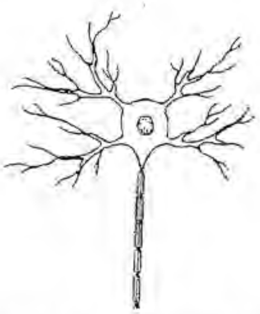
Through connections between neurons, neuronal groups are formed and continual repetitions of this process result in highly complex networks of dendrites. Simplistically put, these complex networks constitute the 'pathways' for activities in the brain. Dendritic branching occurs as a result of stimulation and synaptic connections (see Figure 2-5) are made as new learning occurs and these *linkages are paired down in a specific way that increases efficiency and thought* (Lichtman, Balice-Gordon & Katz in Hannaford, 1994). The magnitude of synaptic connections and the complexity of neuron networks are indicated by the fact that neurons have from 1000 to 10 000 synapses and may receive information from 1000 other neurons (Stevens, 1979, in Hannaford, 1994). Furthermore, it is possible to record neuron activity pulsing at a frequency of 40 to 70 Hz (Vander *et al.*, 2001).

Figure 2-5 Properties of neuron functioning

Figure 2-5 A Dendritic branching



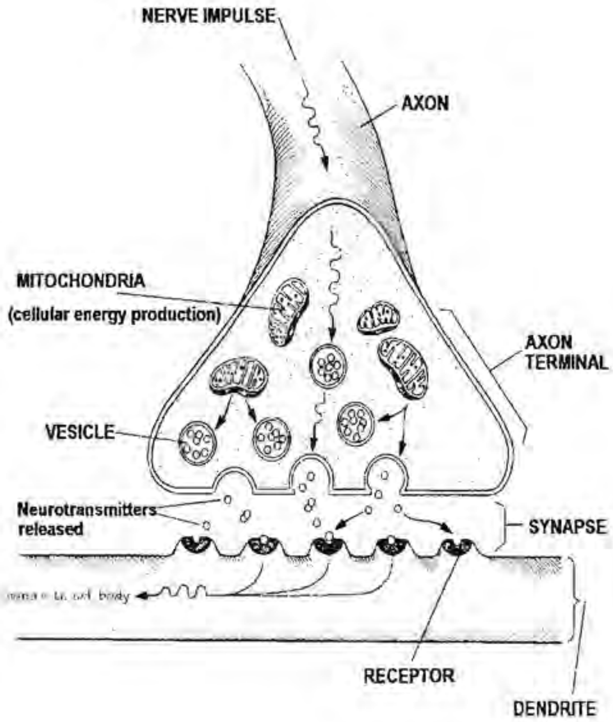
Extensive dendritic branching
(from active challenged minds)



Brain in deficient environment
shows sparse dendritic branching

Jensen (1996:144)

Figure 2-5 B Synoptic area



Sylwester (1995:34)

Crick and Koch (in Vander *et al.*, 2001) point out that conscious experiences require neural processes and that this neural activity is not restricted to a single cluster of 'consciousness neurons' but resides in a set of neurons that temporarily function together in a specific way. As we become aware of different things simultaneously, the particular set of neurons can shift among different parts of the brain dealing with, for example, visual or auditory stimuli; memories or new ideas, emotions or language. Similarly, Sylwester (1995) points out that information flow in the brain is multiplex and brain activity is distributed in the sense that several brain areas combine to process an event or object, even though certain activities are primarily executed in specific brain areas. Figure 2-9 on page 60 illustrates this phenomenon for language based activities.

Haile (1997) points out that learning occurs through the modification of brain structure although it is not yet known how this is done. The brain does not modify itself by growing new neurons but during youth the brain grows in complexity by increasing and refining connections between existing neurons (Ornstein & Thompson, 1984). Restak (in Haile, 1997) points out that the number of neurons is constant through adolescence and degenerates over the remaining lifetime with an average total loss of 10% of the original number. This loss is seemingly insignificant in relation to the brain's capacity. Selkoe (1992:101) remarks that the brain has *considerable physiological reserve to tolerate small losses of neuronal function.* From an educational perspective, Buzan (1991) points out that acquiring and using appropriate skills and practising techniques to aid learning, can contribute to ongoing mental alertness. According to Selkoe (1992:98) the brain is capable of *dynamic remodelling of its neuronal connections, even in the later years.*

Haile (1997) stresses that the brain is a self-modifying neural network and that the functions of the cerebral cortex include describing meaning to and interpretation of external and internal stimuli. He continues and points out that current knowledge of the human brain has implications for the nature of education. Haile (1997) interpreted results of research, done by Calvin, Singer and Searle in the early 1990s, regarding the role of cortical and neural activity in information processing and learning and remarks that these have implications for the nature of education.

Haile's proposals (1997:157) can be summarised as follows:

- **Learning is a natural activity** of the human mind.
- **Memory is a re-creation of information**. To be able to use what they know, students must learn cues that re-create useful neural patterns.
- Since learning creates new structures in the brain by modifying existing structures, **learning can only begin from things the student already knows**.
- The brain modifies neural connections as part of its response in those neurons that are activated to form a pattern. Learning new things amounts to a perturbation of things already known. If the perturbation is too large, then no related neural firing pattern can be created and no learning takes place. Students must be led to **new knowledge in small chunks** of information that allow the brain to modify existing neural networks. **Repetition** is then needed to strengthen new neural connections.
- **Understanding requires interconnected constellations of neurons**. Such elaborate networks allow for quick learning of new things because the vast networks offer numerous nodes that can easily be modified to assimilate new information.
- **Recognition is easier than recall** because recognition forms a meaningful pattern in response to an external stimulus while recall forms a meaningful pattern in response to an internal stimulus.
- **Learning is easier than unlearning.** During learning a neural network is modified to create a new net. Unlearning refers to correcting misunderstanding from earlier learning and involves not only the creation of a new network, but also suppressing the formation (use and strengthening) of the old erroneous pattern.
- **To learn, students must actively participate** in their own education. Only the student can modify his/her own neural networks.
- Quickness of mind versus intelligent thinking. **Intelligent thinking involves the identification of alternatives and choosing from among them**. This cannot necessarily be done quickly.

The author values Haile's views on learning as also being significant for mathematics education. Haile (1997) credibly connects important aspects of learning to neurological research findings. The relevance of Haile's statements above for the model of learning facilitation defined in this thesis is discussed in Chapter 3.

Due to the complex anatomy and physiology of the human brain, brain researchers and scholars focus their study on a specific aspect at one level. Approaches to studying the brain are either on small systems like single cellular brain mechanisms as done by neuroscientists (as in the examples mentioned in the paragraphs above) or a broader approach that focuses on complex cognitive mechanisms as done, for example, by cognitive psychologist (as in the examples noted in sections 2.1, 2.2 and 2.4).

In the following sections different models describing the architecture of the brain are discussed. These models are useful in understanding brain-based learning from an educational perspective but it should be stressed that they remain merely models of a highly complex object like the human brain.

2.3.2 The divided brain

The pioneering work of Sperry, Bogen and Vogel since the 1960s on split-brain patients (Herrmann, 1995 & 1996; Jensen, 1996; Ornstein & Thompson, 1984; Sylwester, 1996) has led to new insights about the human mind in the fields of neuroscience, psychology and anthropology.

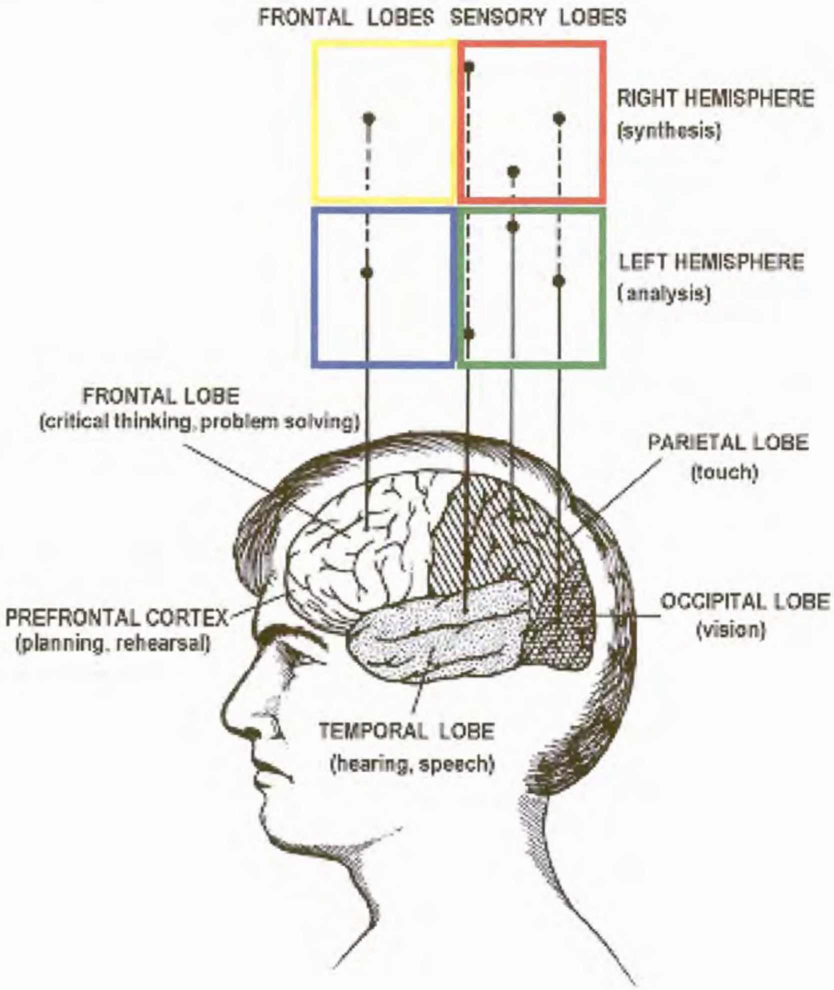
Although the work of Sperry and his colleagues was in the field of neuroscience, the implications thereof have been far reaching. Their research with patients suffering from severe epileptic seizures eventually brought to light the specialised functions of the human brain. In an effort to relieve patients of these seizures, they severed the corpus callosum (see Figure 2-7 on page 57), a thick band of nerve fibres connecting the left and right brain hemispheres. They then designed a series of tests in order to determine the functions of each brain hemispheres. The findings of these tests clearly indicated that unique cognitive functions are associated with each brain hemisphere. The diagram in Figure 2-6 on the following page shows the four brain lobes and a schematic top view of the cortex that is divided into a left and a right hemisphere and each of these is further divided into frontal and sensory lobes.

In the left brain right brain theory both the limbic brain and neocortex consist of a left and a right half. These halves are physically connected by three bundles of axionic fibres enabling the brain to coordinate the activities located in parallel regions of each cerebral hemisphere as well as connecting the activities of each limbic half with the cortex. This ensures left right as well as upper lower connections and coordination of brain function (Herrmann, 1995). Furthermore, these physical connections secure integrated brain activity.

Further research in neuroscience confirmed that functionally, the human brain can also be divided into two hemispheres, each with its own specialised functions, and much of the original findings of Sperry and co-workers remain valid (Gazzaniga, 1998; Jensen, 1994 & 1996; Vander *et al.*, 2001). These specialised functions associated with each hemisphere are listed in Table 2-5 on page 56. It has been established that for most people logical, analytical, quantitative and fact-based knowledge is located in the left hemisphere. The right hemisphere predominantly supports and coordinates intuition, emotion, spatial perception and kinaesthetic feelings.[15] About 90% of the population displays this functional distribution between the left and the right brain hemispheres and the functions are transposed for only 10% of the population (Vander *et al.*, 2001).

[15] The term "kinaesthesia" refers to *the brain's awareness of the position and movement of the body, limbs, etc., by means of sensory nerves in the muscles and joints* (Crowther, 1995:746).

Figure 2-6 The four brain lobes and schematic top view of the cortex



Adapted from Sylwester (1995:48)

Table 2-5 Specialised functions associated with each brain hemisphere

Left hemisphere (right side of body)	**Right hemisphere** (left side of body)
Speech / verbal	Spatial / music
Logical, mathematical	Holistic
Linear, detailed	Artistic, symbolic
Sequential	Simultaneous
Controlled	Emotional
Intellectual	Intuitive, creative
Dominant	Minor (quiet)
Wordly	Spiritual
Active	Receptive
Analytic	Synthetic, gestalt
Reading, writing, naming	Facial recognition
Sequential ordering	Simultaneous comprehension
Perception of significant order	Perception of abstract patterns
Complex motor sequences	Recognition of complex figures

Trotter (1976:219)

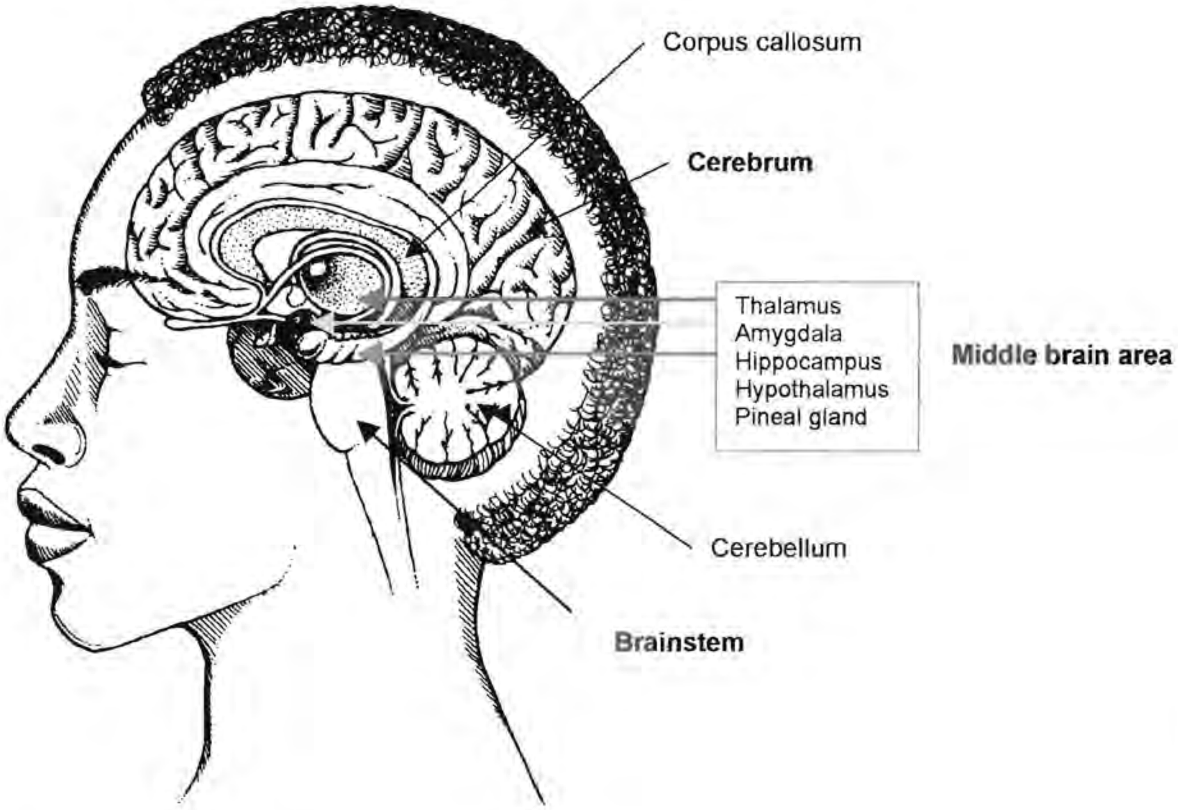
Unfortunately, enthusiasts of the left/right brain hemisphere principle simplistically categorised people as 'left brained' or 'right brained' which, from an educational perspective, resulted in a dichotomous left brain versus right brain view of 'discard the old left-brain way' and 'update to the right brain way' (Jensen, 1994 & 1996), whereas the brain should be understood as an integrated whole.

In addition to Sperry's left brain right brain model, MacLean defined the model of the triune brain (see Figure 2-10 on page 62). The triune model describes the brain as a hierarchy that evolved to process survival, emotional and rational functions. According to the triune model the brain is divided into the primitive reptilian brain, the limbic brain (paleomammilian brain) and the neocortex (neomammilian brain). The neocortex is the centre of higher cognitive activity that is unique to mankind. This model is simple, easily understandable and has been widely used in educational circles (Jensen, 1996; Sylwester, 1995). Jensen (1996:21) feels strongly that the triune model is *outdated, stereotypical and in some cases, dead wrong*. Cytowic (1993, in Sylwester, 1995) feels that the triune model is still useful as a functional metaphor of the brain's organisation but not as an exact model.

Jensen (1996) argues that certain functions of the brain are best understood if a model of the brain is described by a structural division in terms of the lower, middle and upper areas. Jensen describes this division as follows.

- The **lower area** is the brain stem area.
- The **middle brain area** contains the amygdala, hippocampus, thalamus, hypothalamus, pineal gland and other critical areas (Jensen does not specify 'other critical areas').
- The **upper area** is the cerebrum and neocortex covering it (see Figure 2-7).

Figure 2-7 Schematic model of the brain



Adapted from Sylwester (1994:42)

A summary of the functions of the brain according to the three areas proposed by Jensen (1996) is given in Table 2-6 below.

Table 2-6 Functions of the brainstem, middle brain area and cerebrum

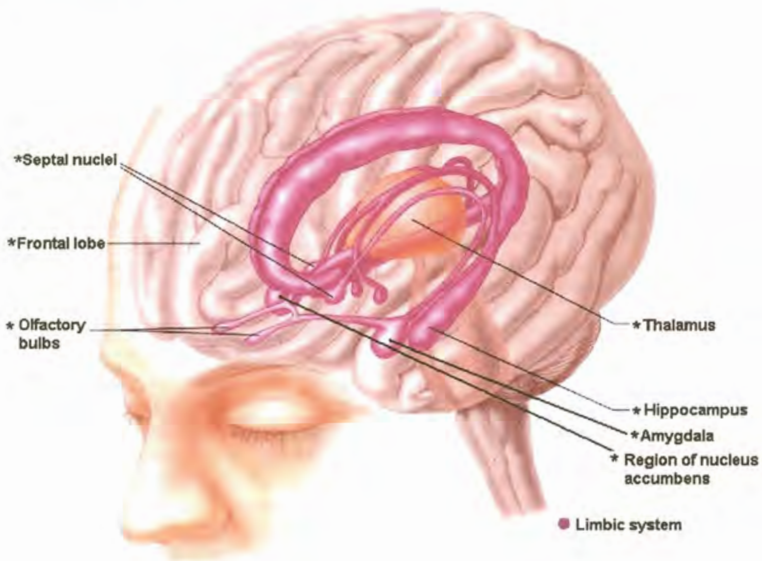
Brain area	Functions / Learner behaviour
Brainstem	Territoriality (defending the own). Social conformity and rituals. Deception (can form subverted aggression). Hierarchy.
Middle brain	Formation of memories. Long-term memory. Immediate expressiveness. Emotions (positive and negative). Sense of space and location. Attention and sleep. Hormones.
Cerebrum	Problem solving and computations. Language, writing and drawing. Thinking, reflection and consciousness. Visualising, envisioning. Reading, translating and composing. Creativity in art, music and theatre. Long range planning, forecasting. Some processing of emotions.

Compiled from Jensen (1996:21-35)

On the one hand Jensen's description of the functional areas of the brain incorporates the aspects of MacLean's triune model but on the other it points toward a 'functional whole brain'. Jensen views brain-based learning with relevance to cognitive, affective and physical aspects and uses the knowledge of the functioning of the brain areas to describe learning in terms thereof.

Selkoe (1992) points out that the limbic system is central to learning, memory and emotion. The diagram in Figure 2-8 on the following page illustrates the limbic system as well as all the brain structures that are involved in attention, emotion and motivation. It should be pointed out that emotion is not restricted to the limbic system but also involves the thalamus and the frontal lobe (Vander *et al.*, 2001). Smith (1998) points out that the formation of long-term memory strongly involves emotion whereas working memory is not related to emotions but to facts. He concludes that educators of mathematics need to stimulate emotional connections to subject matter to aid the transfer to long-term memory.

Figure 2-8 The limbic system and brain structures involved in attention, emotion and motivation



Adapted from Vander *et al.* (2001:215 & 362)

Recent research continues to point to the task specialised functioning of the brain also with regard to mathematical cognition. Using brain imaging techniques, Dehaene and Spalke (1999) report that approximate mathematical calculations take place in the brain's large-scale network involved in visual, spatial and analogical transformations. Rote arithmetic takes place in an area usually reserved for verbal tasks. Dehaene and Spalke also found that that these different kinds of mathematics problems were instantaneously assigned by the brain to their respective areas. These findings suggest that specific neuron circuits complete both the calculation itself and the decision to perform it.

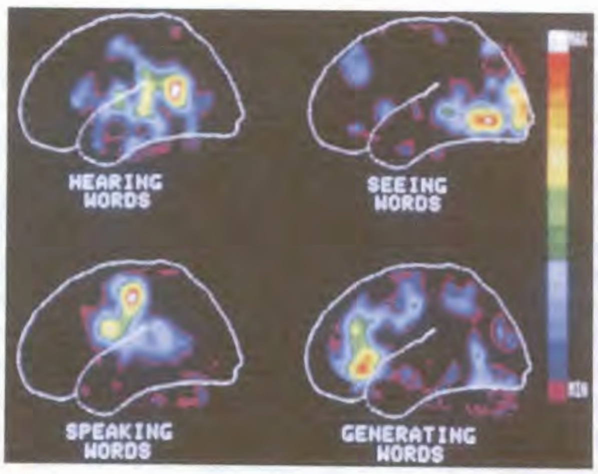
In the following section the focus is on research that indicates that the brain functions as a complex whole.

2.3.3 The integrated brain

Since the early 1990s the development of modern technology has undoubtedly contributed to further understand the complex functioning of the human brain. Computer assisted tomography (CAT) and magnetic resonance imaging (MRI) can distinguish minute brain structures; positron emission tomography (PET) and single photon emission computerised tomography (SPECT) track bloodflow (a sign of brain activity), whereas super conducting quantum interferences devices (SQUID) pick up magnetic fields (also a sign of brain function).

In Figure 2-9 PET scans reveal changes in blood flow during various language-based activities. Although similar images for distributed brain activity when doing mathematics are not readily available, the mentioned research by Dehaene and Spelke (1999) probably showed comparable images.

Figure 2-9 **PET scans of different language based activities**



Vander *et al.* (2001:368)

There is undoubtedly agreement that the brain is highly specialised and that different aspects of thought and action are done in different parts of the brain. In addition, there is also consensus that the brain operates simultaneously on many levels and that events occurring in one hemisphere can and do influence events occurring at the same time in a very different remote part of the other hemisphere.

Crick (in Jensen, 1996:9) affirms that the functions of the brain are *usually massively parallel* and Levy (in Jensen, 1996:14) points out that *both sides of the brain are involved in nearly every human activity.*

Much speculation has been done on how much of the brain's capacity we use. Figures quoted range from less than 2% to 20 % (Buzan, 1991; Lumsdaine and Lumsdaine, 1995a; Bransford *et al.*, 1999). These speculations are based on findings from early experiments recording electroencephalogram (EEG) that measured brain activity when subjects performed different tasks (Herrmann, 1995; Ornstein *et al.*, 1984). The author is of the opinion that the use of new technologies to reveal brain activity may change these figures significantly if PET scans as in Figure 2-9 could be used to show (distributed) brain activities when cognitive tasks are performed.

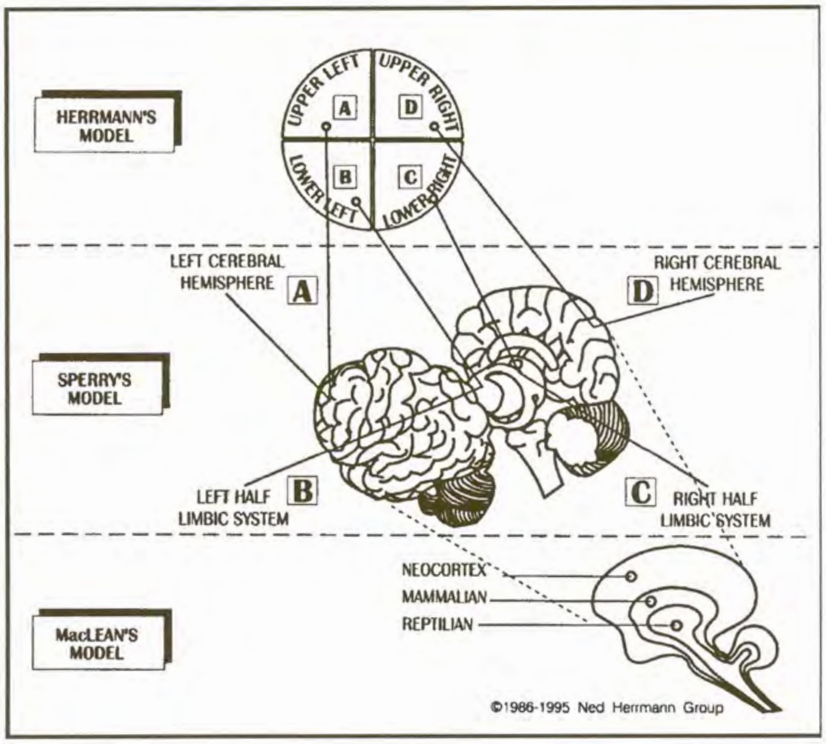
2.3.4 The Herrmann four quadrant whole brain model

In the early 1980s Herrmann (1995; 1996) combined Sperry's left-brain right-brain model of the functioning of the brain with theories of how the human brain is physiologically organised to develop a metaphoric whole brain model. Figure 2-10 illustrates how the four-quadrant concept is embedded in the left/right hemisphere brain theory as well as in the triune brain theory.

Herrmann (1995) regards the four quadrants (A, B, C and D) identified in his model as interconnected clusters of specialised mental processing modes. He points out that they function together 'situationally' and 'iteratively'.[16] Figure 2-11 gives more detail regarding the cognitive modes related to each quadrant.

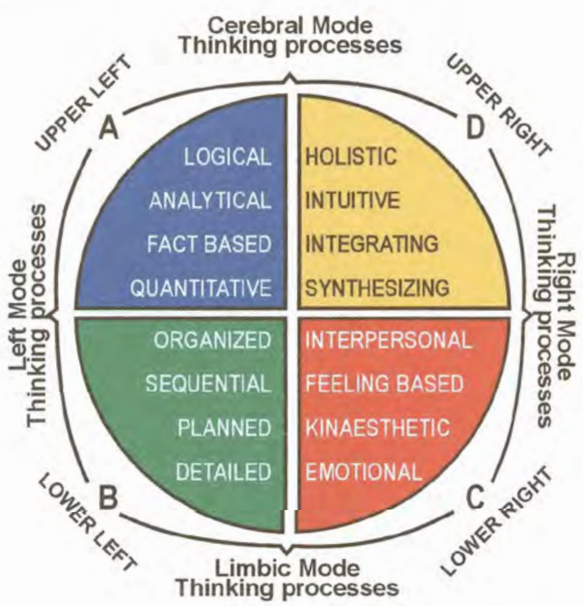
[16] The author assumes that the term "situationally" refers to *in context* (Crowther, 1995:1298) and the term "iteratively" refers to *repeatedly* (Crowther, 1995:723) indicating continuous activity in both hemispheres.

Figure 2-10 The whole brain model of Herrmann and its physiological roots



Adapted from Herrmann (1995:40 & 64; 1996:14)

Figure 2-11 The Herrmann whole brain model



Adapted form Herrmann (1995:411)

According to Hermann the upper cerebral modes function on a higher cognitive level than the lower limbic modes. The dominant processes in the left hemisphere include logic, analysis, words, numbers, sequence, organisation, detail. The dominant processes in the right hemisphere include holistic conceptualisation, synthesis, integration, intuition, imagination, colour, emotions, kinaesthetic feelings, spatial awareness, rhythm and dimension (Herrmann, 1995; Buzan, 1991). Herrmann (1995, 1996, 1998) identifies eight key characteristics of the normal human brain. These are summarised in Table 2-7.

Table 2-7 Key brain characteristics according to Herrmann

The brain is	This means that
Unique	Every human being's brain is as unique as a fingerprint.
Specialised	The human brain is specialised in obvious ways, as in the ability to talk, listen, see, feel, touch, etc. It is also specialised in how we think – the logical processes, procedural processes, emotional processes, the ability to see the whole picture, to think intuitively as well as analytically. All human beings have these specialised modes.
Situational	As one engages in a particular activity that requires, for example, talking or thinking mathematically, the part of the brain that is specialised to perform that function becomes engaged and active in it as required.
Interconnected	The specialised structures of the normal brain are interconnected by millions of axionic fibres. This fact disavows the oversimplification of 'left brain/right brain'.
Iterative	The interconnections in the normal brain provide the structure for the brain to alternate between specialised modes. One can think logically and rationally and also intuitively and conceptually and move back and forth between these separate modes.
Dominant	Dominance of paired structures occurs naturally. Similarly, for the pairs of structures in the brain one becomes dominant with respect to the other.
Malleable	The normal brain is so adaptable that there are virtually no inherent constraints.
Whole	The structures and interconnections all provide the basis for the normal brain to function in its entirety.

Compiled from Herrmann (1995, 1996, 1998) and Herrmann International (1999a).

It should be borne in mind that although Herrmann's model is based on the divisions of the physical brain, it is a metaphoric model. However, the Herrmann model remains a useful way to describe learning and learners. The principles underpinning Herrmann's model is used a point of departure for the learning facilitation strategy proposed in chapter three. Furthermore, the key characteristics listed in Table 2-7 underscores the premise that the mathematics potential of a tertiary learner on a support course can be developed.

2.4 Recent views on learning and learners

Based on the report by the Committee on the Developments in the Science of Learning in the USA (Bransford *et al.*, 1999) the following three core learning principles emerged from new developments in the science of learning.

1. Students come to the classroom with **pre-existing knowledge.**

The initial learning phase of any content (subject) is based on knowledge that people bring to the learning situation. The importance of building on previous experiences and working with existing understandings is relevant and important for learners of all ages. (Bransford *et al.* 1999).

2. To develop competence in an area of inquiry, students must have a **deep foundation of factual knowledge**, understand **facts and ideas** in the context of a **conceptual framework** and **organise knowledge** in ways that facilitate **retrieval and application** (Donovan, Bransford & Pellegrino, 1999).

The mentioned two principles for developing competence emerged from research that compared the performance of novices and experts and from research on learning and transfer. Bransford *et al.* (1999) point out that although it cannot be expected that all learners should become experts, the study of expertise shows what the results of successful learning look like. According to them, research has identified key principles of experts' knowledge that can have implications for learning and instruction. The author of this thesis is of the opinion that of these principles, the following have significance for the learning facilitation of mathematics in a support course:

- Experts notice features and meaningful patterns of information that are not noticed by novices. Research on expertise suggests the importance of providing students with learning experiences that specifically enhance their abilities to recognise meaningful patterns in information. Processing of 'patterns' forms a significant aspect of the strategy for learning mathematics that is proposed in chapter three of this thesis.

- Experts have acquired a great deal of content knowledge that is organised in ways that reflect a deep understanding of their subject matter. Donovan *et al.* (1999:12) add that an *expert's command of concepts shapes their understanding of new information.* In mathematics, experts are more likely than novices to first try to understand problems rather than simply attempt to use formulas to derive an answer (Bransford *et al.* 1999). In organising curricula, care should be taken not to overemphasise or superficially cover facts, but to give learners enough time to develop important organising concepts and promote conceptual understanding. Donovan *et al.* (1999:12) also remark that

  > *The ability to plan a task, to notice patterns, to generate reasonable arguments and explanations, and to draw analogies to other problems are all more closely intertwined with factual knowledge than was once believed.*

- Experts' knowledge cannot be reduced to sets of isolated facts or propositions but, instead, it includes a specification of the context in which it is useful. For mathematics learning in introductory calculus the implication hereof is that learners must thoroughly understand the fundamental concepts of calculus for use as reference.

- Experts are able to flexibly retrieve important aspects of their knowledge with little additional effort. Bransford *et al.* (1999) point out that people's ability to retrieve information can vary from being 'effortful' to 'relatively effortless' (fluent) to 'automatic'. They continue to say that fluency is important because effortless processing places fewer demands on conscious attention. Applying this principle to mathematics learning in introductory calculus means that learners need to acquire the knowledge of the fundamental concepts of calculus in order to access and use these (at least) fluently.

The third core principle that emerged from research on learning and learners and noting the differences between experts and novices is that

3. A **metacognitive approach** to instruction can **help students learn to take control of their own learning** by defining learning goals and monitoring their progress in achieving them. (Donovan *et al.*, 1999).

According to Bransford *et al.* (1999) experts have varying levels of flexibility in their approach to new situations. This provides an important model for learning in the sense that experts approach new situations flexibly and learn throughout their lifetimes. This presupposes a metacognitive awareness of own performance. This principle thus endorses the view expressed on metacognition in section 2.2.2 on page 40.

It seems appropriate that facilitation of learning should also encourage the development of flexibility in approach and thus foster adaptive expertise. Applied to the current study, this view is congruent with the principle to 'develop a learners' mathematics potential' encompassing the ability to learn and do mathematics using all thinking modes as defined in the proposed strategy for learning facilitation of mathematics.

2.5 Learning styles

This section by no means attempts to give a comprehensive account of learning style models that are currently available. The following discussion only gives an overview of thinking and learning styles that contribute to the strategy for learning mathematics proposed in chapter three of this thesis.

Schmeck (1988) describes the term "style" as an inclination to use the same strategy in varied situations and Entwistle and Ramsden (1983) uses "style" to refer to a stable, trait like consistency in one's approach to attending, perceiving and thinking.

In the following sections the Herrmann Brain Dominance model, the Lumsdaine and Lumsdaine model and the Felder Silverman model concerning thinking and learning styles as well as lateral dominance profiles are discussed. The Herrmann Brain Dominance (HBD) model and the Lumsdaine and Lumsdaine model for thinking and learning styles were selected because of their strong relevance to the principle of brain-based learning. The Felder Silverman model was chosen because it emerged from experiences specifically with engineering students. Although the effect of lateral dominance on thinking and learning styles was not researched in this study, the author is of the opinion that this aspect is worth referring to as it can contribute to improve the learning facilitation of mathematics.

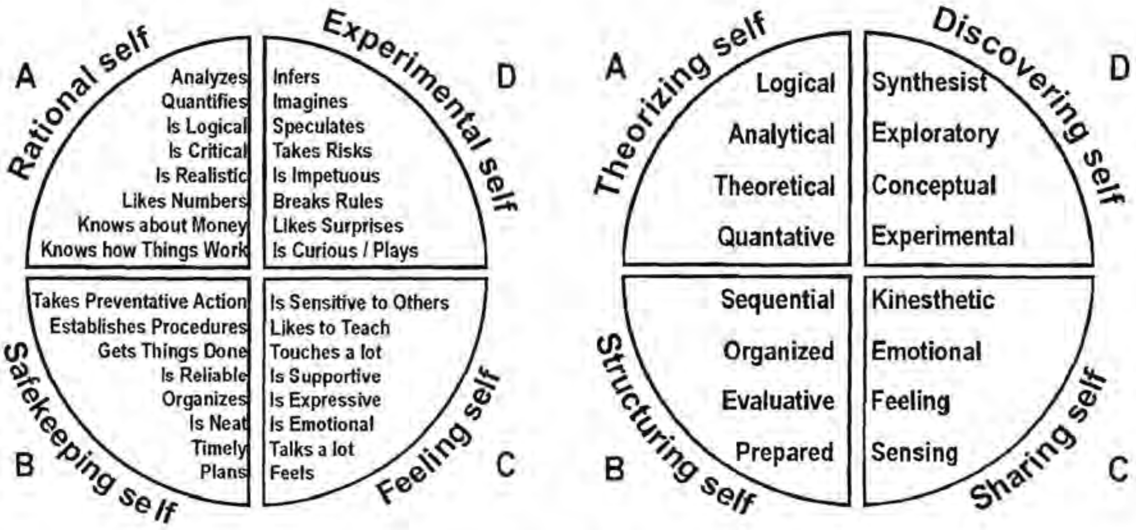
2.5.1 The Herrmann model

Herrmann used his metaphoric whole brain model (section 2.3.4) as a basis for describing thinking style preferences. He sees thinking styles as a 'coalition of four different thinking selves' (Herrmann, 1996). These four different selves are shown in Figure 2-12 A on the following page.

According to Herrmann people develop preferred modes of thinking that can be related to use of the dominant structures in the brain. Lateral dominance (between brain hemispheres, eyes, ears, hands and feet) is innate and influences the way in which the brain and body handle and process information. In the case of hands and feet these differences are quite obvious and the more frequent and repeated use of, for example, the dominant hand, makes it stronger and more capable. Herrmann argues (1995, 1996, 1998) that in the case of the brain, one's preference to think in particular ways results in more frequent use of a particular brain area with the resulting development of greater competency for the set of mental activities that are located in that specialised area. Herrmann continues to say that at birth, the brain is without developed preferences and is therefore essentially 'whole'. As a result of an individual's life experiences, the brain acquires preferences as it matures. The developing brain can be seen as an evolving coalition of many different preferences. The degree of a one's preference for each of the four styles is unique to every person. Herrmann interprets these preferences from different perspectives. Using the perspectives as in Figure 2-12 A and in Figure 2-12 B on the following page, Herrmann describes learners as **analysers**, **organisers**, **personalisers** and **visualisers**.

Figure 2-12 The Herrmann model for learning styles

Figure 2-12 A Different selves **Figure 2-12 B Learning selves**



Herrmann (1996:30) and Herrmann International (1999a)

According to Herrmann (1995; 1996):

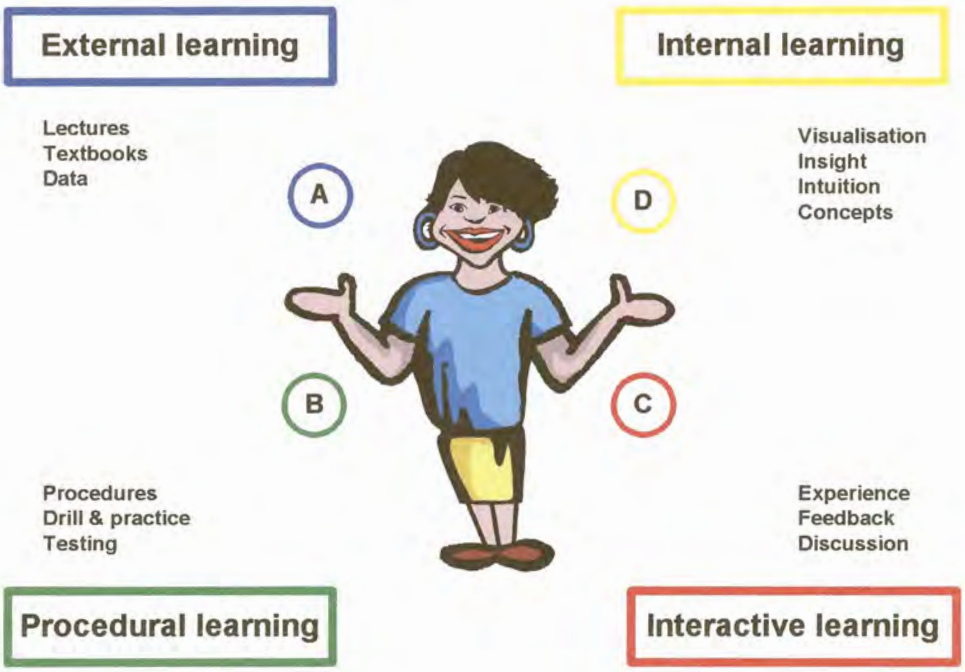
- The A-quadrant **analyser** is characterised by logical thinking, analysis of facts and processing numbers.
- The B-quadrant **organiser** is characterised by planning approaches, organising facts and detailed review.
- The C-quadrant **personaliser** is interpersonal, intuitive and expressive.
- The D-quadrant **visualiser** is imaginative, thinks in big pictures and can conceptualise.

2.5.2 The Lumbsdaine and Lumbsdaine model

Applying the principles of Herrmann's model Lumsdaine and Lumsdaine (1995a) and Lumsdaine, Lumsdaine and Schellnut (1999) distinguish four modes of how tertiary students learn, namely **external** learning, **internal** learning, **interactive** learning and **procedural** learning. An adapted version of the Lumsdaine and Lumsdaine model is illustrated in Figure 2-13 on the following page. The connection of the Lumsdaine and Lumsdaine model with the Herrmann model is indicated in Figure 2-13 and outlined in the following definitions.

- **External learning** is related to teaching from authority through lectures and textbooks. This is predominantly A-quadrant learning in terms of the Herrmann model.
- **Internal learning** is related to learning through insight, understanding concepts globally and intuitively, synthesis of data and personalising content into context. This is predominantly D-quadrant learning in terms of the Herrmann model.
- **Interactive learning** comes from experience, hands-on activities, discussion and feedback (with an opportunity for encouragement). Interactive learning is predominantly C-quadrant learning.
- **Procedural learning** is characterised by a methodical approach, practice and repetition to improve skills and testing. Procedural learning is predominantly B-quadrant learning in terms of the Herrmann model.

Figure 2-13 Lumsdaine and Lumsdaine's four modes of student learning



Adapted from Lumsdaine and Lumsdaine (1995a:97); Lumsdaine *et al.* (1999:63)

2.5.3 The Felder Silverman model

Felder and Silverman (1988:674) point out that *learning in a structured educational setting may be thought of as a two-step process involving the reception and processing of information.* They continue and indicate that reception involves external as well as internal information and processing encompasses memorisation, reasoning and some kind of action. The author of this thesis is of the opinion that this process can also be described as a three-step process of reception, processing and action.

Felder *et al.* (1988) synthesised findings from a number of studies and formulated a learning style model with five dimensions that are particularly relevant to engineering (and science) education. The five dimensions of this model are listed in Table 2-8. Felder *et al.* point out that the dichotomous learning style dimensions of the model are continua and not either/or categories (Felder, 1993).

Table 2-8 Categories of the Felder Silverman model

1	A learner's preference for the type of information that is perceived:	
	Sensory (external) through sights, sounds, physical sensations	**Intuitive** (internal) through possibilities, insights, hunches
2	The modality through which sensory information is effectively perceived:	
	Verbal through words and sounds	**Visual** through pictures, diagrams, graphs, demonstrations
3	How the learner processes information:	
	Reflectively through introspection	**Actively** through engagement in physical activity or discussion
4	How the learner progress towards understanding:	
	Sequentially in continual steps	**Globally** in large jumps (holistically)
5	The organisation of information that is most comfortable to the learner	
	Deductive - principles are given, applications deduced	**Inductive** -observations are given, principles are inferred

Compiled from Felder (1993), Felder *et al.* (1999), Felder *et al.* (1988)

According to Felder (1993) and Felder *et al.* (1988), **sensors** like facts, data, detail, repetition and well-established procedure. They are careful in what they do but may be slow. **Intuitors** like principles, complexities, words and symbols and are quick but may be careless. **Verbal learners** get more information from written and spoken words and mathematical formulas whereas **visual learners** prefer information given in graphs, diagrams, schematics, etc. **Reflective learners** do much of their processing introspectively by thinking things out on their own. **Active learners** like to work in groups and to experiment. **Sequential learners** progress linearly working in small steps and are good at analysis. **Global learners** progress through intuitive leaps and are good at synthesis.

2.5.4 Dominance Profiles

The concept of a profile that depicts lateral dominance and that can be used as a learning style assessment system originated in the early 1970's from studies by Dennison with so-called 'learning disabled' children in which he found that deficits mostly occurred in physical/perceptual abilities (Dennison & Dennison, 1997).

The dominance profiles described by Dennison and Dennison (1997) and Hannaford (1995 & 1997) identify the lateral dominance of eyes, ears and hands in relation to the genetic dominant brain hemisphere. Hannaford (1997:10) points out that a person's lateral dominance is basically innate and that these patterns of lateral dominance *greatly influences the way that information is internally processed by an individual and consequently the kind of learning activities he or she prefers.*

Hannaford (1995, 1997) also points out that a lateral dominance profile gives information about how a person takes in, assimilates and processes sensory information and then how a person responds to and express new learning. A person's sensory intake is ideally facilitated when the dominant eye, ear, hand and foot are on the opposite side of the body from the dominant brain hemisphere. However, Hannaford emphasises (1997) that it is necessary to use both hemispheres of the brain to optimise proficiency at anything.

In section 2.3 of this chapter it was mentioned that increased neuron activity stimulates the branching of dendrites and the more branching occurs, the more connections are formed and the faster processing can occur. Hannaford (1997:18) points out that this principle also applies to the connections between the two brain hemispheres and that the faster the processing between the hemispheres is, the more *intelligently we are able to function*.

Hannaford (1995:112) notes that *every learning situation deals basically with the same steps: sensory input, integration and assimilation, and action*. In order to facilitate the perceptual and physical functions necessary for learning, Dennison developed a set of so-called Brain Gym[17] exercises. According to Dennison and Dennison (1997) Brain Gym exercises are aimed at neural and cortical activation and increasing the supply of oxygenated blood to the brain. Brink (in Hannaford, 1997:112) points out that *a coordinated series of movements produces increased neurotrophins (natural neural growth factors) and a greater number of connections among neurons*.

It should be noted that Dennison and Dennison's Dominance Profiles and Brain Gym exercises were not included in the research activities reported in this study.

2.6 Profile of a learner

The diagrams in Figure 2-14 summarises the view proposed by the author of this thesis concerning the facets (characteristics) regarding a learner of mathematics enrolled for a support course in the first year of tertiary study. For the purposes of this study Woolf's definition (1977:410) the term "facet" is accepted, namely that "facet" indicates *any of the definable aspects that make up a subject (as of contemplation) or an object (as of consideration)*.

The first facet concerns the (mathematics) potential of a learner. The second facet represents the way in which humans think and learn. The third facet concerns the way in which information is processed. The third facet is recognised but was not researched in the study reported in this thesis. Study orientation in mathematics is regarded as the fourth facet. These four facets are embedded in the learner's total environment comprising further multiple facets including aspects related to the learner's physical, social, academic and political circumstances. It inevitably follows that although these facets are identified, their composition is uniquely defined for every individual learner.

[17] Brain Gym is a registered trademark of the Educational Kinesiology Foundation, California, USA.

Furthermore, the author of this thesis is of the opinion that the development of the (mathematics) potential of a learner could be viewed in the light of Maslow's hierarchy of needs. This hierarchy (Schunk, 1996:289-290), consists of *physiological needs* (the lowest level), *safety needs*, *belongingness (love) needs*, *esteem needs* (including self-esteem and esteem from others) and *self-actualization* (the highest level). Maslow (in Schunk, 1996:290) points out that self-actualisation is *the ongoing actualization of potentials, capacities and talents* (in mathematics) and can only be achieved once the lower-level needs have been met. Although the author of this thesis acknowledges that unmet lower-level needs can have an effect on the development of a learner's mathematics potential, this aspect was not explicitly addressed in this study.

The comprehensive profile comprising the characteristics of a learner of mathematics in a support course is illustrated in Figure 2-15. This profile should be interpreted as a dynamic profile in the following way. In the second facet (whole brain learning and thinking learning and thinking) the left side (the sections logical/factual and sequential/structured) and the right side (the sections holistic/conceptual and explorative/intuitive) can be transposed. This is to accommodate the 10% cases of the population where linear cognitive processing is located in the right brain hemisphere and global cognitive processing is located in the left brain hemisphere.[18] To ensure that the positioning (alignment) of the second facet is correct, namely that both sections combined and identified as "linear" and both right sections combined as and identified "global", a triangle and circle are used as markers. The top triangles and bottom circles should always be aligned. The third and fourth facets, representing the information processing modes and aspects of study orientation respectively, can each rotate independently. Each of the aspects in all the facets can be thus aligned (or not aligned) to another.

It follows that the possible combinations of alignment between the aspects in the different facets of this learner profile are multiple. In a way this illustrates the complexity of how a learner's preferences and competencies may be matched or mismatched. One can only speculate about the influence that the degree of such matching or mismatching can have on learning and learning facilitation of mathematics in a support course on first year tertiary level.

[18] See section 2.3.2

Figure 2-14 Facets describing learners of mathematics in a support course

First facet: Learner potential

The learner enrolled for a support course has the potential to succeed in a first semester standard calculus course. The dimensions of potential defined in this chapter[19] are thus reaffirmed. These include that

- potential is genetically given
- the development of potential is dependant on physical care as well as on education
- developed potential leads to functional competency
- developed potential (in mathematics) implies intelligent behaviour (in mathematics).

Second facet: Four quadrant whole brain

The learner is viewed as somebody who has a preferred way of thinking and learning. For the purposes of the research reported in this study thinking preferences are mainly categorised according to the Herrmann four quadrant whole brain model.

A four quadrant whole brain approach entails not only accommodating one's preferences for specific cognitive modes but also developing less preferred modes for thinking and learning.

Third facet: Information processing

The third facet represents the modes by which information is processed. These modes are acknowledged and briefly discussed in this chapter but were not researched in this study.

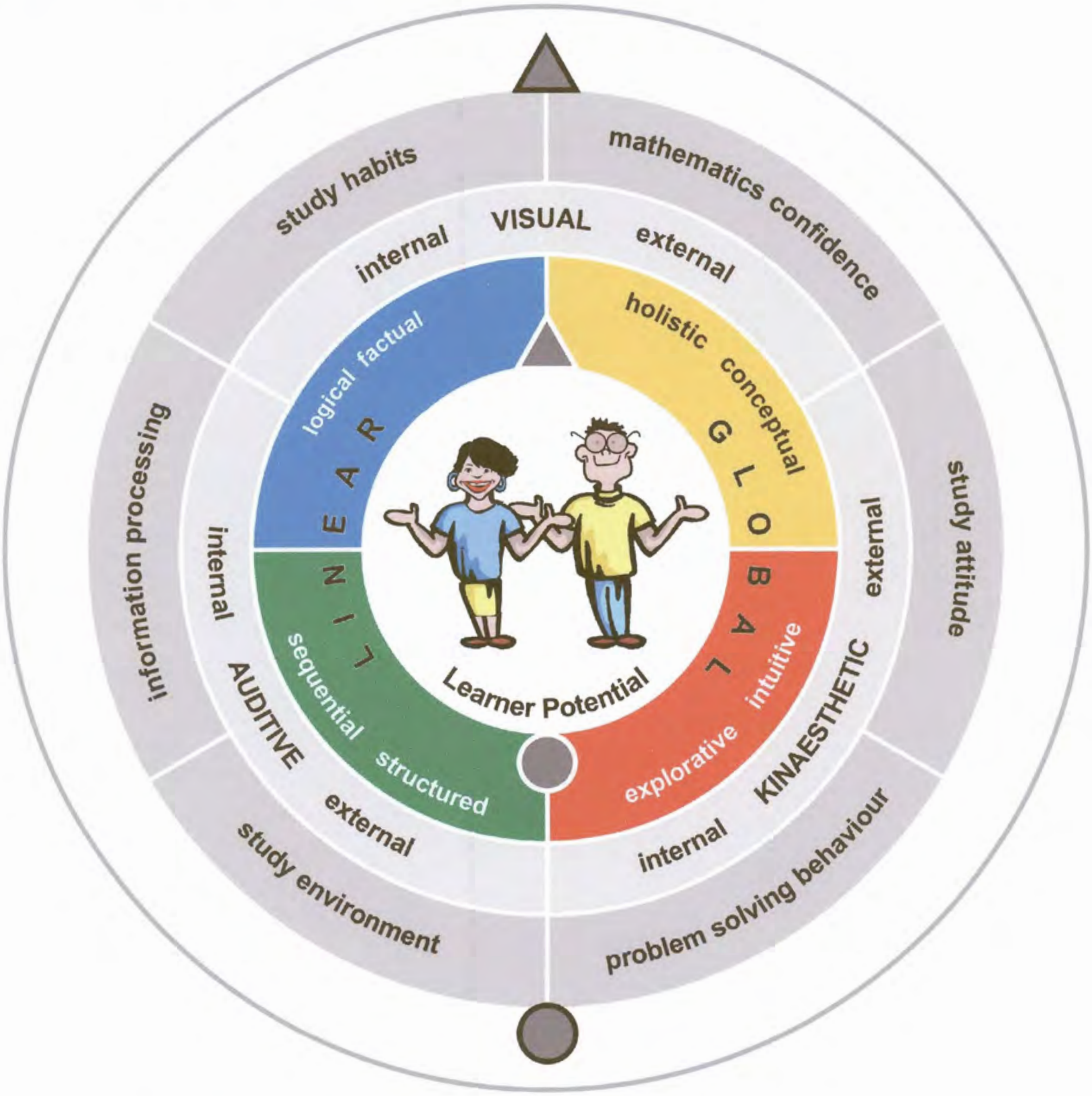
Fourth facet: Study orientation

This facet focuses on six aspects pertaining to study orientation in mathematics. These aspects include study attitude, mathematics confidence, study habits, problem solving behaviour, study environment and information processing.

Proposed and compiled by the author of this thesis.

[19] See page 46.

Figure 2-15 Profile of learners of mathematics in a support course



Proposed and compiled by the author of this thesis.

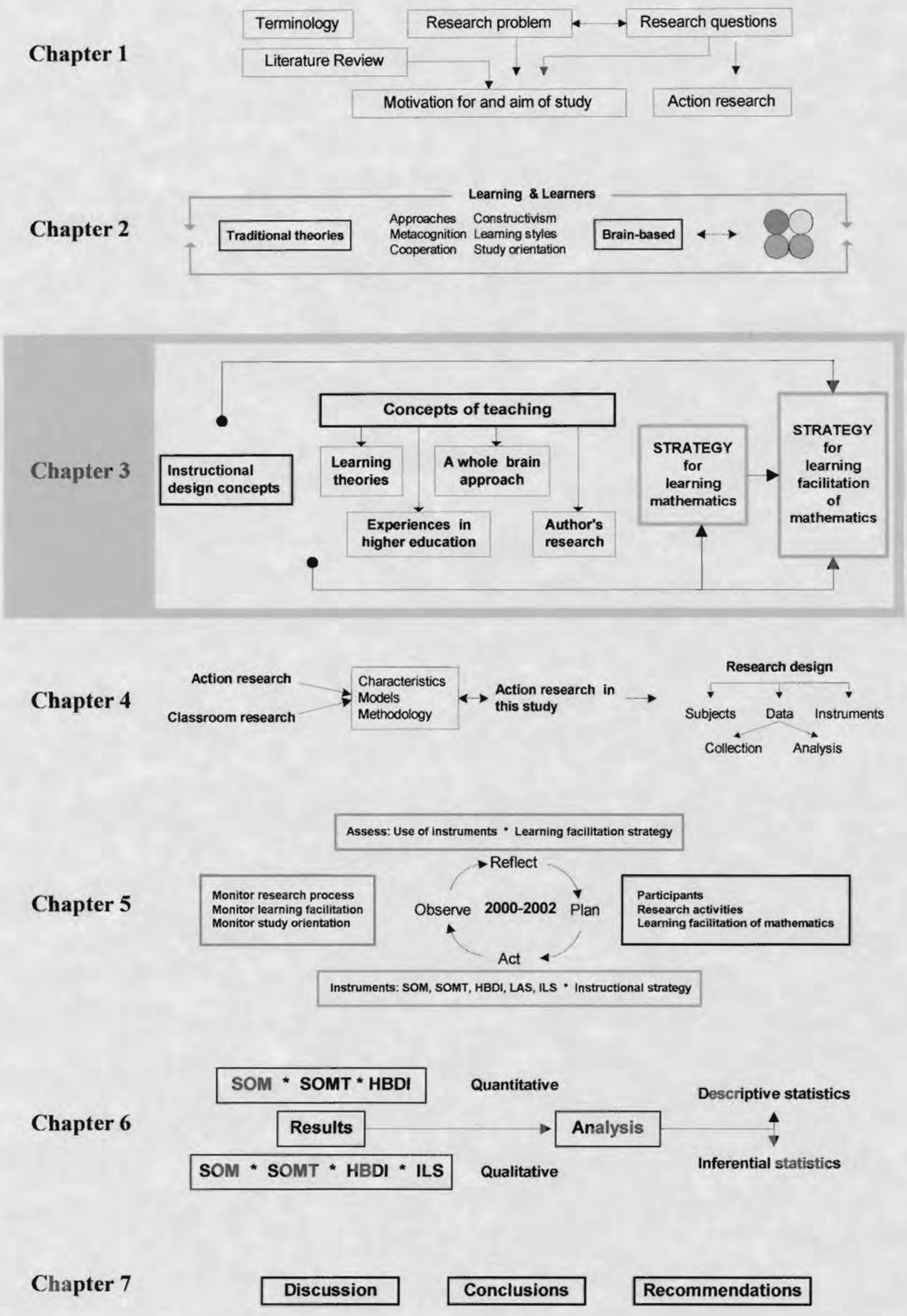
During the research conducted in this study, the learners (participants in the study) were viewed according to the profile proposed in Figure 2-15. Against this background and within the context of the aspects of learning addressed in this chapter, a strategy for the learning facilitation of mathematics in a support course is proposed in the following chapter.

2.7 Summary

The extent of the complexity of human learning is such that it cannot be described by a single definition. It encompasses more than the physical, functional, psychological, developmental and social aspects of an individual. These aspects can be (and have been) described and interrelated by numerous researchers. Justly, Cross (1998:1, 8) remarks that

> *We have more information on learning available to us than ever before in the history of the world, and the amount of research on learning is escalating at an alarming rate. ... Looking carefully at how even one student learns is often quite revealing. ... Every student ... has a lesson to teach us about how students learn. ... If we are to take learning seriously, we will need to know what to look for (through research), to observe ourselves in the act of life-long learning (self-reflection), and to be much more sensitively aware of the learning of the students that we see before us everyday.*

A first year engineering student enrolled for a support course (as is the case with the POSC students who participated in this study) can be viewed as a developing learner that has the potential of multiple intelligences. Traditional theories of learning alone can no longer be used to describe the cognitive activity of such a learner in the early 2000s. The learner should holistically be viewed as an active, creative, rational and emotional human being who is part of a personalised social environment but engulfed in a new tertiary academic environment.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A learning facilitation strategy for mathematics

Chapter 3

A learning facilitation strategy for mathematics

3. Introduction

> *The sheer magnitude of human knowledge renders its coverage by education an impossibility; rather, the goal of education is better conceived as helping students develop the intellectual tools and learning strategies needed to acquire the knowledge that allows people to think productively about .... Mathematics.* (Bransford *et al.*, 1999:5).

In this chapter a theoretical basis for instructional design principles that are applicable to the present study are identified. Examples of perspectives on instruction that contribute to a narrative for the learning facilitation of mathematics in a support course are discussed. A brain-based approach to learning and teaching and aspects of teaching resulting from experiences in higher education are addressed. The results of previous research by the author on the learning facilitation of mathematics in a support course are also summarised. The chapter concludes with the proposal of a strategy for the learning facilitation of mathematics in a support course.

3.1 A theoretical basis for instructional design

Gagné and Briggs (1974:4) point out that

> *The purpose of designed instruction is to activate and support the learning of the individual student. .... The purpose of planned instruction is to help each person develop as fully as possible, in his or her own individual directions.*

Gagné and Briggs (1974:4-5) regard the following five characteristics as fundamental when instruction is designed, namely:

1. Instructional design must be aimed at **aiding an individual's own learning.**
2. Instructional design has **immediate and long-range phases**. Long-range aspects are more complex and varied and concerns designing a course or an entire instructional

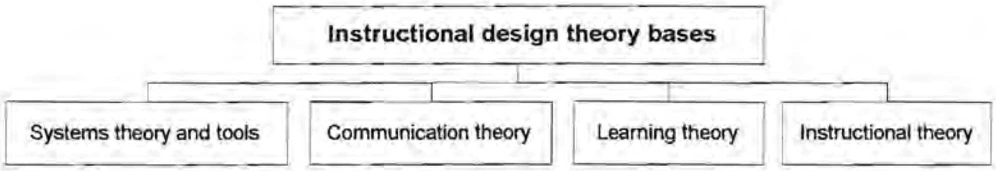
system. The immediate phase involves day-to-day planning and this phase can benefit from proper long-range design.

3. Systematically designed instruction can greatly **affect individual human development**. Providing only a nurturing environment is not sufficient — specific opportunities must be created for learners to develop fully.
4. Instructional design should be conducted by means of a **systems approach**.
5. Designed instruction must be based on knowledge of **how human beings learn**.

According to Smith and Ragan (1993) the most critical assumptions underlying instructional design are that the resulting instruction should be effective, efficient and appealing. Furthermore, students must participate actively and interact mentally and physically with material to be learnt. They also point out that evaluation of the instruction as well as of the learner's performance should be done and these insights ought to be used to revise the instruction. There should also be congruence among objectives, learning activities and assessment — the objectives should direct the activities and assessment.

Smith and Ragan (1993:14) regard the general systems theory, the communication theory, theories of learning and theories of instruction as the major theories that contribute to instructional design. This view is illustrated in Figure 3-1.

Figure 3-1 Theoretical bases for instructional design



Adapted from Smith and Ragan (1993:23)

According to Smith and Ragan's (1993) view, the **systems theory** highlights the interrelationships between the components in instruction and the **communication theory** is important for describing the way in which information is transferred from one person to another. The communication theory is also significant for the selection of the media that is used to support instruction.

The importance of **theories of learning** for instructional design is summarised by Ertmer and Newby (1993:50) when they remark that:

> *Learning theories provide instructional designers with verified instructional strategies and techniques for facilitating learning as well as a foundation for intelligent strategy selection.*

On the other hand Cross (1998:7) points out that researchers of the learning phenomenon should not ignore *the **experience of teachers** [in higher education] who have spent lifetimes accumulating knowledge about learning*. She continues and adds that *faculty should not exchange views about student learning with no reference to what scholars know through study of the matter* (Cross, 1998:7).

The author of this thesis is of the opinion that the views of Cross stress the fact that **relevant theory** and **judicious experiences** from **practice** should be seen in congruence and should be interpreted for the design of tertiary mathematics instruction in a support course. The author also feels that all educators involved in tertiary mathematics instruction should actively and continually be involved in improving their practice through critical self-reflection and by taking cognisance of existing knowledge relevant to the learning and teaching of mathematics. A deep understanding of what "tertiary learning of mathematics" really entails may eventually not only foster our understanding of what constitutes a program of learning in mathematics but also what constitutes a program of **learning facilitation** in tertiary mathematics. Zuber-Skerritt (1992a; 1992b & 1997) argues that the implementation of action research[20] not only has the ability to improve teaching in higher education but can also contribute to research in tertiary (mathematics) education.

For the purposes of the instructional design underpinning the learning facilitation strategy proposed in this study, examples of perspectives on instruction that may have relevance for the focus of this study are discussed in the following section including:

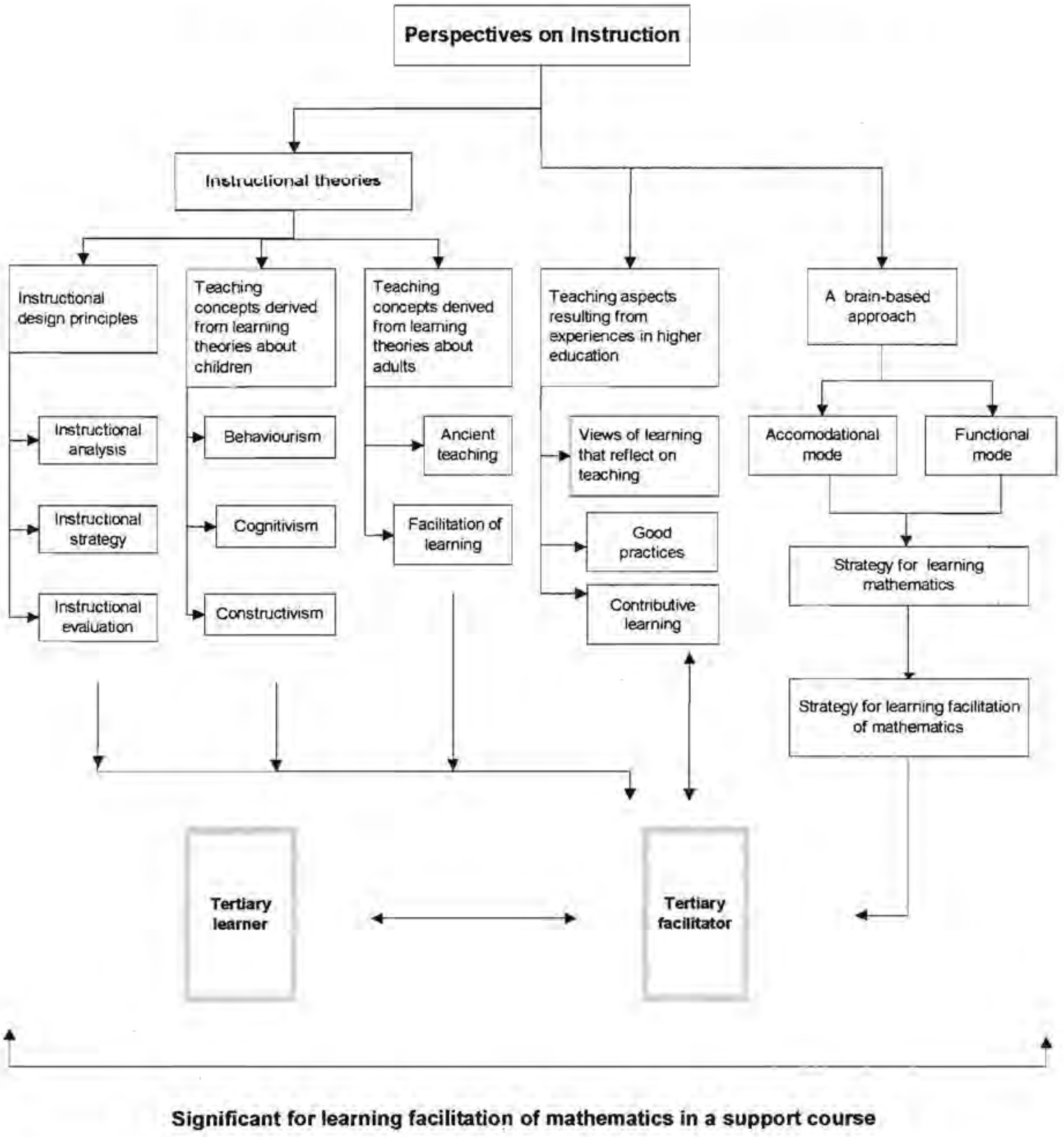
- Accepted instructional design principles.
- Concepts of teaching derived from learning theories about children.
- Concepts of teaching derived from learning theories about adults.

[20] Action research is discussed in Chapter 4 as the main methodology in this study.

- Concepts of teaching derived from experiences in undergraduate education.
- A brain-based integrated approach to teaching.

Figure 3-2 gives an overview of the focus as outlined above.

Figure 3-2 Examples of perspectives on instruction that contribute to a narrative for learning facilitation of mathematics in a support course



Proposed by the author of this thesis

3.2 Instructional design principles

According to Smith and Ragan (1993), an analysis of instruction, a strategy for instruction and the evaluation of the instruction constitute the main characteristics of instructional design principles. In a comparative analysis of models of instructional design Andrews and Goodson (1980) examined forty models of instructional design from various sources and identified 'common tasks' in model development. Gagné and Briggs (1974) present their views on instructional design principles as 'stages' in the design of instructional systems.

If the design principles of Smith and Ragan (1993), as mentioned above, are used as a frame of reference, the 'tasks' identified by Andrews and Goodson (1980) and the 'stages' of Gagné and Briggs[21] (1974) can be categorised according to Smith and Ragan's principles. Table 3-1 summarises these tasks and stages according to the instructional design principles of an analysis of instruction, a strategy for instruction and the evaluation of the instruction. The last mentioned principles are discussed in the following sections.

Table 3-1 A summary of instructional design principles

Principle proposed by Smith and Ragan (1993):	**Analysis of instruction**
Corresponding tasks identified by Andrews and Goodman (1980):	Formulation of goals. Development of pretest and post test matching goals. Analysis of goals for skills/learning required. Characterisation of learner population. Assessment of need, problem identification, occupational analysis, competence or training requirements. Formulation of system and environmental descriptions and identification of constraints.
Corresponding stages identified by Gagné and Briggs (1974):	Analysis of needs, goals and priorities. Analysis of resources, constraints and alternative delivery systems. Analysis of course objectives. Define performance objectives.

[21] It should be pointed out that Andrews and Goodman (1980) included Gagné and Briggs's (1974) 'stages' in all of the fourteen 'tasks' they identified.

Principle proposed by Smith and Ragan (1993):	**A strategy for instruction**
Corresponding tasks identified by Andrews and Goodman (1980):	Sequencing. Formulation of strategy to match subject matter and learner requirements. Selection of media to implement strategies. Development of courseware based on strategies. Development of materials and procedures for installing , maintaining and periodically repairing the instructional program.
Corresponding stages identified by Gagné and Briggs (1974):	Scope of delivery design. Sequence of delivery. Analysis of goals for skills/learning required. Prepare lesson plans. Selecting media and material. Teacher preparation. Installation and diffusion.

Principle proposed by Smith and Ragan (1993):	**Evaluation of instruction**
Corresponding tasks identified by Andrews and Goodman (1980):	Empirical tryout of courseware with learner population. Diagnosis of learning and courseware failures. Revision of courseware based on diagnosis. Consideration of alternative solutions. Costing instructional programs.
Corresponding stages identified by Gagné and Briggs (1974):	Asessing student performance. Formative evaluation. Field testing, revision. Summative evaluation.

Compiled from Smith and Ragan (1993); Andrews and Goodman (1980); Gagné and Briggs (1974)

For the purposes of this study, the instructional design principles as formulated by Smith and Ragan (1993) will be used as a frame of reference for the learning facilitation strategy defined in the study. In the opinion of the author these principles, on the one hand, incorporate conventional views on instructional design as postulated, for example, by Andrews and Goodman (1980), Gagné and Briggs (1974), Gagné and Driscoll (1988) and Reigeluth (1983). On the other hand, the principles as formulated by Smith and Ragan (1993) serve as contemporary and appropriate categories with regard to the learning facilitation strategy defined in this thesis.

In the following sections an overview of Smith and Ragan's (1993) design principles is given and their relevance for the present study is summarised in Table 3-2 on page 87.

3.2.1 Instructional analysis

According to Smith and Ragan (1993) any design and development of instruction should be preceded by an analysis in order to ensure that the instruction is relevant for the intended learners in their learning environment. They distinguish between the following three aspects of instructional analysis:

3.2.1.1 Analysis of instructional context

Analysis of instructional context involves a needs assessment and a description of the learning environment in which the instruction will take place.

A **needs assessment** can be indicated by a number of reasons, including the following:

- Learning goals not being met by given current instruction.
- Current instruction being inefficient.
- Current instruction being unappealing.
- A lack of instruction in a given area.
- New goals being added to the curriculum.
- Changes in learner population.

Analysis of the **learning environment** involves looking at existing conditions that surround and support instruction, namely:

- Characteristics of teachers that will be using the instructional material.
- Existing curricula into which the instruction must fit.
- Availability of instructional media equipment.
- Characteristics of the facilities and the organisation in which the planned instruction will take place.
- Factors in the larger community in which the instructional organisation exists.

3.2.1.2 Analysis of learners

Learner characteristics are regarded as an important aspect when designing instruction (Andrews & Goodman, 1980; Bransford *et al.*, 1999; Cross & Steadman, 1996; Felder &

Brent, 1999; Gagné & Briggs, 1974; Gagné & Driscoll, 1988; Jensen, 1996; McKeachie, 1999; Reigeluth, 1983).

Smith and Ragan (1993) identify four major categories of learner characteristics to be considered in instructional design. In the opinion of the author of this thesis these categories are also relevant for the strategies defined in the thesis and noteworthy mentioning.

- Cognitive (general and specific).
- Physiological.
- Affective.
- Social.

These categories can further be classified in terms of the following dimensions:

- Similarities among people or differences between people.
- Characteristics that change over time or those that remain relative stable over time.

Smith and Ragan (1993:55) use these categories to formulate an outline of learner characteristics by means of which learners can be analised. The following categories from this outline can be included in a learner analysis for the purpose of this study:

Cognitive characteristics that include

General and specific aptitudes.

Language and reading level.

Level of visual literacy, ability to gain information from graphics.

Cognitive processing styles – preferred and most effective.

Specific prior knowledge.

Physiological characteristics that include sensory perception.

Affective characteristics that include

Interests.

Motivation (to learn).

Attitude toward subject matter.

Academic self-concept.

Anxiety level.

Attribution of success (locus of control).

Social characteristics that include relationship with peers and tendencies toward cooperation or competition.

3.2.1.3 Analysis of learning tasks.

A needs assessment should reflect what learners are currently unable to do. The process of the task analysis is necessary in order reformulate the findings of the needs assessment so that it can be used to guide subsequent instructional design. The following steps summarises Smith and Ragan's (1993) views on performing a learning task analysis:

1. Writing instructional goals. These are statements of what learners should be able to do at the conclusion of instruction and can be lesson goals, unit goals or course goals.
2. Determining learning outcomes. Smith and Ragan use the system of Gagné's learning outcomes[22] as foundation for a learning outcomes analysis.
3. Conducting an information-processing analysis of the instructional goal. This analysis describes the mental processes that the learner might go through in completing the goal.
4. Conducting a prerequisite analysis with regard to each step in the information-processing analysis. This means answering the question: "What must the learner know or be able to do to achieve each step?"
5. Writing performance objectives. These are statements of what learners should be able to do when they have completed a segment of instruction.

The outcomes of the instructional analysis phase of the learning facilitation strategy proposed in this thesis was reported by the author in an earlier study (Steyn, 1998). In Table 3-2 on page 87 a summary is given of the main aspects regarding instructional analysis as applied to the present study.

3.2.2 Instructional strategy

According to Reigeluth (1983) instructional strategies are composed of three aspects, namely, organisational strategy, delivering strategy and management strategy.

Instructional organisational strategy refers to the sequence of instruction, the content and the presentation of the content. At the lesson-level Smith and Ragan (1993) regard instructional events as comprising of an introduction, a body, conclusion and assessment. Figure 3-3 is a summary of the contents of each of these aspects.

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[22] Gagné's learning outcomes are discussed in Chapter 2, Section 2.1.2.

Figure 3-3 Instructional events at lesson-level

Introduction	Body	Conclusion	Assessment
• Gain attention • Establish instructional purpose • Arouse interest and motivation • Preview lesson	• Recall prior knowledge • Focus attention • Employ learning strategies • Practise • Evaluative feedback	• Summarise and review • Transfer knowledge • Re-motivate and close	• Assess performance • Evaluative feedback and remediate

Adapted from Smith and Ragan (1993:160)

Instructional delivery strategy characteristics deal with the type of instructional media that will be used and the grouping of the learners.

Instructional management strategies guide the arrangement of the organisational and delivery strategies, namely the scheduling of the instructional events and the mechanisms for delivering these events.

In Table 3-2 on page 87 a summary is given of the mentioned instructional strategies as applied to the present study.

3.2.3 Instructional evaluation

Smith and Ragan (1993:388) stress the point that there are two kinds of evaluation that are critical and essential to the design of instruction. On the one hand, the performances of students need to be evaluated to determine whether the objectives of the instruction have been reached. On the other, the instructional material has to be evaluated. According to them the evaluation of the instructional material occurs at two separate stages during the design process, namely, during the development of the instruction (formative evaluation) and after the instructional strategy have been implemented (summative evaluation).

When an action research approach to classroom practice is followed (as was done in the study reported in this thesis), formative evaluation forms an integral part of the reflection phase of the action research model. The research results reported in Chapters 6 and 7 can be regarded as a summative evaluation of the instructional strategy proposed in this thesis.

3.2.4 Instructional design principles in the present study

In Table 3-2 below a summary is given of the instructional design considerations regarding learning facilitation in the present study using the instructional design principles according to Smith and Ragan (1993) as a frame of reference.

Table 3-2 Instructional design considerations regarding the present study

Instructional design principles (Smith & Ragan, 1993)	**Principles as applied to the present study**
Instructional analysis: Context	
Needs assessment	How can the exploration of two-dimensional functions through their graphs enhance the conceptualisation of fundamental mathematical concepts that underpin a study in calculus? What are the requirements for graphing technology to ensure meaningful visualisation of two-dimensional functions to promote better understanding of the mathematical concepts involved? How should instruction be structured to foster learner cognition and conceptualisation incorporating the visualisation of two-dimensional functions?
Learning environment	The development of the mathematics potential of a learner on a support course needs to be done in addition to the course activities of a main-stream mathematics course. An innovative approach is necessary to keep instruction *effective*, *efficient* and *appealing*. Using computer graphing technology poses the possibility that learners *actively participate* and that they interact *mentally* and *physically* with the material to be learnt.

Table 3-2 continues on the next page.

Instructional analysis: Analysis of learners – Learner characteristics

Cognitive	Students who have the interest and ability to study engineering but who do not meet the admission requirements of the institution need support regarding the development of their mathematics potential. Mainstream courses in mathematics do not necessarily provide this support per se. A developmental approach is proposed addressing the following aspects: existing knowledge in mathematics; language and reading competency in mathematics; competency in graphical analysis and synthesis; thinking and learning styles; problem solving. A brain-based approach aimed at neural patterning and re-patterning[23] and whole brain utilization[24] is proposed.
Physiological	Sensory perception relevant for mathematics namely, visual, auditive and kinaesthetic perception, should be incorporated in the learning facilitation strategy.
Affective	Aspects regarding study attitude, study habits, mathematics anxiety, meta-cognition and knowledge pertaining to thinking and learning preferences should be integrated into the learning facilitation strategy. Learners should be made aware of their study orientation towards mathematics.
Social	Mathematical communication between facilitator and student and peer communication and learning regarding mathematics should be pursued and encouraged. These are essential steps in creating a learning community.

Instructional analysis: Learning tasks

The primary aim with an analysis of the learning tasks is to determine whether the instructional strategy has contributed to the development o f the learner's mathematical potential. A quantitative analysis of performance in mathematics in the short term will give an indication of possible development of potential. However, eventual long term success in engineering mathematics is the ultimate goal.

Table 3-2 continues on the next page

[23] See Haile's view regarding the functions of the cerebral cortex and neural networks discussed in Chapter 2, section 2.3.1 on page 51.
[24] See Herrmann's four quadrant whole brain model discussed in Chapter 2, section 2.3.4.

Instructional strategy

Organisational	The instructional events at lesson level in the strategy proposed in the present study differ significantly from Smith and Ragan's (1993) model. Lesson level activities comprise of students doing structured worksheets using a computer graphing utility, analysing, interpreting, synthesizing, communicating and writing down mathematics. The instruction is individualised and at a learner's own pace. Feedback and remediation are given through communication with the lecturer, tutors and peer discussions.
Delivery	Mathematics activities are done in a computer laboratory setting with each student at his/her own computer. Explorative activities are structured by making use of a computer graphing utility, a paper based workbook and completion of answer sheets formatted to match a specific worksheet.[25]
Management	The use of technology for a group of learners necessitates prior planning and arrangement. Consideration has to be given to the fact that not all learners have been exposed to technology and that technology can be non-accessible at times.

Instructional Evaluation

Learner performance	Evaluation of learner performance is not restricted to the course content of the support course, but is in essence reflected in learner performance in the mainstream mathematics courses.
Instructional material	The instructional material being used has been evaluated formatively and summatively.[26] However, due to the action research approach followed in the support course, the improvement of the instructional material is an ongoing process.

Compiled by the author of this thesis

3.3 Concepts of teaching derived from learning theories

It was pointed out in Chapter 2 that the "tertiary learner" of mathematics in a support course should be regarded as a developing learner. This view necessitates a diverse approach to understanding such a learner and also requires a diverse approach in discussing the "tertiary teaching" of mathematics in a support course. In this section a brief discussion of examples of teaching concepts derived from learning theories will be given.

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[25] During this study the instructional material, *Fundamentals of 2-D Function Graphing - A practical workbook for precalculus and introductory calculus* (Greybe, Steyn & Carr, 1998) was used.
[26] Steyn (1998).

The focus in each case will be with relevance to the strategy proposed in the present study and according to the following two questions formulated by Ertmer and Newby (1993:53), namely:

> *What basic assumptions/principles of the theory are relevant to instructional design?*
>
> *How should instruction be structured to facilitate learning?*

3.3.1 Concepts of teaching resulting from cognitive learning theories

Cognitive learning theories emphasise that instruction should be aimed at making information meaningful to learners and helping learners relate new information to their existing knowledge.

Examples of the assumptions and principles of cognitive learning theories that are relevant to the instructional strategy in this study and the way that the instruction should be structured according to these principles are summarised as follows.

1. **Learner involvement**

The instructional design regarding mathematics for students on a support course should promote the active involvement of the learner. Astin (1985:36) points out that the vast and diverse literature on higher education and human learning indicates that *the key to an effective learning experience is student involvement.* According to Astin (1985:36) *student involvement refers to the amount of physical and psychological energy that the student devotes to the academic experience.* Although Astin (1985) sees involvement in a wider (macro) context than its mere relevance to a specific course, the author of this thesis is of opinion that the underlying principle of **activity** to promote academic well-being is also applicable on the micro level of a single course. In the mathematics component of the support course described in this study, the learner is in essence **personally involved** in the development of his/her mathematics potential through the facilitation of mathematical content and the development of skills as proposed in the strategy for learning facilitation defined in this thesis.

In the learning facilitation strategy for mathematics proposed in this study, learner involvement, for example on a micro level in a typical class activity, entails that the learner has to use the computer graphing software to construct a visual representation of some mathematical concept. The learner is then actively involved in analysis and interpretation of the image on the computer screen as the computer graphing software, used in this instructional model, was purposefully designed as graphing tool and not as an instrument that generates answers. This involvement promotes, amongst others, learner control, self-paced instruction and the development of meta-cognitive skills (Steyn, 1998).

Astin (1985:38) points out that *the theory of student involvement encourages educators to focus less on what they do and more on what the student does.*

2. **Feedback**

Feedback should be used to guide and support accurate and mental connections (Thompson, Simonson & Hargrave in Ertmer & Newby, 1993). Astin (1985:36) points out that in addition to learner involvement *an excellent learning environment* is further characterised by *high expectations and assessment and feedback*. The author of this thesis regards **personal** feedback as of exceptional importance in the learning facilitation strategy proposed in this study. The author is of the opinion that the only way by which it can be known (either by the facilitator or the learner) whether mathematical concepts have been mastered is through (mathematics) communication (orally and in writing) and feedback thereon.

In the strategy for learning facilitation of mathematics proposed in this study, feedback is given through continuous communication with the learners. The communication comprises conversations on mathematics and writing of mathematics. Conversations between facilitator and learner as well as peer communication between learner and learner pose opportunities to the learner to formulate mathematics. The facilitator (lecturer or tutor) is compelled to listen carefully and guide the student to correct formulation and expression of mathematics concepts. A learner has the opportunity to write down what was orally formulated by completing answer sheets or doing assignments that are then assessed and graded. It should be stressed that the focus is not on quantitative feedback in terms of numerical right or wrong answers but to **guide and support a learner to achieve accurate concept mastering of fundamental mathematical concepts**.

Concerning the importance of feedback to improve learning, Angelo and Cross (1993:9) point out that *students need to receive appropriate and focused feedback early and often; they also need to learn how to assess their own learning.* Davis (1998:38) adds that careful and prompt grading and feedback thereon *show students that they are a high priority*. Similarly, Astin (1993) strongly argues that feedback received directly form the lecturer (facilitator) correlates positively with most academic outcomes such as general knowledge, knowledge in the field, analytical and problem solving skills, writing skills and overall academic development. Chickering and Gamson (in Cross, 1998) regard giving prompt feedback as one of seven principles[27] of good practice in undergraduate education.

3.3.2 Concepts of teaching resulting from constructivism

Constructivism is aimed at making learning a more realistic and meaningful process in order to enable the learner to *create meaning from his or her own experiences* (Jonassen, 1991:10).

The assumptions and principles of constructivism relevant to the learning facilitation strategy proposed in this study can be summarised as follows:

1. According to the principle of **active involvement**, learners should be active participants in the learning activities. In the learning facilitation strategy proposed in this thesis, the learner actively has to explore mathematical concepts. This exploration is specifically structured to guide the learner in mastering concepts.

2. Constructivism postulates that **information** should be **presented in different ways**. With regard to tertiary mathematics education, this principle is addressed in calculus textbooks of the 1990s which propose an instructional approach incorporating graphical, numerical and algebraic methods (Finney *et al.*, 1994; Larson *et al.*, 1998). Elaborating on the multi-representation of calculus, Smith (1994) points out that in the early 1990s calculus reform was popularised by the 'Rule of Three' namely, the experience of calculus concepts in symbolic, numerical and graphical form. According to Smith (1994) Hughes Hallett later on proposed the 'Rule of Four', with the fourth form of representation being writing. Smith (1994) further points out that educators of calculus also suggest a 'Rule of Five' with oral communication being considered evenly balanced with graphical, numerical, symbolic and written presentations in mathematics education.

[27] The *Seven Principles of good practice in higher education* are listed in section 3.4.2 on page 98.

A variety in the way concepts are presented, in the use of instructional material and in the facilitation of learning is in accordance with the concept of whole brain utilisation in learning[28] and whole brain utilisation in teaching.[29]

Furthermore, it can be noted that the principle of "communicating mathematics orally and in writing" was also formulated by the author resulting from experiences with first year mathematics students during 1991-1997 (Steyn, 1998).

These views of educators in mathematics and the findings of the author as expressed above underscore the constructivist principles of **verbalisation** of concepts and **communication** as an essential aspect of learning facilitation.

3. Another principle that is stressed by constructivism is that **learning content** should be experienced **in context**. This principle has culminated in the concept of "problem-based learning". Furthermore, it is generally accepted that problem-based learning should be accomplished within the context of real-life experiences (Ertmer & Newby, 1993; Barr & Tagg, 1995; Berson, Engelkemeyer, Olario, Potter, Terenzini & Walker-Johnson, 1998).

In the opinion of the author, the concept of problem-based learning, in real-life context, cannot merely be applied to learning content involving fundamental conceptual knowledge such as in the basic sciences, for example mathematics. Figure 3-4 on page 95 was constructed by the author to illustrate this view on "context based learning" and the facilitation thereof.

The author distinguishes between "subject content-based context" and "application-based context". **Subject content-based context** refers to aspects and relationships of fundamental concepts within a specific subject. It is inevitable that the composition of and structure of fundamental concepts in one subject differ from that in another. **Application-based context** refers to the appropriate application of subject content in real-life context. In the opinion of the author both application-based context and content-based context constitute **problem-based** learning and instruction. However, the author feels that the competence of a learner in fundamental subject knowledge (content-based context) is a prerequisite for successful problem solving and transfer of knowledge to application-based

[28] See Chapter 2, section 2.4.
[29] See section 3.5.

context (real-life problems). The author feels that this is most probably the case with mathematical knowledge.

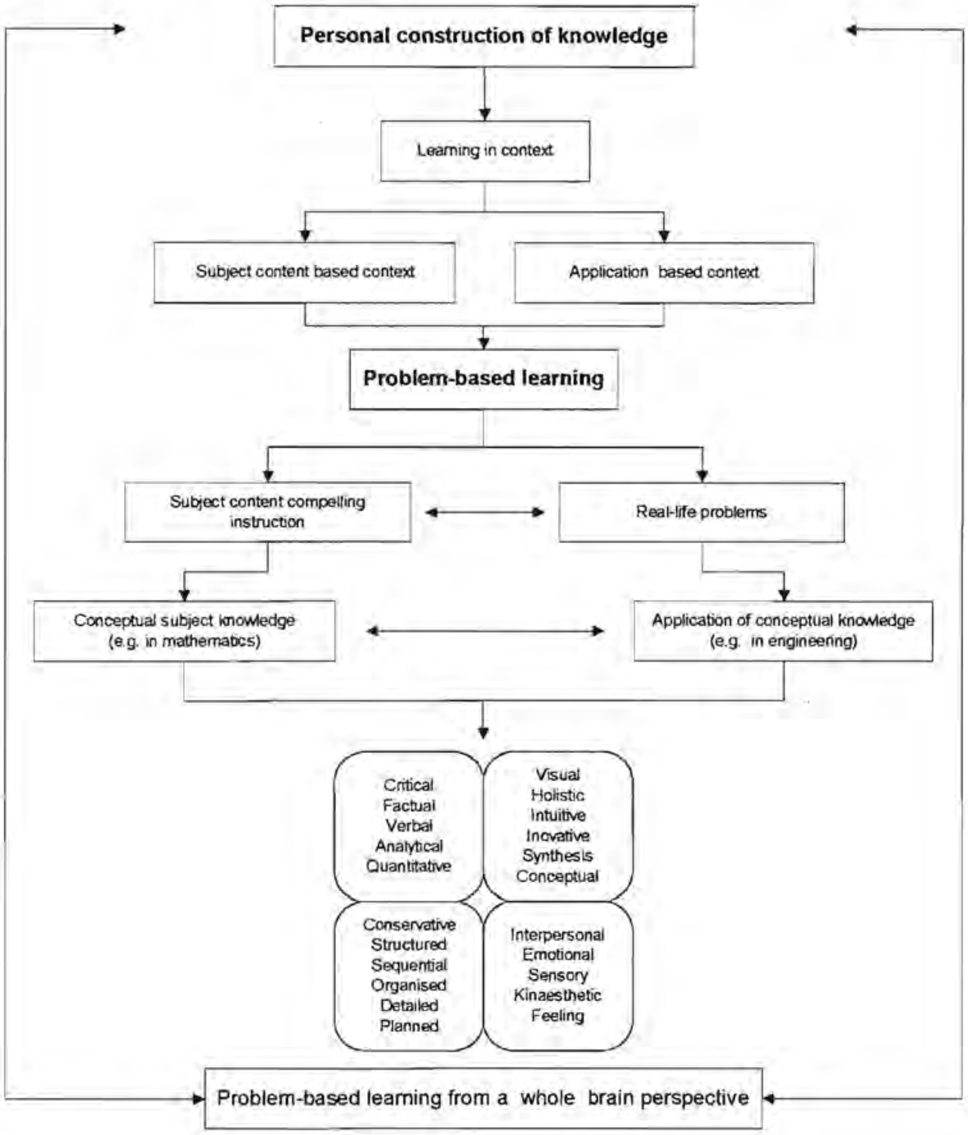
4. The **value of fundamentals** as a learning principle was articulated by the Lewis Commission at the Massachusetts Institute of Technology (MIT) in 1949 (Hansman & Silbey, 1998). In September 1998, this principle was reaffirmed in a report on student learning at MIT and elaborated on as follows:

> The information revolution exacerbates the need to focus on fundamentals. Because *information will be cheap in the future, our students will need a fundamental basis to evaluate information and apply knowledge.* (Hansman & Silbey, 1998:12).

The need for conceptual knowledge is also expressed by Larson *et al.* (1998:xi) who state that *we have found no evidence that it is somehow possible to apply calculus in real-life situations without first being able to understand and "do" calculus.* Similarly, according to Bransford *et al.* (1999) point out that to develop competence in an area of inquiry, students must have a deep foundation of factual knowledge; understand facts and ideas in the context of a conceptual framework and organise knowledge in ways that facilitate retrieval and application. Bransford *et al.* (1999:50) also point out that overly contextualised knowledge (like case-based and problem-based learning) can result in learners not being able to transfer this knowledge flexibly to new situations. They continue to point out that *wide transfer of learning* and *general principles* will lead to more flexible transfer (Bransford *et al.*, 1999:51).

The author is of the opinion that learners need a thorough base of fundamental concepts in a subject in order to apply their knowledge (in real-life contexts). The mathematical content of the support course described in this study strongly focuses on fundamental concepts underpinning a study in calculus and the focus is thus on (mathematical) content based context. This, however, does not imply that application based context is ignored. For example, in the worksheet example given in Appendix B, an application-based context (a scuba dive) was used for the exploration of mathematical content-based context (two-dimensional piece-wise defined functions) after the mathematics concepts *per se* have been explored.

Figure 3-4 Conceptual knowledge in a whole brain problem-based approach



Compiled by the author of this thesis

3.3.3 Concepts of teaching derived from learning theories about adults

According to Knowles (1990) the concepts of teaching that are derived from theories of learning in studies of adults differ remarkably from those that see the role of the teacher as a shaper of behaviour. Teachers of ancient times taught adults and they perceived learning to be a process of active inquiry and not passive reception of the transmitted content. An example of this is the Socratic dialogue, whereby teaching is done by means of a series of questions and answers. The author is of the opinion that the Socratic principle is of great importance in the facilitation of (tertiary) mathematics in a support course. Ideally, a facilitator should interpret a learner's question promptly in order to establish the learner's need for asking. The question should then be answered, not by giving an answer, but by guiding the learner to the correct solution through asking a (series of) follow-up question(s).

In the realm of adult education (Knowles:1990) the role of the teacher is in essence seen as that of a **facilitator of learning**. The author is of the opinion that the role of the tertiary educator in a support course should indeed also be that of a **facilitator of learning**.

The relevance of the concept "facilitation" for **all** education is endorsed by comparing the meaning of "facilitate" to that of "instruct". These definitions[30] highlight the fact that "facilitate" indicates a more **supporting approach** to aid understanding whereas "instruct" indicates a more **commanding approach** in transferring content.

The author of this thesis is of the opinion that the role of an educator as a facilitator is of great significance in the early 2000s. Tertiary education is immersed in a changing environment that is, amongst others, characterised by an overload of information and technology. The tertiary lecturer of a support course for mathematics can no longer only "transfer" mathematical content that students are supposed to have, but should aid students in verifying their understanding of fundamental concepts needed for their studies in mathematics. Therefore, the view of Rogers (in Knowles, 1990:42) dating back to the 1960s that the aim of education must be the *facilitation of learning* is still very appropriate. Rogers provides guidelines (in Knowles, 1990:78) for a facilitator of learning of which the following have significance for the purpose of this study:

- The facilitator has much to do with setting the initial mood of the class experience and in so doing create a climate for learning.
- The facilitator can help to utilise a particular individual's (student's) own motivational force for significant learning.
- As the acceptant learning environment becomes established, the facilitator increasingly also becomes a participant learner.

[30] The terms "facilitate" and "instruct" are defined in Chapter 2, section 1.2.2.

Barr and Tagg (1995) argue that the shift in higher education should be from teaching to (the facilitation of) learning. They point out that

- The mission of higher education is not instruction but that of producing learning.
- Student learning and success set the boundary of what institutions for higher education can do.
- Students, faculty and the institution take responsibility for learning outcomes.
- The goal for all students is not simply access to higher education, but to achieve success. Barr and Tagg (1995:15) define success as

> *The achievement of overall student educational objectives such as earning a degree, persisting in school, and learning the 'right' things – the skills and knowledge that will help students to achieve their goals in work and life.*

3.4 Aspects of teaching resulting from experiences in higher education

3.4.1 Views of learning that reflect on teaching

In accordance with the opinions expressed in the introduction to this chapter, namely, that relevant theory and the practice of instruction in higher education should be seen in congruence, teaching aspects resulting from experiences in higher education are considered in this section.

It seems as if a trend in higher education in the late 1900s (into the early 2000s) is evolving that postulates aspects of student learning derived from practice and to use these as principles for the facilitation of learning. (Barr & Tagg, 1995; Cross, 1998; Berson *et al.*, 1998; Felder & Brent, 1999; McKeachie, 1999; Smith, 1998 & 2001). It is then presupposed that facilitators of learning in higher education should construct their instruction to promote the learning principles that they have identified.

> *By applying these principles to the practice of teaching, the development of curricula, the design of learning environments, and the assessment of learning, we will achieve more powerful learning.* (Berson *et al.*, 1998:15).

It is interesting to note that most of the learning principles listed by Berson *et al.* (1998) in essence correlate with the known learning concepts postulated by the cognitive learning theory and constructivism. However, it is noteworthy that Berson *et al.* (1998) also explicitly refer to learning principles that reflect on the contribution of neuroscience and the utilisation of brain functions to student learning. In the realm of tertiary mathematics education Smith (2001) suggests that teachers should become aware of the implication of (recent) neurobiological research for learning.

The focus on learning as a basis for instructional design is further stressed by Barr and Tagg (1995) who postulate a "learning paradigm" instead of a "teaching paradigm" as a model for undergraduate education. They argue that a learning paradigm requires a constant search for new structures and methods that work better for students' learning. They point out that

> *Instead of fixing the means – such as lectures and courses – the Learning Paradigm fixes the ends, the learning results, allowing the means to vary in its constant search for the most effective and efficient paths to student learning.* (Barr & Tagg, 1995:21.)

The implication of the view to take learning as the premise for constructing facilitation compels the (tertiary) facilitator to take cognisance of the concepts that underpin student learning and to design his/her instruction accordingly. Obviously, in designing instruction, the special structure of the specific subject content would influence the design to some extent.

3.4.2 Examples of principles relating to 'good practice' in higher education

In 1987, Chickering and Gamson (Cross, 1998) formulated the *Seven Principles of Good Practice in Undergraduate Education* for higher education in the USA. These principles seem to have influenced higher education in the USA since their creation. Recently the implementation of these principles has also been interpreted with relevance to technology as a lever for instruction (Chickering & Ehrman, 1997). Although a detailed discussion of the seven principles is beyond the scope of this study, the author feels that they, in essence, also underpin the principles of the learning facilitation strategy proposed in this study. Chickering and Gamson's seven principles (Cross, 1998:6) are:

1. Good practice encourages contacts between students and faculty.
2. Good practice encourages cooperation among students.
3. Good practice encourages active learning.

4. Good practice gives prompt feedback.
5. Good practice emphasises time on task.
6. Good practice communicates high expectations.
7. Good practice respects diverse talents and ways of learning.

Smith (2001) points out that these principles employ six powerful forces in education, namely, activity, cooperation, diversity, expectations, interaction and responsibility. Although each of the principles can stand on their own, their effects multiply if they are all present.

3.4.3 Contributive learning

During the research activities of the author since 1991, an aspect regarding learning and teaching that differs from the known concepts of cooperative learning and collaborative learning was identified. In cooperative and collaborative learning the focus is on learning via the interaction between learners (Bruffee, 1995; Matthews, Cooper, Davidson & Hawkes, 1995). When the learner as well as the facilitator learns during the facilitation of learning, the author feels that this learning activity can best be defined by the phrase **contributive learning**.

Thompson (1995:291) defines the term "contributive" as *help to bring about a result* while Gove (1961:496) defines it as to *add (as knowledge or effort) to a common interest or activity*. Both these definitions underpin the author of this thesis' view of the term "contributive learning" which is as follows:

Contributive learning indicates the involvement of both the **learner as a learner** and the **facilitator as a learner** in a mutual process of learning. For the facilitator this learning is not confined to subject content. It can be diverse and can, for example, include aspects of student learning as well as successes and pitfalls of instructional activities.

During the mentioned research (Steyn, 1998), contributive learning occurred as a result of the restructured approach to the tuition of calculus that was followed incorporating use of computer graphing technology as a tool for learning. In this regard the author and colleagues had, amongst others, experienced how the use of technology can enhance mathematical concepts and what the requirements for a computer graphing tool need to be to promote mathematics conceptualisation (Steyn, 1998; Steyn & Maree, 2002).

Furthermore, contributive learning can give a facilitator new insights into learners' construction and comprehension of mathematical concepts.

3.5 A whole brain approach to facilitation: an instructional design perspective

It was pointed out in Chapter 2 that the principle of whole brain utilisation may be seen as new paradigm for elucidating learning in a support course for first year tertiary students. The implications for a facilitator is to take cognisance of the functioning of the brain by noting that, on the one hand, different cognitive functions are predominantly located in different parts of the brain but, on the other, that the brain functions as a composite whole. Ideally, the facilitation of the learning must be structured so that whole brain utilisation results.

A whole brain approach has been advocated extensively in the fields of learning, creative thinking and creative problem solving (Buzan, 1991; Buzan & Buzan 1997; Dennison & Dennison, 1989 & 1997; Hannaford, 1995 & 1997; Herrmann, 1996; Jensen, 1994 & 1996; Lumsdaine & Lumsdaine, 1995b; Swartz, 1991).

Documentation on a whole brain approach to the facilitation of learning in tertiary mathematics education is scarce although an awareness for the approach is seemingly developing (Steyn, 1998; Smith, 2001).

The author of this thesis is of the opinion that a whole brain approach to teaching does not exclude conventional instructional design principles or any concepts of instruction that result from learning concepts or experiences in teaching as discussed in the preceding sections. Furthermore, the author feels that a whole brain approach to teaching utilises and endorses these principles. A facilitator of learning should thus ideally **incorporate all relevant concepts of learning and principles of instructional design within the framework of a whole brain approach.**

The following discussion gives an instructional design perspective on a whole brain approach to learning facilitation. In the opinion of the author two modes can be distinguished in this approach to learning facilitation, namely, an "accommodational mode" and a "functional mode".

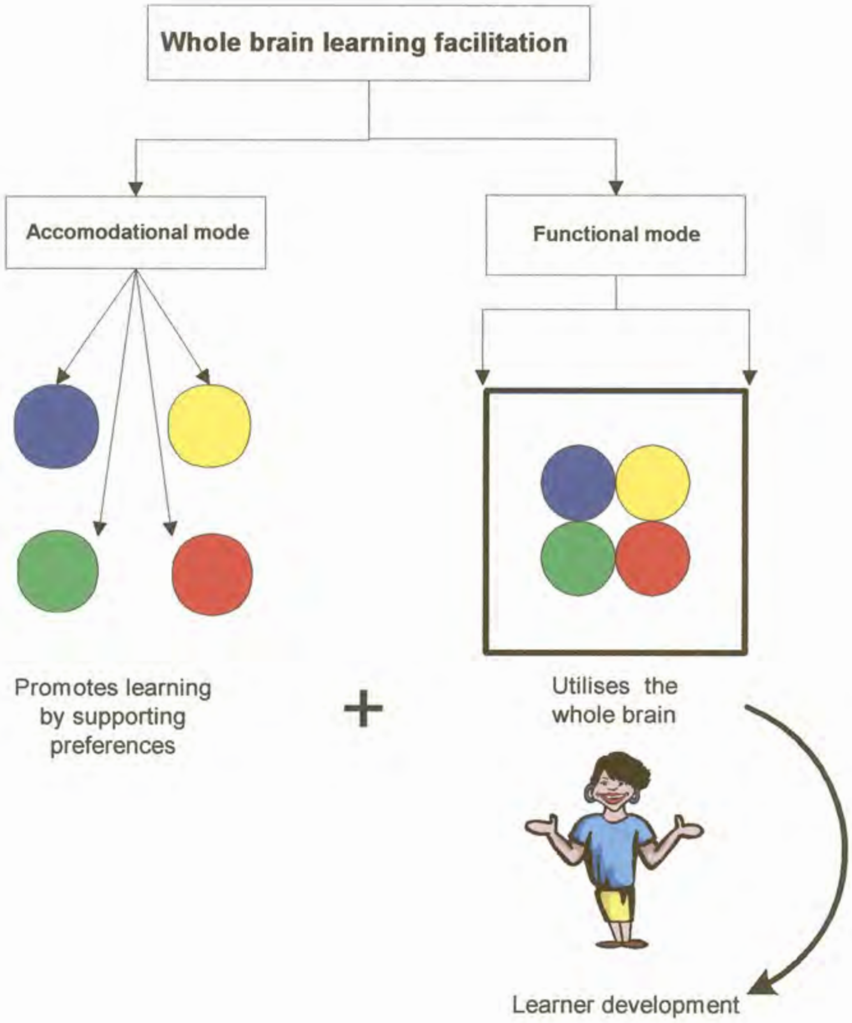
Gove (1961:12) defines the term "accommodation" as to *adapt; to bring into agreement or concord* or to *adjust.* Woolf (1975:7) defines it as *to give consideration to* or *to allow for the special interest of various groups.* Thompson's (1995:9) definition of "accommodation" is similar to that of Woolf, namely, *an adjustment or adaptation to suit a special or different purpose.* The term "functional" is defined by Gove (1961:921) as *dependently related* and as *existing or used to contribute to the development or maintenance of a larger whole.* These definitions underpin the author of this thesis' view of the terms as they are held in this study and discussed in the following paragraphs.

Figure 3-5 on page 102 illustrates the relevance of the concepts "accommodational mode" and "functional mode" for a whole brain approach to learning facilitation.

In the **accomodational mode** the focus is on designing instructional activities that promote learning by supporting the preferred thinking (learning) styles[31] of individual learners. In the **functional mode**, the focus is on designing instructional activities in such a way that not only preferred thinking and learning styles are used but less preferred thinking and learning modes are also utilised.

[31] Thinking (learning) style preferences are viewed in this model according to the four quadrant whole brain model of Herrmann that is discussed in Chapter 2, Section 2.3.4.

Figure 3-5 Promoting and utilising the whole brain in learning facilitation



Proposed by the author of this thesis

If the **accomodational mode** is interpreted with relevance to the Herrmann model[32] it means that for learners with an A-quadrant preference, instruction should be formally and verbally structured, should include factual data and stimulate critical and analytical thinking. For learners with a B-quadrant preference, instruction should be organised sequentially, should be well planned and strictly adhere to the plan. Instruction should also be accompanied by detailed instructional material. Instruction for A- and B-quadrant learners should further be planned so that they can work individually. On the other hand, instruction for learners with a C-quadrant preference should be planned around group

[32] Aspects of the Herrmann model are discussed in Chapter 2 sections 2.3.4 and 2.5.1.

interaction. Learners with a C-quadrant thinking preference value experiential opportunities that incorporate sensory stimuli. For learners with a D-quadrant preference, instruction should focus on the visual representation of data and to present a global picture of the instructional content. Furthermore, for learners with a D-quadrant preference, instruction should not be rigidly structured but should encourage intuition, self-discovery and the forming of concepts.

In the **functional mode** of the whole brain approach to teaching, the focus is not on promoting the different thinking (learning) modes but is on ensuring that **all learners** with presumably different preferences are compelled to utilise their less preferred or un-used styles of thinking and learning. This means that, for example, a learner with an A-quadrant preference will also be encouraged to respond to facilitation strategies aimed at utilising potential competencies (such as working in a group) that are predominantly classified in the other quadrants and by so doing he/she will be encouraged to utilise his/her whole brain (according to the Herrmann model).

The author feels that both the accomodational and the functional modes are relevant for learning facilitation of mathematics in a support course. Furthermore, the author feels that the **functional mode of whole brain utilisation** could also be regarded as an **instructional principle for the facilitation of fundamental mathematical concepts**. This premise underpins the instructional strategy defined in section 3.9 of the chapter.

In Table 3-3 on the following page a summary of the learning and learning facilitation considerations discussed in the foregoing sections are applied to the present study.

Table 3-3 Learning and learning facilitation considerations in the present study

Principles of learning and learning facilitation	Principles as applied to the present study
Learner involvement	Active participation of the learner in information processing and knowledge construction.
Feedback	Continuous and appropriate feedback by the facilitator to guide the learner to achieve accurate mastering of fundamental concepts underpinning a study in calculus.
Developmental	A main focus is to develop the mathematics potential of the learners.
Multiple representation	Mathematical concepts are addressed graphically, symbolically, in writing and by way of oral communication.
Value of fundamentals	Exploration activities are aimed at a thorough understanding of fundamental concepts underpinning a study in calculus.
Interaction with facilitator	Communication, assessment and feedback are highly valued.
Interaction with peers	Spontaneous discussions amongst learners in informal groups of two or three are encouraged by the exploration activities. Establishing a learning community.
Contributive learning	Learners and facilitators contribute to each others knowledge including aspects related to mathematical content, learning, teaching, cognitive developmental aspects and academic related social communication.
Self-paced	When working through the exercises on the structured worksheets, learners set their own pace exploring the content.
Time on task	Mathematics activities are scheduled so that learners can master the concepts covered in a worksheet within 60 to 90 minutes.
Study skills	Study skills for mathematics study are addressed as an aspect of the developmental approach and students strongly encouraged to apply them
Accommodate preferences	From a whole brain perspective, exploration activities include aspects of all the cognitive modes according to Herrmann's four quadrant whole brain model. Students' preferred modes as well a non-preferred modes are called upon.
Develop competencies	
Personal construction of concepts	Exploration activities and mathematical communication (orally and in writing) contributes to learners' personal construction of concepts.

Compiled by the author of this thesis

3.6 The relevance of thinking styles, learning styles and teaching styles for a learning facilitation strategy in mathematics

According to Sternberg (1994:109) thinking styles refer to *the processes used to solve a problem or to devise an answer* and learning styles refer to *the processes of obtaining knowledge and skills by means of studying, instruction or experience.* Cilliers and Sternberg (2001:14) point out that teaching styles refer to *preferred ways or methods of teaching, and are closely related to preferred styles of thinking and learning.*

It should be pointed out that thinking styles, learning styles and teaching styles do not refer to abilities but to preferences. Furthermore, people's styles of learning and behaviour differ from individual to individual and there is not any one learning approach, style or orientation that is, in itself, the best or most desirable (Zuber-Skerritt, 1992a).

It can thus readily be assumed that both learners and facilitators of learning have different preferred modes of thinking and doing. An instructor's preferences have, most probably often unknowingly, a strong impact on the way he/she designs and delivers instruction. Felder (1993:288) points out that *teachers tend to favor their own learning styles, in part because they instinctively teach the way they were taught.* Furthermore, educators (of mathematics) are not necessarily aware of the diversity in the thinking style preferences and ensuing learning style preferences of their students nor of their own style that dictates their instructional approach.

Within the realm of tertiary mathematics education, there is seemingly a growing awareness that differences in students' learning styles should be taken into consideration when designing learning experiences and instruction. The Delta '99 Symposium on Undergraduate Mathematics Education in November 1999, had the principle of "diversity" as core theme of the conference, presumably proposing an awareness of the importance of "getting to know" the learners of tertiary mathematics. Although papers specifically reflecting on learning and teaching styles were scarce (Spunde, Cretchley & Hubbard, 1999), contributions regarding learning and teaching styles that were presented at the conference (Smith, 1999; Steyn, De Boer & Maree, 1999) were well received.

Becker and Pence (1994:7) remark that

> *Learning styles is a major area in need of further research. In particular, we need to identify how much difference it makes if teaching methods are incongruent with a student's preferred style.*

The author of this thesis acknowledges Becker and Pence's view but also feels strongly that the focus should not merely be on accommodating different thinking and learning styles but also on developing all cognitive skills available that are needed and appropriate for successful study (of mathematics). This necessitates an awareness of students' thinking and learning preferences as well as of the preferences that facilitators have. Determining students' thinking preferences and making them aware thereof, is one of the aspects addressed in the research questions stated in Chapter 1.[33]

Concerning facilitators of mathematics, awareness of diverse thinking and learning styles of both students and facilitators could become a point of departure for re-thinking the way in which tertiary mathematics are learned and taught. Congruency between learning styles and instructional styles will certainly be beneficial to learners but students also need to realise that incongruence between their own style and that of an instructor can and will occur during their studies. Students will always encounter teaching environments that do not match their preferred style. Once realised that this can happen, students need to develop the skills to cope with such situations.

Felder (1988, 1993) points out that the idea is not to determine each student's learning style and then teach to it exclusively but to simply address each side of the dimension of a learning style.[34] Felder's view regarding learning styles endorses the accomodational as well as functional modes regarding a brain-based instructional approach proposed in section 3.5 on page 100. If learning and teaching styles are viewed in terms of Herrmann's whole brain model,[35] the ideal is that both students and facilitators (of mathematics) should become aware of the principles of whole brain utilisation. The author of this thesis is of the opinion that if the principle of whole brain utilisation is acknowledged, understood, accepted and implemented, the learning and learning facilitation of mathematics could be beneficial to the learners and rewarding to the facilitator.

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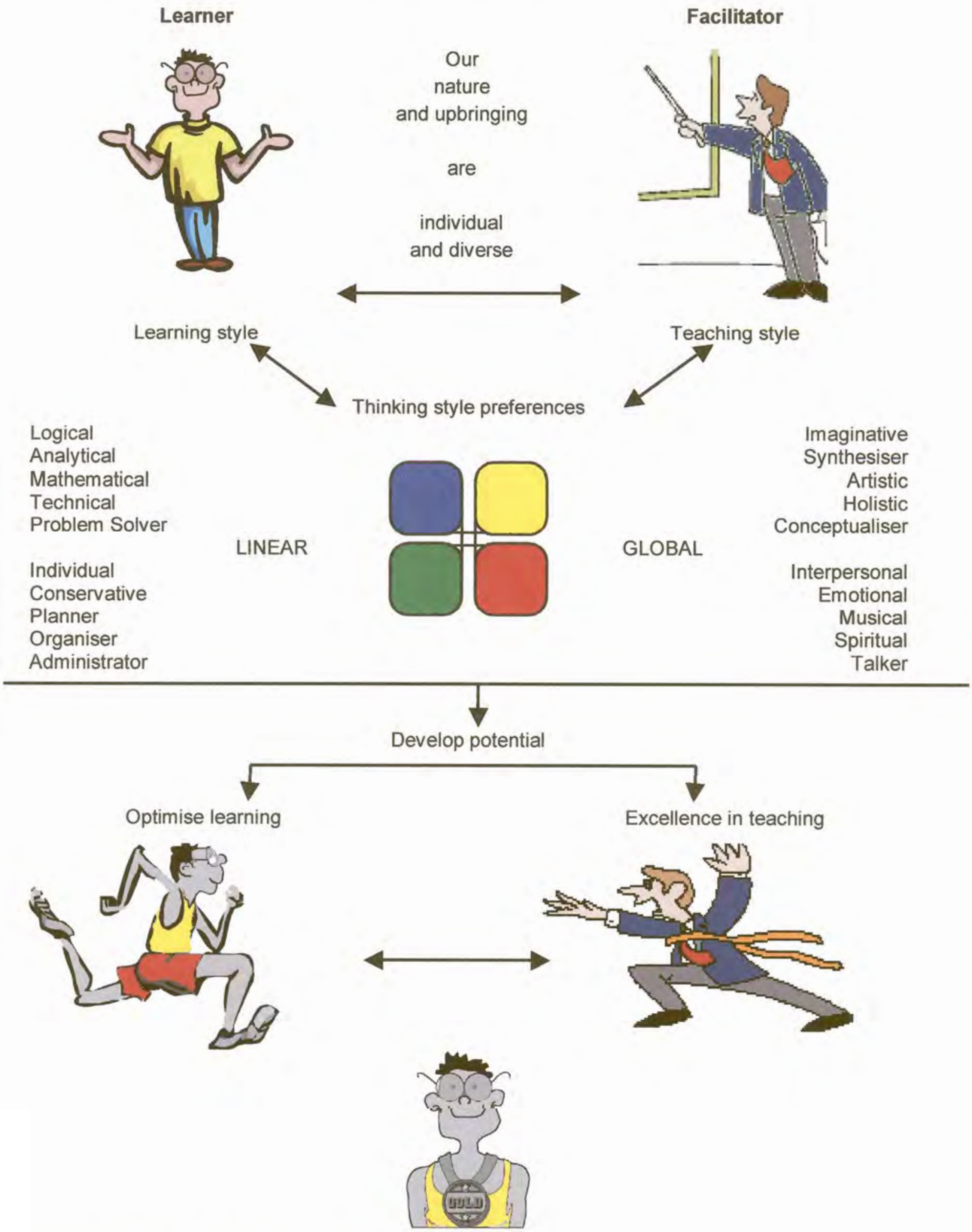
[33] The research questions are stated in Chapter 1 section 1.4 on page 8.
[34] The dimensions of Felder's learning style model are given in Chapter 2, Table 2-6.
[35] Herrmann's four quadrant whole brain model is presented in Chapter 2, section 2.3.4.

Figure 3-6 summarises the discourse regarding the matching of learning and teaching viewed according to the principles of the Herrmann whole brain model. What students learn seems to be less than what educators teach and what they hope students learn. Learners and facilitators are individual and diverse due to their personal nature, nurture and educational history. Learning styles and teaching styles can match or mismatch. Facilitators of mathematics need to realise that they cannot change their students' thinking and learning preferences. However, if they could align their teaching practice to accommodate and develop their students' styles of thinking when learning and doing mathematics, this could result in the development of the (mathematics) potential of the student. Ultimately, in this scenario, learning could be optimised and teaching could excel.

Figure 3-6 Matching learning and facilitation – a matter of styles



Adapted from Steyn, De Boer and Maree (1999)

3.7 The contribution of results from research during 1993-1999 to the learning facilitation of mathematics in a support course

In this section the main findings of research during 1993-1999 that formed the background to the study reported in this thesis are discussed.[36] The aim of the 1993-1998 research activities was to examine the use of computer graphing technology in an introductory calculus course for students on a support programme in the Faculty of Natural Sciences (Steyn, 1998). This research was done by the author of this thesis in collaboration with lecturers and tutors of the Gold Fields Computer Centre for Education and the Department of Mathematics at the University of Pretoria. During 1998 and 1999 studies were done that added further dimensions to the facilitation of mathematics introductory calculus level. The 1998 study (Steyn & De Boer, 1998) showed that mind mapping could successfully be used as a study tool for introductory calculus. The 1999 study indicated that learners of mathematics in a first course in calculus represent diverse thinking styles (De Boer & Steyn, 1999).

In the following sections the main results of the 1993-1999 studies, that are relevant for the present study, are briefly discussed.

3.7.1 Results regarding a computer graphing tool

In the 1993-1998 studies computer graphing software and pen and paper were regarded as "graphing technology" for teaching and learning mathematics. Technical, didactical and pedagogical features that a computer graphing utility should have for use in mathematics instruction were identified and were based on observing the influence that the use of technology can have on a learner as well as the effect that computer aided instruction can have on a learner's mathematical conceptualisation.

For the purpose of the 1993-1998 studies the use of graphing utilities in mathematics education were categorised as "exploratory" and "illustrative" (Steyn, 1998). In the **exploratory use** of graphing technology, technology is regarded as an aid (tool) to support a learner in the thorough investigation and examination of mathematical concepts that are represented by a graphical (visual) image. In this sense exploring a graph entails much more than only looking at the visual image. The **illustrative use** of graphing technology is

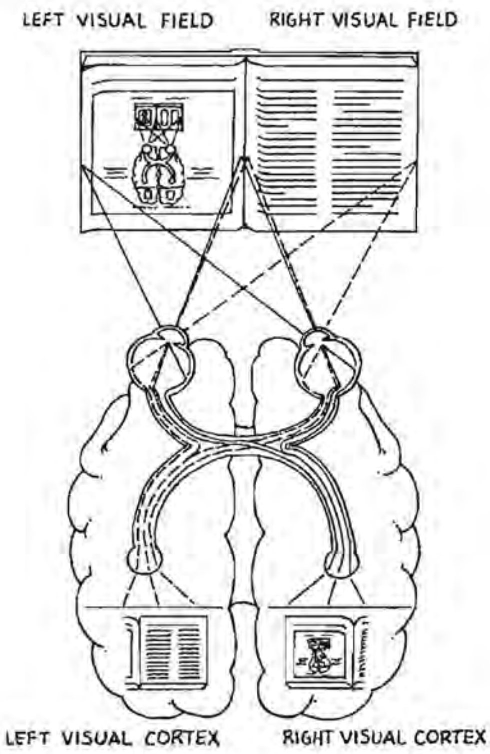
[36] Figure 1-3 on page 13 of Chapter 1 gives an overview of the action research cycles of the 1993-2001 studies.

defined as merely 'have-a-look-at-it'. On the one hand this implies showing a learner the visual image in order to get an overall idea of the graph. On the other, a 'have-a-look-at-it' use presupposes proficiency in the use of graphing technology as well as the necessary knowledge to interpret a graphical image. The latter scenario implies competence regarding the interpretation of graphical images that students, taking a first course in calculus, do not necessarily have.

1. **Technical features of graphing utilities**

The first technical aspect concerns the **user interface** of a graphing utility. The presentation of text and images on the screen should be conducive to learning in the sense that the utilisation of left and right brain functions are promoted and optimised if text is in the right visual field and visual images (graphics) are in the left visual field (Herrmann, 1995). The diagram in Figure 3-7 illustrates correct placement of text and graphics for optimising left and right brain functions.

Figure 3-7 The left and right visual fields



According to Herrmann, text should be in the right visual field and visual images (graphics, illustrations, etc.) in the left visual field to optimise brain functions.

Adapted from Herrmann (1995:14)

The layout of the user interface of the graphing utility in Figure 3-8 A is structured according to these principles but this is not generally a feature of educational graphing software.

As the human brain has an inherent fast response to colour, shape and contrast (Jensen, 1996), the use of colour in the user interface of a graphing utility should also be presented in such a way so as to aid and not to impair learning. Furthermore, care should be taken when using colour as a code for classification. This may affect interpretation of images by users who are colour blind. A further aspect pertaining to the user interface and the exploratory use of graphing technology concerns the size of the visual image. Activities during the 1993-1998 research studies contributed to the facilitators' opinions that the size of a computer screen is more conducive to true exploration than that of a graphing calculator (Steyn, 1998; Steyn & Maree, 2002).

Figure 3-8 The function $f(x) = \dfrac{5.1x^2 + 7.79x}{4.2x^2 - 17.64}$ **displayed by two graphing utilities**

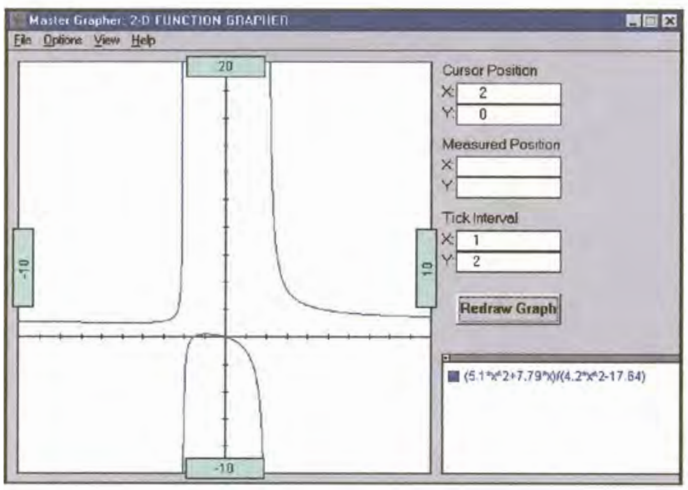


Figure 3-8 A

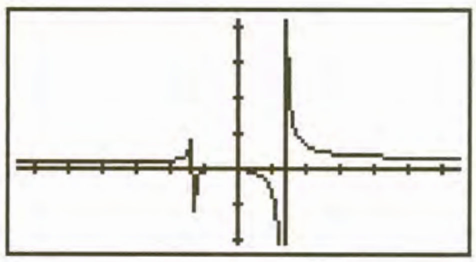


Figure 3-8 B

Compiled from Steyn (1998:114 & 123)

A second aspect required for the exploratory use of graphing technology concerns **technical capabilities**. An educational graphing tool must promote opportunities for authentic explorations and convincing observations. For example, entering functions must be easy. It ought to be possible to display more than one function simultaneously and functions must be distinguishable from each other. Real exploratory activities, such as physically following a curve with a pointing device (mouse), can enhance one's intuitive feeling for a graphical image. Changing the dimensions (minimum and maximum values on the *X* and *Y*-axes) of the graph window (viewing rectangle), in which the graph is displayed, must be easy and toggling between consecutive graph windows should be possible. As it is not always possible to represent in only one window all the mathematical characteristics of a function one would like to visualise, an easily accessible zoom feature ought to be available. Very useful features, for the meaningful exploration of related changes in *x* and *y*-values, are moving vertical and horizontal lines as well as the ability to add fixed vertical and horizontal lines to the image displayed by the graphing utility.

2. **Didactical and pedagogical features of graphing utilities**

Experiences gained during the 1993-1998 research have indicated that when technology is incorporated into a mathematics tuition programme, the focus should not be on the technology. This means that the skill of using a graphing utility should be easily acquired and retained by the learners for whom the instruction is intended. Technology should add value to students' learning experiences and should facilitate rather than dictate learning.
In using graphing technology as a tool to explore mathematics, learners need to be able to get an intuitive feeling of the graph through the activity (for example, following the curve with the pointing device to get a feeling of whether a function is increasing or decreasing). This highlights the fact that the screen size of a computer and the relative ease in manipulating a pointing device (mouse) in comparison with those of graphing calculators are beneficial to authentic experiential activities. In this regard, Fuchsteiner (1997:14) points out that *intuition and concepts constitute the elements of all our knowledge ... no reform in the education of mathematics can be successful which does not focus on how we can strengthen intuition.*

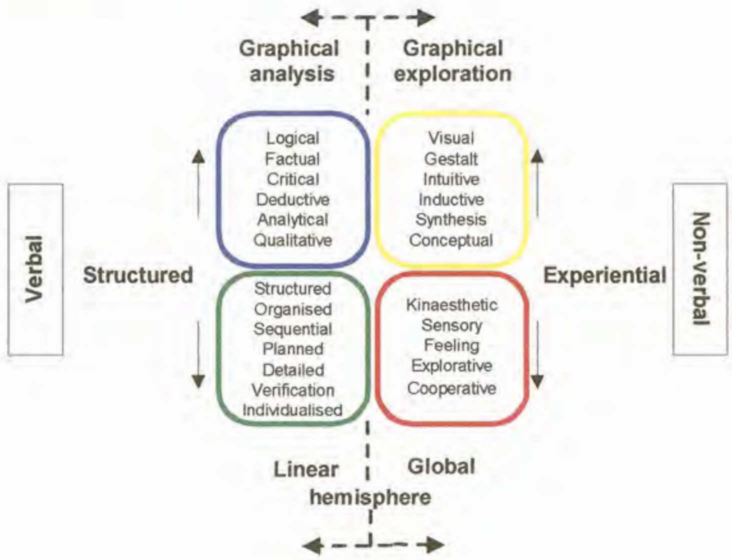
A further aspect that was distinctly noticed when a graphing approach is used for the teaching and learning of fundamental concepts related to two-dimensional functions, is that the images, displayed by the graphing utility, should be accurate representations of the functions. Figure 3-8 A illustrates the graph of a rational function drawn by the computer graphing tool developed during the 1997 research (Carr & Steyn, 1998) and Figure 3-8 B illustrates the same function drawn by a graphing calculator. Images like the one in Figure

3-8 B proved to be very confusing. For example, when students had to interpret the image on the screen (as in Figure 3-8 B) and draw a freehand graph, it invariably occurred that they drew an exact copy of the image on the screen. When then asked to explain the graph, students reported that the graph had 'sharp' turning points for some x-value(s) on the interval (-2, -1) and that the graph 'stopped' below and above the X-axis for x-value(s) on the interval (1, 2). In an example such as this one concerning a rational function (Figure 3-8), the image as in Figure 3-8 B cannot be used to enhance concepts, e.g. in this case, the concept of vertical asymptotes or the range of the function. This ambiguity forfeits the purpose of a visual image. Experiences with students in this research have undoubtedly shown that ambiguous graphical images give rise to mathematical misconceptions.

3.7.2 Results regarding the enhancement of mathematical concepts

During the 1993-1998 research studies, the significance that the exploration of two-dimensional functions through their graphs has for enhancing conceptualisation of fundamental mathematical concepts that underpin a study in calculus was examined according to the convention illustrated in Figure 3-9, namely that graphical exploration is experiential and non-verbal and is mainly focused on the utilisation of functions of the "global" hemisphere of the human brain and graphical analysis is verbal and structured and is mainly focused on the utilisation of functions of the "linear" hemisphere of the brain. This view of learning facilitation and the distinction between the global hemisphere and linear hemisphere of the human brain are treated in Chapter 2 section 2.3.

Figure 3-9 Manifestation of mathematical concepts through graphical analysis and exploration: a whole brain perspective



Adapted from Steyn (1998:136)

The predominant categories that emerged in the research activities during 1993-1998 in determining how the exploration of two-dimensional functions through their graphs can enhance mathematical conceptualisation are the **visualisation** of functions; viewing functions as **gestalt (wholeness)** entities; a combination of **inductive** and **deductive** approaches to graphical exploration of functions and **verbalisation** in mathematics.

A major contribution that a graphing utility can make in revealing mathematical concepts lies in the visualisation of functions through their graphs. The importance of visualisation in mathematics education is extensively discussed by various authors in Zimmerman and Cunningham (1991). Visualisation interpreted from a whole brain perspective (as in Figure 3-9) also implies utilisation of a predominantly global hemisphere functions. Graphical representations further enhance conceptualisation through wholeness. This means that a mere glance at the graphical representation of a function (as in Figure 3-8 A) conveys more information regarding the features of a function than is the case when an equation alone, for example $f(x)=\frac{5.1x^2+7.79x}{4.2x^2-17.64}$ representing the function in Figure 3-8 A, is considered.

When students learn mathematical concepts by exploring examples graphically and intuitively (mainly global hemisphere utilisation[37]), and discovering key aspects themselves, this approach can be described as inductive. The study revealed that the structured exploration of a variety of examples on the same topic leads to logical analytical deductions (mainly linear hemisphere utilisation), that should ideally lead to synthesis and conceptualisation (mainly global hemisphere utilisation). A deductive approach to graphical exploration occurs when students already know an analytical theorem or rule (mainly linear hemisphere utilisation) and then study a graph (mainly global hemisphere utilisation) illustrating the theorem (rule). The ensuing analysis of graphical images compels a learner to formulate his/her conceptualisation of the mathematics involved.

Experiences with students during the 1993-1998 studies have also shown that verbalisation (orally and in writing) with regard to the mathematics content, eventually helps learners to become sensitive to the degree of correctness or incorrectness of their own mathematical formulation and conceptualisation.

During 1996-1998 a questionnaire was administered at course end. In their responses, the students, amongst other things, indicated that the visual image contributed to their understanding of two-dimensional functions and that the concept of a graph was more meaningful after the exploration activities in the course than before; that the practical course sessions helped them to improve their ability to formulate mathematical concepts and express themselves in the language of mathematics and that their skill in writing mathematics improved. The data in Table 3-4 on the following page give the responses of students to end of course questionnaires 1996-1998. Using the binomial test and comparing the proportion of 'yes' and 'no' responses to the assumption that 50% would respond 'yes', the results were that for all the years the 'yes' response to all the questions was significantly high ($p<0.5$ throughout).

[37] See Chapter 2, Table 2-5 on page 56.

Table 3-4 Responses of students to end of course questionnaire 1996-1998

		Number of student responses			
		1996	1997	1998	Total
Do you think that using visual images made the mathematical concepts more clear?	Yes	58	114	113	285
	No	7	10	5	22
Is the concept of a graph now more meaningful to you than before you used the computer graphing tool?	Yes	65	121	113	299
	No	2	3	4	9
Do you think that the practical graphing sessions helped you to improve your ability to formulate mathematical concepts and express yourself in the language of mathematics?	Yes	66	115	108	289
	No	1	9	10	19
Do you think that completing the worksheets improved your skill in writing down the mathematics correctly?	Yes	65	114	106	285
	No	2	10	12	24

Compiled from Steyn and Maree (2002)

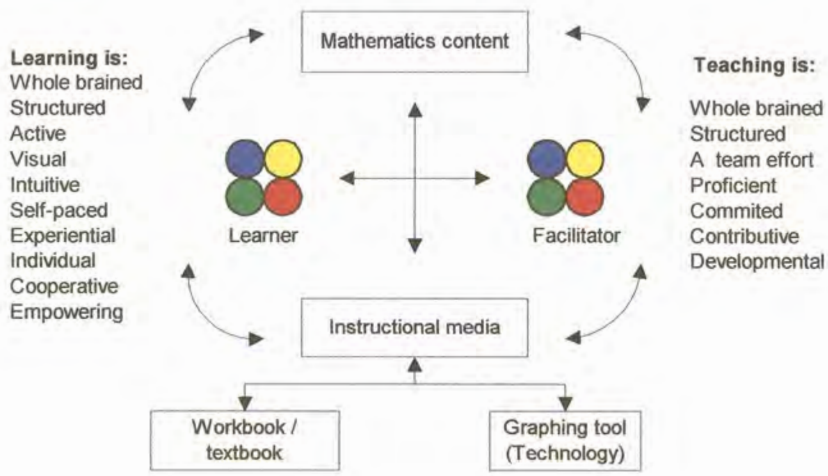
3.7.3 Results regarding an instructional strategy incorporating computer graphing technology

Experiences during the 1993-1998 studies indicated that the meaningful combination of graphical exploration and graphical analysis could be regarded as a prerequisite for the manifestation of mathematical concepts in a teaching and learning approach aimed at whole brain utilisation.

The instructional model (Steyn, 1998) in Figure 3-10 presupposes an interdependence between teaching, learning, instructional media and instructional content when technology is used in (tertiary) mathematics education. This model comprises four main components, namely, the mathematical content; the learner; the facilitation of learning and the instructional media. The fundamental premise in this model is that the components are interdependently linked. The arrows in Figure 3-10 illustrate this interconnectedness.

The mathematical content of the model in Figure 3-10 deals with aspects associated with a first course in calculus. These include principles from precalculus that underpin a study in calculus, concepts related to the Cartesian coordinate system, two-dimensional functions, the concepts of limit, continuity and differentiation and the application of the first and second derivative. In this model, the concept of whole brain utilisation is used as a paradigm for elucidating the teaching and learning of introductory calculus in a support course. The facilitation of learning in this model is also based on research and experiences related to learning discussed in Chapter 2 and the preceding sections of Chapter 3.

Figure 3-10 An instructional model for graphing technology aided mathematics tuition



Steyn (1998:128)

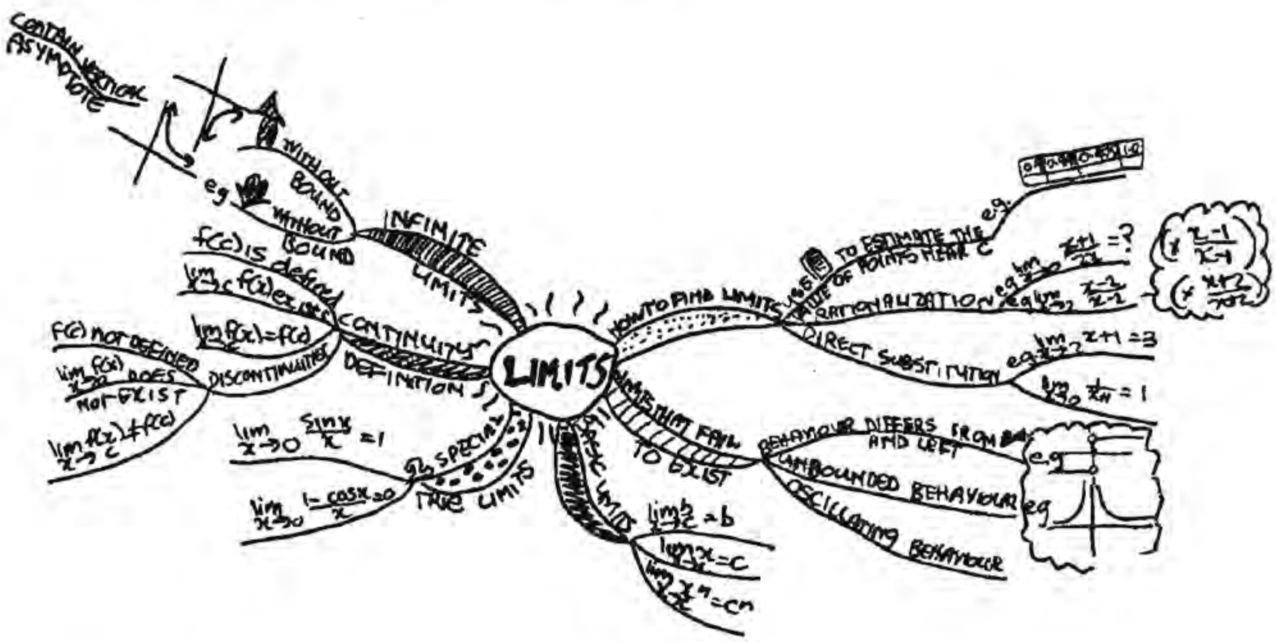
3.7.4 Results regarding mind mapping as a study strategy

During 1998 a group of students were exposed to mind mapping[38] as a study tool in order to foster a deeper approach to learning and to monitor the possible effect thereof on the academic disposition of the students (Steyn & De Boer, 1999). As all the students were enrolled for the calculus course in a support programme in the School of Natural Sciences, one of the mind maps they had to construct and submit for assessment had to be on their

[38] The term "mind mapping" is used to describe the principle as postulated by Buzan (Buzan, 1991; Buzan & Buzan, 1997).

mathematics preparation for an upcoming mathematics test. The mind map on limits in Figure 3-11 was done by one of the students.

Figure 3-11 Example of a mind map on limits



Steyn and De Boer (1998:128)

The principle findings of the study were that the students on the BSc Extended Programme lacked a workable study strategy for learning mathematics and science; that all of the students commented that previous presentations of mind mapping as a study tool lacked guidance regarding the format and structure and they had not been given the opportunity to implement the technique or to have it assessed; that the compulsory use of the mind mapping strategy resulted, in most cases, in an improvement in grades and that students experienced an empowerment of their academic disposition (Steyn & De Boer, 1998).

Melton, Reed and Kasturiarachi (2001:27) also report that results from an experiment with mind maps in a college algebra class *support the hypothesis that the use of mind maps by these students can improve their mathematical skills.*

3.7.5 Results regarding students' thinking style preferences

During 1999 the Herrmann Brain Dominance Instrument (HBDI)[39] was used to determine the thinking style preferences of two groups of students, both taking a first course in calculus (Steyn & De Boer 1999; Horak, Steyn & De Boer, 2000). The aims were to give the students insight into their own thinking style preferences; to determine the distribution of the students' preferred modes of thinking and to determine the homogeneity and/or diversity of the groups' preferences.

Both studies indicated that the two groups of students (one being science students on an extended programme and the other first year engineering students on a regular programme) had distinct preferences for thinking modes associated with the linear hemisphere and lesser preference (even lack of preferences) for thinking modes associated with the global hemisphere. The studies confirmed the existence of preferred and non-preferred thinking modes across the four quadrants of the Herrmann model. Aspects of the results of these studies are discussed in Chapter 6 of this thesis.

The results of the mentioned studies during 1993-1999 paved the way for the construction of the strategy for learning mathematics and the learning facilitation strategy that are proposed in this thesis.

In the next section a strategy is proposed for mathematics learning. This strategy is then applied to propose a learning facilitation strategy for mathematics in a support course for first year engineering students as it was implemented by way of action research activities during 2000 and 2001.

[39] The HBDI is discussed in Chapter 4, section 4.4.2.3 and in Chapter 6, section 6.6.3.

3.8 A strategy for learning mathematics in a support course

3.8.1 Components of the strategy

The strategy proposed in Figure 3-12 on page 123 comprises the following components, namely:

- The learner.
- The sense modes for learning mathematics.
- The information environment.
- The structure for processing mathematics information.

In the following paragraphs each of the components is discussed.

3.8.1.1 The learner

In the strategy for learning mathematics in a support course the learner is regarded as the active participant in learning and as someone who personally has to take action regarding his/her mathematics learning. The central focus is on the learner, his/her learning experience and his/her development as a learner. The learner is viewed as having the potential to study mathematics (in a first course in calculus). It is acknowledged that the learner comes into the support course with an existing study orientation in mathematics that results from the learner's personal background and experiences in mathematics. It is also assumed that the learner has established thinking and learning style preferences based on genetics as well as on educational experiences gained through formal schooling and also informal learning.

3.8.1.2 The sense modes for learning mathematics

From the five human senses (visual, auditory, kinaesthetic, olfactory and gustatory) the sense modes relevant to mathematics learning at introductory calculus level are visual, auditive and kinaesthetic. It should be pointed out that for the purposes of this study, the sense modes are regarded as modes that are available to all learners to be put to best use in learning and learning facilitation. However, an analysis pertaining to learners' individual preferences or competencies in using the different modes was not done in the study reported in this thesis.

3.8.1.3 The information environment

In the strategy for learning mathematics in a support course the information environment for learning is regarded as the modes by which information is obtained from the environment. In this strategy the four modes for mathematics learning are described according to Lumsdaine and Lumsdaine's[40] view of how a tertiary student learns namely, external learning, internal learning, interactive learning and procedural learning. The attributes of these modes that constitute the information environment for mathematics learning are summarised in Table 3-5.

Table 3-5 Attributes of the information environment for mathematics learning

External learning	Procedural learning	Interactive learning	Internal learning
Technology Workbook; textbook Information by the facilitator	Procedures used for graphical exploration Exercises Assessment	Experiential activities Feedback Discussion	Visualisation Insight Intuition Concepts

Compiled by the author of this thesis

3.8.1.4 The structure for processing mathematics information

In the strategy for learning mathematics in a support course, information processing by the learner is regarded as being done by utilising cognitive modes according to the Herrmann whole brain model. This structure for processing mathematics information is inherently part of the learner and forms a focus in the strategy. Herrmann's four-quadrant whole brain model[41] was adapted for the strategy defined in Figure 3-12 on page 123. These adaptations are listed in the different quadrants of the component in the centre of the strategy illustrated in Figure 3-12.

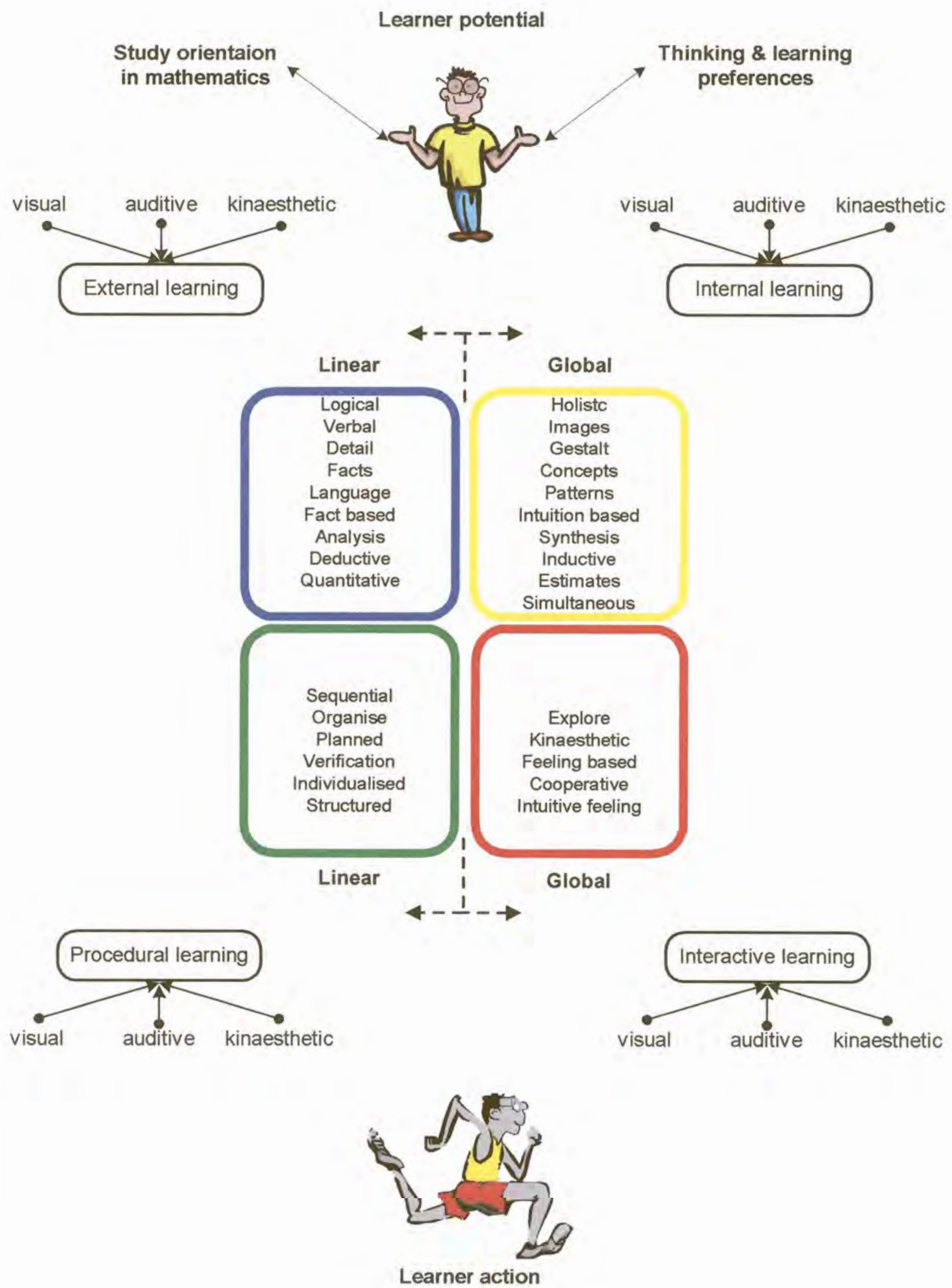
In the strategy defined in Figure 3-12 the left/right hemispheric division of the brain concerning the processing modes that are associated with each hemisphere is endorsed.

[40] See Chapter 2, section 2.5.2.
[41] See Chapter 2, section 2.4.4.

However, it should be pointed out that the following terminology, describing the functions associated with a particular brain hemisphere, is used.

The term "linear" is used to describe the brain functions generally associated with the left brain hemisphere and the term "global" is used to describe those functions generally associated with the right brain hemisphere. For about 90% of all learners the "linear" hemisphere will coincide with the left brain hemisphere and the "global" hemisphere will coincide with the right hemisphere (Vander, 2001:368). For about 10% of learners the functions of the hemispheres are transposed meaning that for them the "linear" hemisphere will coincide with the physical right brain hemisphere and the "global" hemisphere will coincide with the physical left hemisphere. Using the terms "linear" and "global" thus reflect on the functions associated with the particular hemisphere and do not indicate the left or right side of the body.

Figure 3-12 A strategy for learning mathematics in a support course



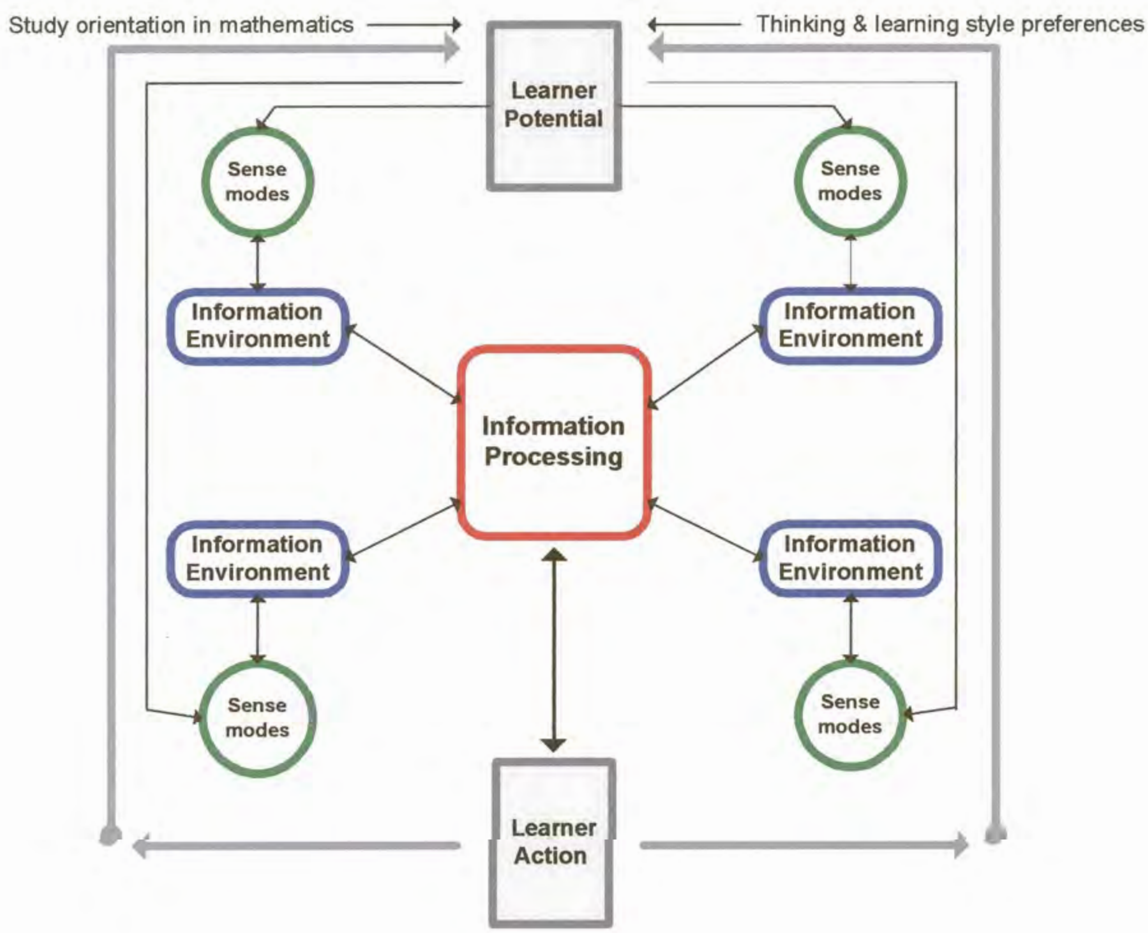
Proposed by the author of this thesis

3.8.2 Functional aspects of the strategy

Functionally, the strategy can be described in terms of information input, information processing and information output. On a physiological level Diamond (1999) points out that the activation of specific brain regions and their chemical and electrical frequency characteristics are relevant for information input, information processing and information output.

The functioning of the strategy for learning mathematics defined in the previous section is illustrated in Figure 3-13. The arrows indicate the relationship between the learner and the attributes of the strategy.

Figure 3-13 Functioning of the strategy for learning mathematics



Proposed by the author of this thesis

In the following sections the three functional processes (information input, information processing and information output) are briefly discussed. Although the author of this thesis fully acknowledges the relevance of physiological functioning, this discussion only reflects an educational perspective based on the Herrmann whole brain model, the mentioned categories of Lumsdaine and Lumsdaine and the sense modes relevant for mathematics learning.

3.8.2.1 Information input

According to the strategy in Figure 3-13 information input is through the sense modes and the information environment. The sense modes include visual, auditory and kinaesthetic input. The information environment includes input through external sources (such as information by the facilitator, appropriate technology, a workbook and textbook); through procedures (such as exercises and assessment); through interaction (such as exploration activities, discussion, feedback) and through internal cognition (such as intuition and insight).

Concerning the sense modes, Jensen (1996:131) distinguishes between internal and external input. External input is from an outside source and internal input is created by oneself, in the own mind. For example, visual external would be a person looking outward, visual internal would be a person visualising it ('seeing' it in the minds eye or making mental pictures). Auditory external is through verbal communication with others whereas auditory internal is by way of 'communication' with the self. Kinaesthetic external is 'hands-on' activity whereas kinaesthetic internal is intuitively and feeling based.

According to Hannaford (1997) when new information is taken in via the senses a learner has greater access to those senses that are directly linked to the dominant brain hemisphere. More specifically, sensory intake is ideally facilitated when the dominant eye, ear, hand and foot are on the opposite side of the body from the dominant brain hemisphere. This means that if the linear hemisphere is dominant and located in the left brain hemisphere the dominant eye, ear, hand and foot should be on the right side of the body. Although the author acknowledges these facts, it must be pointed out that the relation between the dominant hemisphere and the dominance of the senses as well as the effect hereof on mathematics learning were not considered or investigated in this study.

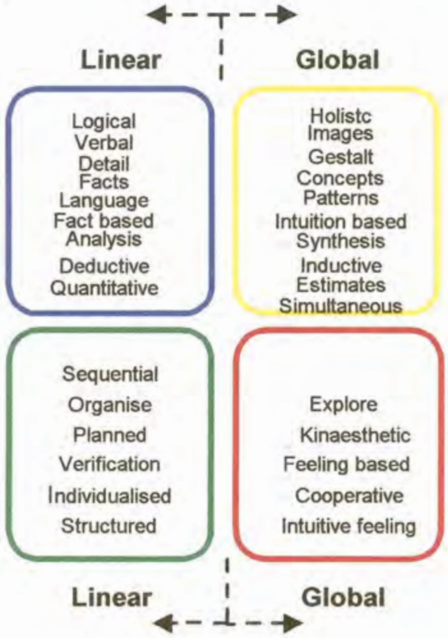
Stice (in Felder *et al*., 1988:677) reports on research that determined the retention of information presented in different ways as follows. Students retain 10% of what they read, 26% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say and 90% of what they say as they do something. These figures illustrate that a combination of the sense modes of visual, auditive and kinaesthetic could be favourable for learning mathematics.

Ideally, information should be presented in such a way that information input fosters the functional mode (see Figure 3-5 on page 102) of whole brain utilisation that should then in turn contribute to whole brain utilisation with relevance to information processing.

3.8.2.2 Information processing

According to the strategy in Figure 3-13, information processing is dependant on input via the sense modes and the information environment. Information processing is also influenced by a learner's study orientation in mathematics and preferences related to individual thinking and learning styles. In the strategy information processing of mathematics in a support course is viewed in terms of utilising cognitive functions described by the Herrmann whole brain model that have been adapted for describing mathematics learning. The diagram in Figure 3-14 below illustrates a whole brain perspective on information processing regarding mathematics as presented in the strategy in Figure 3-12.

Figure 3-14 A whole brain perspective on information processing regarding mathematics



Adapted from Steyn (1998:136)

In the following paragraph a generic description is given that demonstrates, in a simplistic manner, how information processing of an aspect of mathematics could be interpreted from a whole brain perspective.

When students explore two-dimensional graphs generated by an appropriate computer graphing tool[42] as used in the mathematical activities referred to in this thesis, the initial information processing concerns a visual image, gestalt input and possibly also kinaesthetic input from hand-on experiences or intuition. This processing mainly represents activities related to global hemispheric functions. This can then be followed by analysis, deductions and formulation of observations that mainly represent linear hemispheric functions. This again can be followed by inductions, estimates, synthesis and concepts (mainly global hemispheric functions) that result in verbalising the concepts orally and/or in writing (mainly linear hemispheric functions). Similarly, the sequence of information processing can start with analysis of mathematical text (mainly representing linear hemispheric functions) which can be followed by exploration activities using the graphing tool (mainly representing global hemispheric functions). It should, however, be

[42] *Master Grapher for Windows.*

kept in mind that the human brain functions as a composite whole and these functions occur both simultaneously and iteratively.[43]

3.8.2.3 Information output

According to the strategy in Figure 3-13, information output is viewed in terms of learner action. Learner action comprises the following attributes namely, mastering of fundamental concepts that underpin a study in calculus; a restructured study orientation in mathematics and an awareness of the effect of thinking and learning style preferences on mathematics learning.

The author of this thesis is of the opinion that a learner's study orientation in mathematics and his/her preferred style of thinking and learning have an influence on information input, information processing and information output. These aspects are addressed through the research questions stated in Chapter 1 of this thesis.[44]

3.9 A learning facilitation strategy for mathematics in a support course

3.9.1 Aspects of the strategy

The main aspects regarding a learning facilitation strategy for mathematics in a support course for first year engineering students defined in this thesis comprise all the **attributes of learning** as well as their **functional aspects** that are defined in the strategy for learning mathematics and which have been discussed in the preceding sections of the chapter. In addition, a **learning environment** contributes to the mentioned strategy. Figure 3-15 on page 132 illustrates this proposed strategy.

The main aim of the proposed learning facilitation strategy, is to develop the mathematics potential of the learners. This development is attained by optimising the learning of mathematics according to the strategy illustrated in Figure 3-12 (page 123). In the strategy illustrated in Figure 3-15, the prospective optimisation is achieved within a learning environment. In the following paragraphs the concept "learning environment" and its relevance for the proposed learning facilitation strategy is discussed.

[43] See Chapter 2, Table 2-7 on Key brain characteristics.
[44] See Chapter 1 section 1.4.

The term "learning" was defined in Chapter 1 and further discussed in Chapter 2. The term "environment" is defined as *the conditions, circumstances, etc. affecting a person's life* (Crowther, 1995:387) and as the *aggregate of social and cultural conditions that influence the life of an individual or community* (Woolf, 1977:382). Thompson (1995:452) and Woolf (1977:382) define the term "environ" as *encircle, surround.*

These definitions of "environ" and "environment" clearly convey their meaning with regard to the learning facilitation strategy for mathematics defined in this thesis. In this strategy the "learning environment" is viewed as the *social and academic conditions that surround and influence the learning of mathematics in a support course.*

3.9.2 Learning environment

According to Smith and Ragan (1993:37) a learning environment comprises of teachers; existing curricula; instructional equipment; the institution and the larger community. Du Plessis and Quagraine (2000) identify the following aspects regarding a learning environment that influence the way in which students cope at university, namely, teaching strategies; the curriculum; the method(s) of assessment; resources; teacher characteristics; institutional administration and peer group.

The author of this thesis acknowledges the mentioned attributes but wishes not to restrict the concept "learning environment" to formalised attributes with regard to the proposed strategy. The author regards **any physical, social and/or academic condition that surrounds and influences the learning of mathematics** as part of a "learning environment" – a view that is confirmed by Du Plessis (2000). It inevitably follows that these conditions may vary according to the characteristics of the learners and the community wherein the learning takes place. The following are examples of social and academic aspects that formed part of the research activities during 2000, 2001 and 2002 when the strategy was implemented and which contributed to the learning environment.

3.9.2.1 Facilitator characteristics and activities

According to the proposed strategy, the activities of the facilitator should ideally incorporate all relevant concepts of learning (discussed in Chapter 2) and principles of instructional design and aspects of teaching (discussed in the preceding sections of this chapter) within the framework of a whole brain approach. In a whole brain approach the complex physiology of the brain involved in learning is not the primary focus for facilitating learning but the author is of opinion that a facilitator of mathematics cannot ignore the results pertaining to the functioning of the human brain and the implications thereof for educational activities.

The author of this thesis is also of the opinion that to facilitate learning one needs to be aware of the students' existing learning experiences, their learning preferences and how they view learning. Rodgers (1983:18) points out that *teaching is more difficult than learning because what teaching calls for is this: to let learn.* Similarly Steen (1988b:91) remarks that *in a sense, no one can teach mathematics. What we hope is that a good teacher can stimulate a student to learn mathematics.*

Felder's reflections on the teaching of first year engineering students may very well also apply to the learning facilitation of mathematics in a support course and he remarks that

> *Teaching freshmen can be exasperating, and it's easy to conclude that it isn't worth the effort to overcome the obstacles they put in the way of their own learning and growth. .... If you're [the facilitator] sufficiently patient, thick-skinned, and positive, and if you maintain unshakable faith in their [the students'] ability to succeed despite themselves, they will reward you ... with understanding and skills you would not have believed possible.* (Felder, 1997:16).

3.9.2.2 A learning community

The creation of a community for learning mathematics in a support course entails both social and academic matters. Landis (1997:9) identifies three stages in the building of a learning community in any class, namely, socialisation; group building and human relations training. Socialisation entails that each student should know all the other students in the class by name. Once this has been achieved, students should work and study in peer groups. Human relations training should focus on developing personal, academic and social skills that will contribute to their development as learners. These aspects regarding a learning community is endorsed by the learning strategy for mathematics discussed in this section.

Furthermore, the author of this thesis is of the opinion that learners on a support course in mathematics need to experience "support" beyond the mere understanding of mathematics content. The author feels that students need to feel valued as learners and that their academic success is a shared commitment including themselves as well the facilitator. However, learners also need to increasingly take responsibility for their own learning (in mathematics) and they need to be supported to develop the skills for self-directed and life-long learning that will hopefully not be restricted to the domain of mathematics content. Philip (1991) points out that the domains of the teacher's and the learner's responsibilities are not mutually exclusive. Philip (1991:9) regards *teachers and learners as occupying positions on a continuum extending from teacher-control at one extreme to learner-control at the other, where the deliberate surrendering of certain prerogatives by the teacher is accompanied by the concomitant acceptance of responsibilities by the learner or learners.*

3.9.2.3 Physical learning facilities

Concerning the personal physical well being of the students, they need to be made aware of the benefits of mental and physical health and a lifestyle supporting it. Landis (2000:187) specifically points out that it must be conveyed to students that they must *eat nutritionally, engage in regular aerobic exercise, get adequate sleep and avoid drugs.*

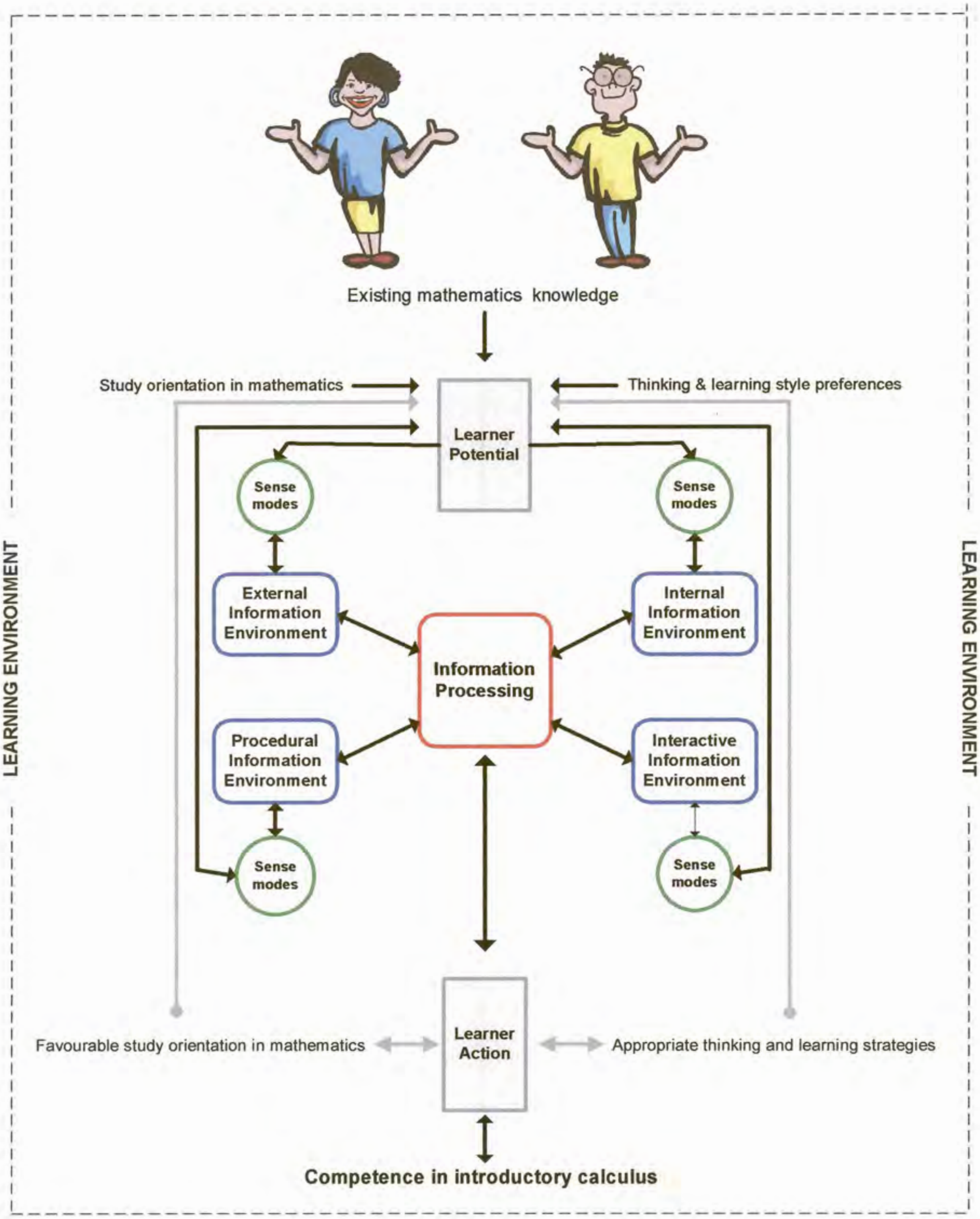
3.9.3 Implementation of the strategy

The strategy for the learning facilitation of mathematics defined in this chapter were implemented during 2000, 2001 and 2002 and assessed through action research studies. These studies are discussed in Chapter 5 and the results of data pertaining to the studies are analysed in Chapter 6 and discussed in Chapter 7. It should, however, be pointed out that only those aspects of the strategy pertaining to the research questions[45] were analysed.

Figure 3-15 on the following page illustrates the learning facilitation strategy proposed in this thesis and which was followed in the studies discussed in Chapter 5.

[45] For details of the research questions, see Chapter 1 section 1.4.

Figure 3-15 A learning facilitation strategy for mathematics in a support course for first year engineering students



Proposed by the author of this thesis

3.10 Summary

In this chapter it was indicated how principles of instruction and views of learning from various perspectives contribute to a strategy for learning facilitation that has as core principles the development of a learner's mathematics potential, learner involvement and whole brain utilisation.

It should be noted that although the strategy for learning mathematics as well as the strategy for the learning facilitation of mathematics presented in this chapter are partially embedded in the writer's own research experiences during 1993-2001 with students on support programmes, the components of the learning strategy and the principles that constitute the strategy address fundamental aspects related to human learning and learning facilitation. The writer is of opinion that the strategy may be relevant for any learning facilitation regarding mathematics and in particular in a first course in calculus.

With regard to the instruction of mathematics in tertiary education, Ruthven (1998:92) points out that:

> *Teachers of university mathematics courses, on the whole, have not been trained to, and do not often consider educational, didactic or pedagogical issues beyond the determination of the syllabus; few have been provided with the incentives or encouragement to seek out the results of mathematics education. In days gone by responsibility was placed on students' shoulders: it was assumed that faculty's responsibilities were primarily to present material clearly, and that good students would pass and poor ones fail. The climate today is that academic staff is considered to have greater overall responsibility for students' learning. The role of instruction (specifically, of lectures) and staff accountability are being reconsidered.*

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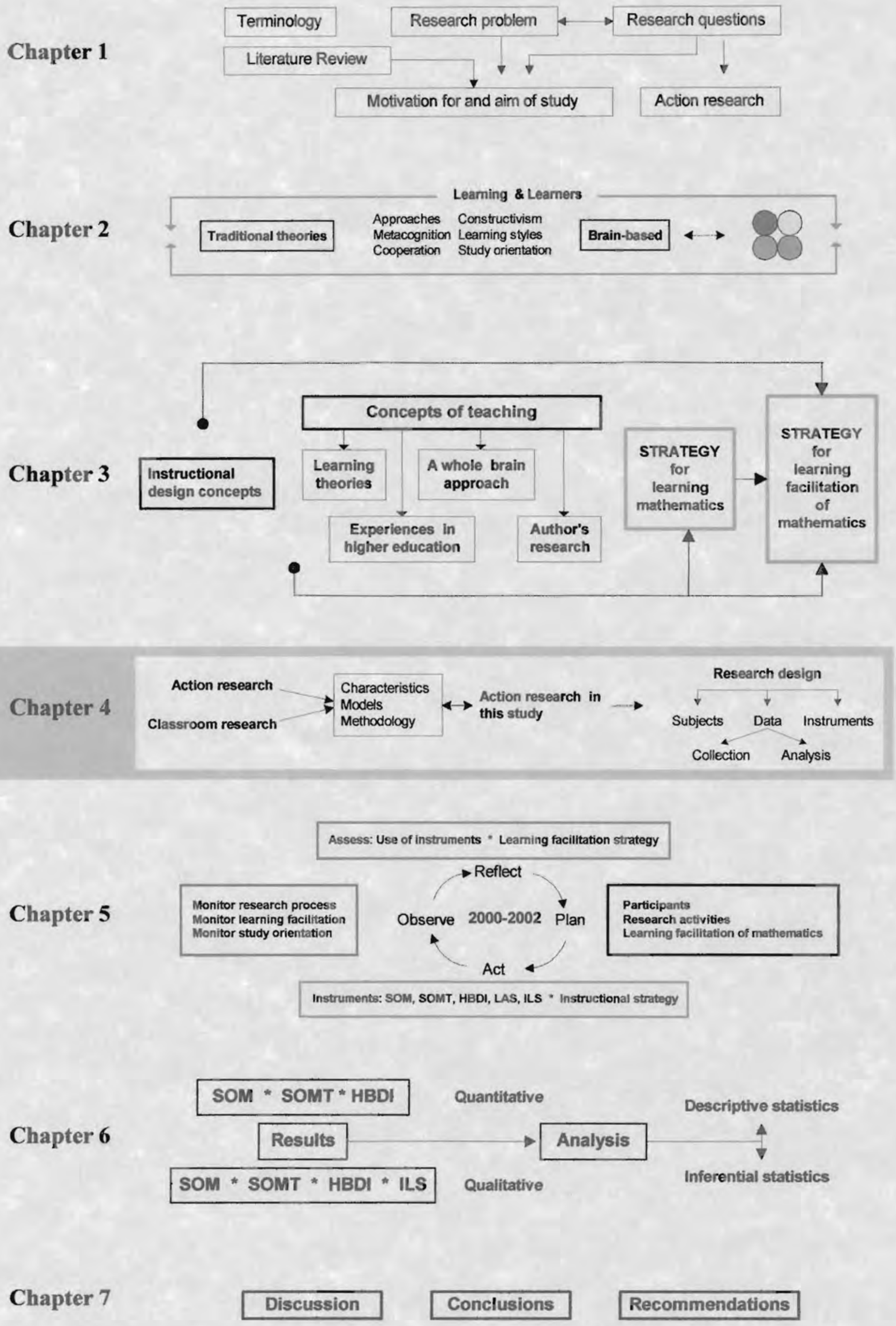

Research design

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Chapter 4

Research design

4. Introduction

In this chapter the research design of the present study is addressed. Firstly an epistemological overview is given of the philosophy underpinning the research approach followed in the study. Then the particulars of the research approach adopted for the study are given. The specifics of the research design are discussed dealing with ethical considerations, validity, the subjects in the study and the data. Thereafter the details of the data collection procedures, the methods and instruments as well as the data processing procedures are discussed.

4.1 Aims of the research

The primary objective of the research reported in this thesis is to propose a strategy for the learning facilitation of mathematics in a support course for first year engineering students, to define the aspects that constitute such a strategy and to determine the possible effects of the strategy on learners' study orientation towards mathematics and on their performance in mathematics. The proposed strategy for the learning facilitation of mathematics was defined in Chapter 3. The resulting aims of the research are multiple.

Firstly, it is to determine the study orientation towards mathematics of the students enrolled for the POSC and to gain insight into their thinking style preferences. Furthermore the aim is to determine if a learning facilitation strategy, designed to enhance fundamental mathematical concepts, to create an awareness of study orientation and to foster an awareness of the existence of different thinking styles and cognitive processing modes, can contribute to improved academic performance in a standard first semester course in calculus. The aims of the research thus entail investigating the possible and potential relationship between study orientation, thinking style preferences, learning facilitation of mathematics and performance in mathematics. The following question arises: How can this relationship be fostered to optimise the development of a learner's potential for mathematics and have it displayed as an outcome in the learner's grades in mathematics? In order to establish the mentioned relationship and to determine the effect thereof on academic performance, the present study was done following an action research approach and incorporating additional methodologies to investigate specific aspects.

4.2 Research approach: Action research

The main research approach adopted for the study described in this thesis is action research. In the following paragraphs an overview of the origins and definitions of action research is given as well as the characteristics and models of action research relevant to the present study. The research approach in this study also displays some of the core principles of classroom research as postulated by Angelo and Cross (1993) and Cross and Steadman (1996). In the opinion of the author of this thesis the principles underpinning an action research approach in education are similar to those proposed in the classroom research approach. In the subsequent sections the research approach and methodologies of the present study are given.

4.2.1 Origins of action research and teacher involvement in research

Action research emerged from the social research studies of Kurt Lewin in the 1940s. Noffke (in Feldman, 1994:84) points out that in Lewin's formulation of action research, there is a clear focus on instituting change by taking actions, carefully collecting information on efforts and then evaluating them, rather than formulating hypotheses to be tested. This represents a clear distinction from the dominant educational research form of that time but also emphasises Lewin's concern with resolving issues and not merely collecting information and writing about them. The theory that developed as a result of the research was theory about change, and not about the problem or topic itself.

Although Lewin did not originally apply his methodology to education, he introduced a research process consisting of spiral steps that was transferred to research in education. Emerson (1999) gives a concise account of the origins of action research in education. She points out that in the 1950s, mainly in the USA, a few researchers (such as Corey, Taba, Noel, Marsh and Shumsky) developed action research as an educational methodology but during that period it was a methodology in disrepute. In the early 1970s the teacher-as-researcher movement developed in Britain as a result of Stenhouse's work on curriculum development and a revival of interest in action research as an educational methodology emerged. Emerson (1999) points out that in the 1970s an external researcher directed the research process and evaluations were mostly interpretative. In the 1980s the interpretations of the teachers themselves were beginning to emerge as being of critical importance (McNiff, 1988).

Elaborating on the notion of teacher involvement in educational research Cross and Steadman (1996) point out that research on teaching and learning in the classroom cannot exclude those who are most involved and most affected, namely teachers and students themselves. Cross and Steadman (1996) strongly argue for teacher and student involvement in educational research and remark that in the USA research on college students was traditionally conducted by middle-class white male researchers studying white-male students and that the resulting conclusions were *sexist, biased, misleading and unreliable* (Cross & Steadman, 1996:13). They further point out that the student population in the late 1990s is diverse in almost every aspect and research cannot accept a methodology that excludes aspects of student diversity. The views of Cross and Steadman on current approaches to research of tertiary teaching and learning are presumably equally true within a South African context and with relevance to the early 2000s. Reaffirming teacher involvement in research, Cross and Steadman (1996:15) further remark that

> *The major tenet of Classroom Research is that college teachers are capable of doing their own research on the questions that interest them. Classroom research capitalizes on the talents and competencies that teachers bring to the systematic study of teaching and learning: knowledge of the subject matter, experience in teaching it to others, and an interest in gaining a greater understanding of how students in their classrooms learn what teachers are trying to teach.*

4.2.2 Action research: definition

Although an action research approach is widely acknowledged in the research field, there is no universally accepted definition because the concept is interpreted in various ways. McMillan and Schumacher (2001) regard action research as a variation of evaluation research. They point out that evaluation research *assesses the merit and worth of a* *particular practice at a given site (or sites)* and that *evaluation studies provide information for immediate use as ... practices are developed, implemented and institutionalised* (McMillan & Schumacher, 2001:21).

Cohen *et al.* (2000:226) point out that the combination of *action* and *research* has contributed to its attraction to researchers and that *the scope of action research as a method is impressive.*

Cohen and Manion (1994:186, 192) define action research as a *small-scale intervention in the functioning of the real world and a close examination of the effects of such intervention.* They continue and describe action research as

> *An on-the-spot procedure designed to deal with a concrete problem located in an immediate situation ... The process is constantly monitored over varying periods of time ... ensuing that the feedback may be translated into modifications, adjustments, directional changes, redefinitions ... no attempt is made to identify one particular factor and study it in isolation, divorced from the context giving it meaning.*

Zuber-Skerritt (2001:in press) describes action research as

> *a cyclical iterative process of action and reflection on and in action. Through reflection we conceptualise and generalise what happened (action). We can then investigate in new situations whether our conceptions were right; that is, we try to find confirming or disconfirming evidence.*

Zuber-Skerritt (1992a & 1992b) strongly argues for the capability of action research to improve teaching practice whilst simultaneously empowering all those involved in the research process. From the perspective of higher education she defines action research as

> *Collaborative, critical inquiry by the academics themselves (rather than expert educational researchers) into their own teaching practice, into problems of students' learning and into curriculum problems.* Zuber-Skerritt (1992b:1-2)

Kemmis and McTaggart (1988:5) give an all-inclusive definition, namely that

> *Action research is a form of collective self-reflective inquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out.*

Kemmis and McTaggart (1992) distinguish action research from everyday teaching actions in that it is more systematic and it is not simply aimed at problem solving but is motivated by the quest to improve practice and in this sense action research also poses problems to be investigated.

Another approach describing teacher involvement in research on the improvement of the practice of teaching is found in the concept "classroom research" that is defined in the following section.

4.2.3 Classroom research: definition

> *Classroom Research may be simply defined as ongoing and cumulative intellectual inquiry by classroom teachers into the nature of teaching and learning in their own classrooms. At its best, Classroom Research should benefit both teachers and students by actively engaging them in the collaborative study of learning as it takes place day by day in the particular context of their own classrooms. Teachers are learning how to become more effective teachers, and students are learning how to become more effective learners.* (Cross & Steadman, 1996:2)

Both action research and classroom research advocate involvement in and commitment to the improving of the practice of teaching. The characteristics of these approaches display similarities. The characteristics of action research are summarised in Table 4-1 and those of classroom research in Table 4-2.

4.2.4 Characteristics of action research

In Table 4-1 certain common characteristics of action research are given. These characteristics are deduced from the views of various researchers.

Table 4-1 Characteristics of action research

1 Situational	*It is concerned with diagnosing a problem in a specific context and attempting to solve it in that context* (Cohen & Manion, 1994:186).
2 Collaborative	*It usually (though not inevitably) involves teams of practitioners and researchers* (Cohen & Manion, 1994:186).

3 Participatory	*The researcher is not considered to be an outside expert conducting an enquiry with 'subjects', but a co-worker doing research with and for the people concerned with the practical problem and its actual improvement* (Zuber-Skerritt, 1992b:12-13).
4 Critical	*Participants not only search for practical improvements in their work ... but also act as critical and self-critical change agents ... they change their environment and are changed in the process* (Zuber-Skerritt, 1992b:14).
5 Self-evaluative	*It involves the modification being continuously evaluated within the ongoing situation. The ultimate objective being to improve practice in some way or other* (Cohen & Manion, 1994:186). *Of teaching performance, of individual courses and of whole programmes by the practitioners themselves (individually and collaboratively) ... teaching and research activities need not be isolated.*(Zuber-Skerritt, 1997 III-3:15).
6 Accountability	*Helps to ensure continuous quality improvement and has built-in accountability at each stage or single action phase* (Zuber-Skerritt, 1997 III-3:15).
7 Practical and theoretical	*It seeks to unite its two central concerns – improvement in practice and increased knowledge and understanding – by linking them into an integrated cycle of activities, in which each phase learns from the previous one and shapes the next* (Winter, 1989:11). *The focus on local practice provides for immediate change in that practice and for the development of local theories* (Willcoxson, 1994:93).
8 Interpretative	*Social enquiry is not assumed to result in the researcher's positivist statements based on right or wrong answers to the research question, but in solutions based on views and interpretation of the people involved in the enquiry* (Zuber-Skerritt, 1992b:13).
9 Research into teaching	*Action research provides a platform for academics to be assertive of their ownership and control of their teaching practice. Action research conducted by practitioners on their own teaching practice appears to be more appropriate than educational research carried out by theorists ... action researchers' practice could be informed by theory, but need not be confined by often abstract theories* (Zuber-Skerritt, 1997 III-3:15).
10 Professional development	*Action research can contribute to the professionalism of higher education teachers. To become truly professional, academics are obliged to demonstrate the quality of their teaching ... by being involved in educational research on which they base their practice* (Zuber-Skerritt, 1997 III-3:15).
11 Continuous	*The task is not finished when the project ends. The participants continue to review, evaluate and improve practice* (Bell, 1987:5).

Compiled by the author of this thesis

4.2.5 Characteristics of classroom research

According to Cross and Steadman (1996) the aspects summarised in Table 4-2 characterise classroom research.

Table 4-2 Characteristics of classroom research

1 Learner-centred	The primary objective is improving *learning*. Day to day observation and study of learning as it takes place in the classroom contributes to teachers' gaining insight into making their teaching more effective and students gain lifelong skills of assessing and improving their learning.
2 Teacher-directed	Teachers are regarded as active investigators rather than consumers of research on teaching.
3 Collaborative	This entails the active involvement of students as partners in the research and can also include discussion and participation by all who have something to learn and to contribute.
4 Context-specific	The research is conducted to shed light on specific questions of an identified classroom. Although the results may be generalisable to other populations, classroom research does not require technical research skills such as sampling and making statistical inferences.
5 Scholarly	It builds on the knowledge base of research on teaching and learning. It requires careful planning and appropriate research design and a consideration of the implications for practice.
6 Practical and relevant	Practical questions that emerge from the classroom are investigated. The measure of quality of the project is its contribution to the knowledge and practice of the teacher and not to advance knowledge in general or to publish findings.
7 Continual	It is ongoing and can be regarded more as a process than as a product.

Compiled from Cross and Steadman (1996:2-4)

In the study reported in this thesis the mentioned principles of classroom research are acknowledged and incorporated within the teaching practice. However, the research approach of the study is in essence action research and is based on the models discussed in the following section.

4.2.6 Models of action research relevant for this study

Lewin's original concept of action research was further developed by researchers such as Kemmis and McTaggart (1981), Elliot (1981), Ebbutt (1983), Zuber-Skerritt (1992), McLean (1995) and Stringer (1996). The model of Kemmis and McTaggart (1981), and the adaptations thereof by Zuber-Skerritt (1997), form the basis of the action research approach used in the present study.

The action research model of Kemmis and McTaggart (1981) is based on the cyclic and spiral principles of action research postulated by Lewin. The original model of Kemmis and McTaggart is shown Figure 4-1 A. This model was simplified by Zuber-Skerritt (1990) and co-workers (Zuber-Skerritt, 1997 III-3:12), resulting in the model shown in Figure 4-1 B.

Figure 4-1 The action research spiral of Kemmis and McTaggart (1981 & 1990)

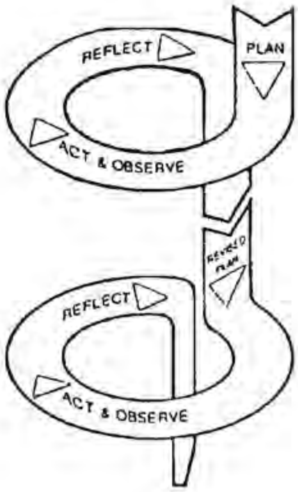


Figure 4-1 A

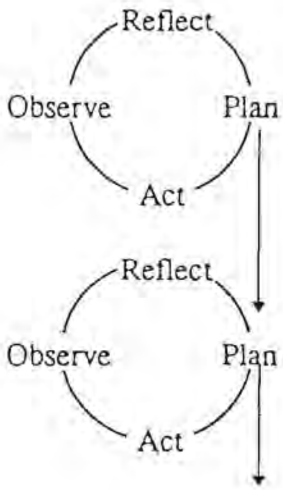


Figure 4-1 B

Adapted from Kemmis and McTaggart (1988:11) and Zuber-Skerritt (1997 III-3:13)

Further adaptation of the Kemmis and McTaggart model was done by Zuber-Skerritt resulting in the models shown in Figure 4-2. Firstly, the downward arrows were changed sideways (Zuber-Skerritt, 1992b:13) resulting in the model displayed in Figure 4-2 A. Then the arrows were changed upwards as displayed in Figure 4-2 B. Zuber-Skerritt (1997 III-3:13) motivates this change as follows:

> *I now believe that the arrows should go upwards .... to indicate the continuous improvement of practice and extension of knowledge, both personal knowledge and knowledge in the field.*

Figure 4-2 Action research cycles by Zuber-Skerritt (1992 & 1997)

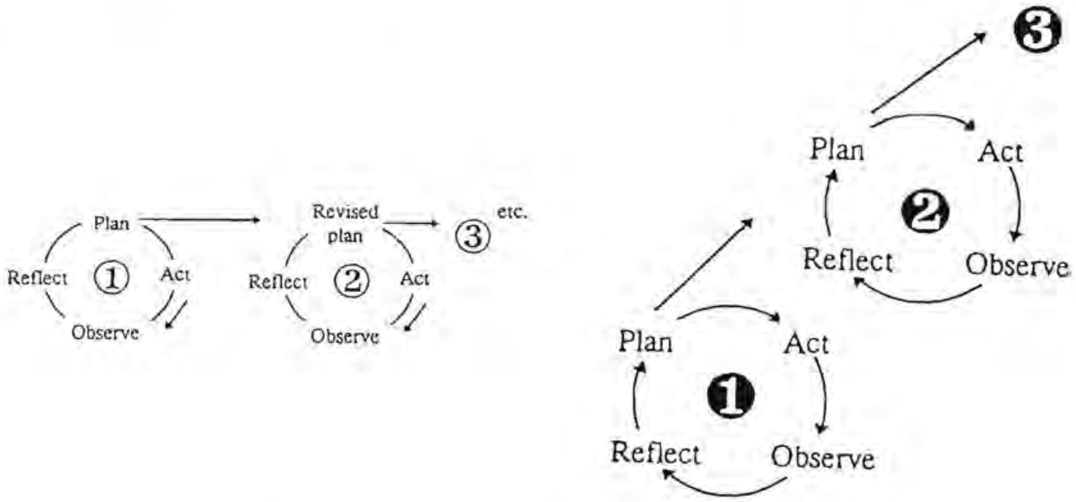


Figure 4-2 A **Figure 4-2 B**

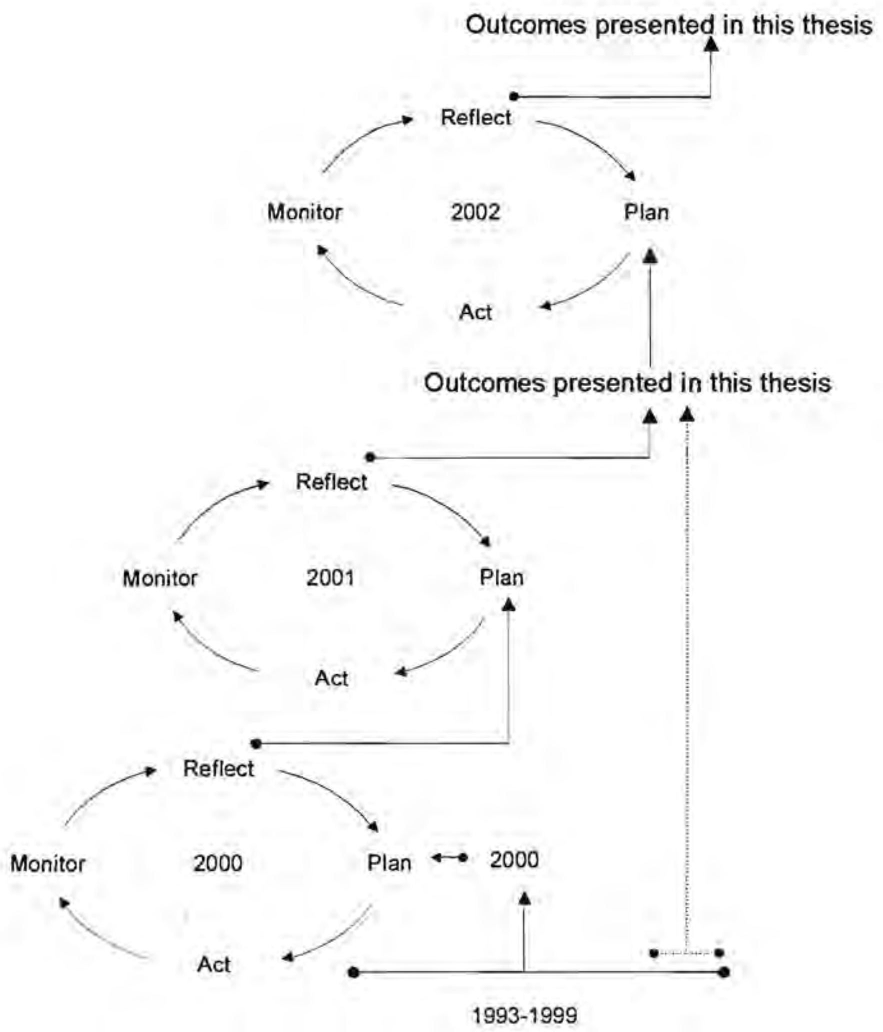
Zuber-Skerritt (1992b:13, 1997 III-3:13)

4.2.7 Research approach in the present study

The diagram in Figure 4-3 was compiled by the author of this thesis to illustrate the structure of the research approach and the research activities during 2000-2002. The action research approach followed in the present study is based on Zuber-Skerritt's 1997 model. It should be mentioned that the research activities reported in this thesis were initiated by insights and findings of research activities during 1993-1999. In Chapter 3 section 3.7 the contribution of the results from the 1993-1999 studies are discussed. Figure 1-3 in Chapter 1 gives an overview of the research activities since 1993 in which the author of this thesis was involved and which paved the way for the 2000 and 2001 studies reported in this thesis.

Similarly as in the Zuber-Skerritt (1997) model, the *continuous improvement of practice and extension of knowledge* (Zuber-Skerritt, 1997 III-3:13) have been strong focuses throughout the research activities during 1993-1999 and also those of 2000-2002.

Figure 4-3 Research approach used in this study



Compiled by the author of this thesis

4.2.8 Particulars of the action research approach in the present study

The present study displays most of the characteristics of action research listed in Table 4-1 as well as those of classroom research listed in Table 4-2 and the applicability of the mentioned characteristics can be summarised as follows:

The study was **situational** and **context-specific** in the sense that a problem (the possible relationship between a learner's study orientation towards mathematics, a learner's awareness of thinking styles and cognitive processing modes and the learner's academic performance in mathematics) was diagnosed in a specific context (first year engineering students on a support course taking a first course in calculus) and the problem was addressed within that context.

The research was in essence **participatory** in nature as the researcher was not an outsider conducting an enquiry with 'subjects'. Researcher and 'subjects' were inherently co-workers concerned with improvement of learning and learning facilitation.

Critical (self-) evaluation by the researcher (author) was an important factor throughout the project.

Accountability was taken by the researcher for the participatory activities of all involved in this research.

The action research activities of this project led to an increased **theoretical** knowledge and understanding of the thinking and learning style preferences and study orientation towards mathematics of the students in the participatory group.

The action research activities during this project can be described as **research into teaching**, **teacher directed** and **learner centred**. It contributed to the professional development of the researcher and to students' gaining skills in assessing and improving their learning.

Finally, it can be stated that the task is not finished with the completion of this thesis. Continuous reviewing of students' study orientation towards mathematics and the learning facilitation strategy for mathematics in a support course is an ongoing (action research) activity that ought to contribute to the further improvement of practice.

It should be pointed out that the research during 2000-2001 was not a collaborative effort involving a team of practitioners or researchers. It was conducted by the author of this thesis.

4.2.9 Steps and activities in the action research process

Zuber-Skerrit's model (Figure 4-2 B) defines the research activities as given in Table 4-3. Combining Zuber-Skerrit's model with adaptations of other models as suggested by Hodgkinson (1998), the steps and activities of the action research process in the study reported here are summarised in Table 4-4. These activities are discussed in detail in Chapter 5 of this thesis.

Table 4-3 Steps and activities of Zuber-Skerritt's action research model

Plan	Analysis of the problem. Devise a strategic plan.
Act	Implementation of a strategic plan.
Observe	Evaluation of action by appropriate methods and techniques.
Reflect	Reflect on results of evaluation. Reflect on the whole action. Reflect on the research process. Identify a new problem. Start a new cycle of planning, acting, observing and reflecting.

Adapted from Zuber-Skerrit (1992b:11)

Table 4-4 Steps and activities of action research in the present study

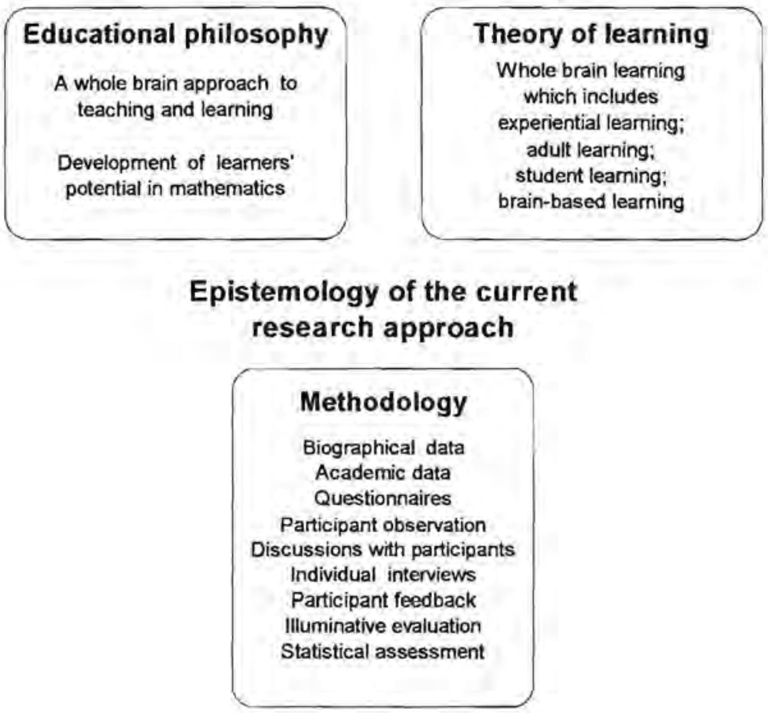
Plan	Analysis of the problem Identify the vision, the general idea. Formulate general idea that something might be improved. State questions to be addressed. Select the research procedures, methodology and instruments. Choose evaluation procedures: qualitative and quantitative. Prioritise and define the sequence of tasks and activities. Define the intervention.
Act	Implement the intervention.
Observe	Monitor effects. Gather evidence. Note errors, mistakes and problems. Classify and analyse the data.
Reflect	Assess outcomes. Assess effectiveness. Reflect on the whole action. Reflect on the research process. Identify further aspects to be researched. Start a new cycle. (Start a new research project.)

Compiled by the author of this thesis

4.2.10 Methodologies used in the present study

Zuber-Skerritt (1997 III-3:15) points out that action research means different things to different people and continues that for her it is not just a technique, but a philosophy, methodology and theory of learning. She also points out that every action researcher should have an own and explicit theoretical framework. For this thesis the framework presented in Figure 4-4 underpins the action research approach reported here. The educational philosophy and theories of learning indicated in Figure 4-4, are covered in Chapters 2 and 3. The research methodology is addressed in this chapter and the specific research detail is discussed in Chapter 5.

Figure 4-4 Theoretical framework underpinning the research in the present study.



Proposed by the author of this thesis

Concerning the methodology aspect in Figure 4-4, Willcoxson (1994:94) points out that the overall methodology in action research is responsive to the needs and interest of and is guided by all those touched by the research. According to Zuber-Skerritt (1992a:134) participant observation means that

> *The researcher is not an objective, outside observer (with a set of pre-formed and specific hypotheses to be examined and tested), but that he/she is directly involved in the social [teaching/learning] world he/she is studying. He/she is guided by a theoretical framework, but the research itself is open and flexible. Meanings and interpretations evolve through the views and perceptions of the people in the natural [teaching/learning] setting.*

For the purpose of this study participant observation can be categorized as "one-to-one" observation and "one-to-many" observation. One-to-one observation refers to the explicit observation of a single individual. One-to-many observation refers to more general observations focused on more overall activities.

Insights gained through participant observation were supported and/or followed up by discussion with the participants, individual interviews and seeking feedback from participants.

According to Zuber-Skerritt (1992a:136) illuminative evaluation *tries to describe, interpret, inform and illuminate, rather than to measure and predict and attempts to make a connection between the learning milieu (learning-teaching environment) and the intellectual experiences of students.*

Insight gained through the aforementioned methodologies were continually assessed and used as summative evaluation in the research process.

4.2.11 Quality criteria for action research

In Chapter 1 section 1.6.6 opinions on the validity of action research are dealt with. In addition to these opinions, Altrichter and Posch (in Feldman, 1994:89) identify four quality criteria for action research, namely

1. Consulting alternative perspectives: Are the understandings gained during a research process confronted with the perspectives of other persons concerned or other researchers?
2. Testing through practice: Is care taken in the action research process that the results are tried out and evaluated in practical action?
3. Ethical justifiability: Is the research process compatible with the educational aims and does it correspond with principles of human interaction?
4. Practical compatibility: Are the research process and the instruments of investigation structured in a way that can be used by professional practitioners for the further development of their practice without an excessive additional expenditure of time?

Reflecting on these criteria, Feldman (1994) explicitly points out that ethical considerations must be an integral part of all teacher-research, that the research must be embedded in some way in what the teacher is already doing and that hypotheses should be generated and tested while teaching.

With regard to the study reported in this thesis, the following measures were taken to act in accordance with Altrichter and Posch's proposed quality criteria above:

1. Although a literature survey revealed that no studies similar to the one reported in this thesis have been carried out, 'alternative perspectives' (encountered in literature surveys) were considered with regard to specific aspects of the current research.

2. The research undertaken in the 2000, 2001 and 2002 cycles are embedded in the 1993-1999 studies and is thus based on what the author (researcher) was already doing. The hypotheses postulated in this thesis were generated and tested as part of the teaching.

3. With regard to 'ethical justifiability' it is stated emphatically in Chapter 1 section 1.8 that the author views research participants as an integral part of the research process and not as empirical objects for research.

4. Altrichter and Posch's fourth criteria concerning the instruments used in research, is addressed with relevance to the research reported in this thesis in section 4.4 of this chapter. The recommendations for implementing the strategies defined in the thesis and the principles that have been identified in the research are presented in Chapter 7.

4.3 Research design: ethical considerations

The author acknowledges that *it is not possible to identify all potential ethical questions or adjudicate on what is correct research behaviour* (Cohen *et al.*, 2000:71). Furthermore, *one's ethical antennae need to be especially sensitive [in the area of] action research* (Cohen *et al.*, 2000:67).

McMillan and Schumacher (2001) identify ten principles that educators need to take into account when conducting research. These principles are listed in Table 4-5.

Table 4-5 Principles of ethics in educational research

1. The primary investigator is responsible for the ethical standards of the study.
2. The subjects of the research must be informed on all the aspects of the research.
3. The investigator should be as open and honest with the subjects as possible.
4. Subjects must be protected from physical and mental discomfort, harm and danger.
5. Informed consent from the subjects to participate in the study must be secured.
6. Information about the subjects must be held confidential.
7. When research is conducted through an institution, approval for the research must be obtained.
8. The researcher must guard against potential misinterpretations and misuse of the research and must communicate the results so that misunderstanding is minimised.
9. The researcher has the responsibility not to withhold potential benefits from a control group for the sake of documenting an experiment.
10. Subjects should have the opportunity to receive the results of the study in which they are participating.

Compiled from McMillan and Schumacher (2001:196-198)

The author would like to present a personal code of ethical practice with regard to action research and teacher involvement in research. The following aspects are acknowledged in the research reported in this thesis.

- A research initiative should only be undertaken if both the process and the outcomes of the research contribute to improvement of the practice of learning and teaching.
- Research should benefit all participants, especially the research 'subjects'.
- Research should not harm the subjects in any way.
- The subjects should have the option to abstain from participation in any aspect or activity of the research if they so wish.
- The dignity, feelings, privacy and interests of the participants should be respected.
- Data should be treated confidentially.
- Data should be reported anonymously.

- The researcher must have (or develop) an intuitive sensitivity towards other people especially with regard to participant observation and in personal communication with participants.
- The researcher must continually validate the code of practice by an own sense of correctness.

It should be mentioned that towards the end of 2000 the University of Pretoria instituted a code of ethical conduct for all researchers at the University. The different faculties of the University are responsible for seeing that this code is followed. Permission for the use of data concerning the engineering students in this thesis was obtained from the Faculty Committee for Research Ethics and Integrity of the Faculty of Engineering, Built Environment and Information Technology. Permission for the use of data regarding the group of science students was obtained from the Ethics Committee of the Faculty of Natural and Agricultural Sciences. The documents regarding these consents are attached in Appendix A.

4.4 Research design: validity

Research in education is invariably confronted with the issue of validity that is customary considered in terms of internal validity and external validity.

Regarding the concepts "internal validity" and "external validity" Tuckman (1978:4) notes that a *study has internal validity if the outcome of the study is a function of the program or approach being tested rather than the result of other causes not systematically dealt with in the study*. He further defines that a study *has external validity if the results obtained would apply in the real world to other similar programs and approaches.*

Cohen *et al*. (2000: 107) explain that internal validity *seeks to demonstrate that the explanation of a particular event, issue or set of data which a piece of research provides can actually be sustained by the data .... The findings must accurately describe the phenomena being researched.*

According to Cohen *et al*. (2000: 109) external validity *refers to the degree to which the results can be generalized to the wider population, cases or situations.* They further point out that the issue of generalisation is problematic in the sense that it is interpreted differently by different research approaches. For example, positivist researchers want to execute absolute control over variables whereas ethnographers regard human behaviour as *complex, irreducible, socially situated and unique* (Cohen *et al.*, 2000: 109).

Concerning external validity in an action research study with specific participants in a particular setting, the author of this thesis endorses the view of Bogdan and Biklen (in Cohen *et al.*,2000:109) on generalisability. Bogdan and Biklen argue that they are *more interested not with the issue of whether their findings are generalizable in the widest sense but with the question of the settings, people and situations to which they might be generalizable.*

McMillan and Schumacher (2001:407) point out that *validity refers to the degree to which the explanations of phenomena match the realities of the world and that validity in qualitative research includes both internal (casual inferences) and external (generalizability), and issues of objectivity and reliability*. They further remark that *validity of qualitative designs is the degree to which the interpretations and concepts have* ***mutual meanings*** *between the participants and the researcher* (McMillan & Schumacher (2001:407). According to McMillan and Schumacher (2001) claims of validity in qualitative research rest on the data collection and analysis techniques. They point out that qualitative researchers use a combinations of strategies to enhance validity. In Table 4-6 ten possible strategies to enhance validity are summarised.

Table 4-6 Strategies to enhance design validity

Strategy	Description
Prolonged and persistent field work	Allows interim data analysis and corroboration to ensure the match between findings and participant reality.
Multi method strategies	Allows triangulation in data collection and data analysis.
Participant language; verbatim accounts	Obtain literal statements of participants and quotations from documents.
Low-inference descriptors	Record precise and detailed prescriptions of people and/or situations.

Multiple researchers	Data collected by a research team.
Mechanically recorded data	Use of tape recorders, photographs and videotapes.
Participant researcher	Use of participant recorded perceptions and/or anecdotal records.
Member checking	Check informally with participants for accuracy during data collection.
Participant review	Participants asked to review researcher's synthesis for accuracy of reporting.
Negative cases or discrepant data	Actively search for, record, analyse and report negative cases or discrepant data that are an exemption to patterns or that modify patterns in the data.

Adapted from McMillan and Schumacher (2001:408)

Table 4-7 Strategies to enhance design validity in the present study

Strategy	Description
Prolonged and persistent field work	Interim data analysis was done during each of the action research cycles.
Multi method strategies	Triangulation through different instruments in data collection and quantitative as well as qualitative data analysis methods.
Participant language; verbatim accounts	Researcher's interview notes. Students' comments. Students' written analysis.
Low-inference descriptors	Precise and detailed prescriptions of the participants and the action research activities during 2000, 2001 and 2002.
Mechanically recorded data	Limited use of photographs.
Participant researcher	Researcher's own anecdotal records.

Compiled by the author of this thesis

4.5 Research design: subjects in the study

A non-probability procedure, convenience sampling, was used to select the subjects. All the subjects in the 2000, 2001 and 2002 studies were students in the School of Engineering. In the action research cycle of 2000 there are four categories of subjects whose data contribute to the findings of the study. These are the participating 2000 POSC students (who were enrolled for the POSC in 2000) and three additional groups, namely, a group of first year civil engineering students, other[46] first year students on the 5YSP, and freshman students on the regular four year study programme. In 2001 there are three categories of subjects whose data contribute to the findings of the study. These are the participating 2001 POSC students (who were enrolled for the POSC in 2001) and two additional groups, namely other first year students on the 5YSP and freshman students on the regular four year programme. For the additional groups on the five and four year programmes only those students who wrote the final exam in the standard main stream first semester calculus course (coded as WTW114 in 2000-2001 and as WTW158 in 2002) were selected. Table 4-8 gives a summary of the population sample.

Table 4-8 Summary of the population sample

	2000	2001	2002
POSC students	33	40	51
Civil engineering students	30		
Other 5YSP students	62	46	41
4YSP students	406	431	547

In 2000 the participating POSC students consisted of 33 students of whom five were female and all of them wrote the exam in the standard first semester calculus course. In 2001 the participating POSC students consisted of 40 students of whom 13 were female and 39 wrote the exam in the standard first semester calculus course. In 2002 the participating POSC students consisted of 52 students of whom 12 are female and 51 of them wrote the exam in the standard first semester calculus course.

[46] "Other" refers to those students on the 5YSP that are **not enrolled** for the POSC.

With regard to the other 5YSP students who participated in the study, 62 wrote the exam in the standard main stream first semester calculus course in 2000, 46 students wrote it in 2001 and 41 students wrote it in 2002.

With regard to the regular 4YSP students who participated in the study, 406 wrote the final exam in the standard first semester calculus course in 2000, 431 students wrote the exam in 2001 and 547 wrote it in 2002.

In addition to the mentioned subjects an additional set of data is also incorporated in the research results presented in Chapter 6 and discussed in Chapter 7. This data concerns results pertaining to thinking style preferences of a group of first year science students on a support course in 1998 in the School of Natural Sciences.

4.6 Research design: data collection

4.6.1 Procedures

Due to the nature of the action research approach in the study, the collection of data pertaining to the participating POSC students formed part of the formal activities of the POSC during 2000-2002. The developmental and supportive nature of the course necessitated careful time planning and this was done to ensure that the questionnaires, surveys and interviews were done at the most appropriate time. Furthermore, special care was taken to ensure that the students felt comfortable and relaxed when questionnaires and surveys were administered. The same caution was taken during personal interviews with the students so that they felt at ease and not as 'research subjects'. The details of the research and activities are discussed in Chapter 5.

The data obtained from the surveys and questionnaires were processed by the researcher and prepared in a format as required by the statistical consultants.

The data pertaining to mathematics performance in the regular first semester calculus course (WTW114) in 2000 and 2001 was obtained from the official records of the University.

4.6.2 Methods and instruments

Qualitative and quantitative data collection methods and instruments were used so that the effects of the learning facilitation strategy followed in the support course could be observed and monitored. The qualitative measures included surveys, questionnaires, observations and interviews. The quantitative methods also included the questionnaires as well as the official student records. Table 4-9 gives an overview of the data collection methods and instruments used in the study.

The instruments discussed in the following paragraphs were used during the 2000-2002 research activities. The author is vigilant of the fact that the usefulness of any type of questionnaire is limited by its dependence on honest answers by the respondents. This endorses the author's stance that the respondents should not be regarded as 'experimental subjects' *per se* but as participants in the research. Furthermore, the author is also of opinion that any educational research activities should be conducted in an existing relationship of mutual trust and that the overall objective of the research and its resulting outcomes must be beneficial to both the researcher and the participants.

Table 4-9 Data collection methods and instruments in the present study

	Methods	Instruments
Qualitative measures	Biographical data	Student records
	Administration of surveys and questionnaires	Paper-based surveys Paper and computer based questionnaires Structured and unstructured. Herrmann Brain Dominance Instrument (HBDI) Lumsdaine and Lumsdaine learning activity survey (LAS) Felder Soloman Index of Learning Styles (ILS) Study Orientation Questionnaire in Mathematics (SOM) Study Orientation Questionnaire in Mathematics Tertiary (SOMT)
	Participant observation	Communication Informal interviews Writing assignment
Quantitative measures	Administration of questionnaires	HBDI, LAS, SOM and SOMT
	Records	Official student records

Paper based surveys were used to obtain personal information in addition to the official biographical data. These included information on the students' mother tongue, the language of instruction in high school and the students' computer experience prior their enrolment at the University.

The Study Orientation Questionnaire in Mathematics (SOM) was used to determine the students' study orientation in mathematics. Adaptations to the wording of certain questions of the SOM were made to portray a tertiary focus. This adapted questionnaire is referred to as the Study Orientation in Questionnaire in Mathematics Tertiary (SOMT). The details of these changes are discussed in section 4.6.5.

The Herrmann Brain Dominance Instrument (HBDI) was used in 2000 to determine the thinking style preferences of the students. An adapted version of the Lumsdaine and Lumsdaine learning activity survey (LAS), based on the HBDI, was used during 2000 and

2001. The adaptations to the LAS are discussed in section 4.6.7. During 2001 and 2002 the Felder Solomon Index of Learning Styles (ILS) was used. The ILS is discussed in the section 4.6.8.

4.6.3 Validity and reliability of the instruments

The validity of a measuring instrument can be defined as the extent to which it meets the defined purpose (De Zeeuw in Maree *et al.*, 1997). For the purposes of this study the validity and reliability of the Study Orientation Questionnaire in Mathematics (SOM) and the Herrmann Brain Dominance Instrument (HBDI) were accepted *a priori*. The validity and reliability of the SOM is documented by Maree (1997) and Maree, Claassen and Prinsloo (1998) and that of the HBDI by Herrmann (1995). Although the SOM was standardised for learners up to Grade 12, the scholars who designed and standardised the questionnaire feel that it is unlikely that a learner's study orientation will change significantly from Grade 12 to the first year of tertiary study (Claassen, 2001; Maree, 2000). Furthermore, as the Study Orientation Questionnaire in Mathematics Tertiary (SOMT) is in essence the same as the SOM with only changes in the wording of some questions, the validity and reliability op the SOMT are thus assumed for the purposes of the research reported in this thesis. It should be pointed out that item analyses were done on the SOMT on three occasions. These include an item analysis done on the SOMT for the 2000 POSC and the 2001 POSC group combined and item analyses were also done on the SOMT as a pre- and post-intervention instrument for the 2002 POSC group. The results of the Cronbach alpha coefficients on the item analyses carried out on the SOMT are reported in Chapter 6.

With regard to the validity of the Felder Solomon Index of Learning Styles (ILS), Felder (2001) points out that a preliminary version of the ILS was administered to several hundred people and the data were subjected to factor analysis. Some items that were not providing noticeable discrimination were replaced with new items as in the current version (which is used in the research reported in this thesis). No formal additional reliability or validity studies have been performed on the ILS (Felder, 2001).

To the knowledge of the author of this thesis, no validity or reliability studies have been carried out on the LAS. However, it must be pointed out that for the purposes of the study reported in this thesis the results of the LAS and the ILS are only qualitatively interpreted.

Cohen *et al.* (2000:105) remark that *it is impossible for research to be 100% valid* and according to them Gronlaud suggests that validity *should be seen as a matter of degree rather than as an absolute state*. However, Cohen *et al.* (2000:105) conclude that researchers *should strive to minimise invalidity and maximise validity.*

4.6.4 The Study Orientation Questionnaire in Mathematics (SOM)

Maree (1997) remarks that several methods can be used to assess students' study orientation in mathematics including observation, interviews, checking assignments and writing tests. However, the questionnaire method is seldom used because questionnaires that are applicable to mathematics learning are not readily available. The SOM was designed and developed in South Africa in the mid 1990s using a stratified random sample of 3013 pupils in Grades 8-11 (Maree, Prinsloo & Claassen, 1997). The item choice and structure of the SOM were influenced by questionnaires that were developed in the 1970s and 1980s (Maree *et al.*, 1998). These questionnaires are the Informal Study Orientation Questionnaire in Mathematics by Schminke, Maertens and Arnold (1978); the Summary of Study Habits and Attitudes (SSHA) by Du Toit (1980); the Learning and Study Strategies Inventory (LASSI) by Weinstein (1987) and the Motivated Strategies for Learning Questionnaire (MSLQ) by Pintrich, Smith and McKeachie (1989).

Although the SOM was originally developed for use with learners in Grades 8-12, Maree (2000) points out that the SOM can be used with first year tertiary learners and recommends that research with South African tertiary students using the SOM should be considered (Maree, 1998). However, it should always be borne in mind that in the use of all psychological instruments and questionnaires care must be taken with interpretation of results.

The SOM comprises six fields including 92 statements that relate to how an individual feels or acts regarding aspects of his/her achievement in mathematics. A respondent is placed in various hypothetical situations that agrees or disagrees with his/her feeling or probable actions. Each statement must be answered according to a five-point scale, namely, almost never, sometimes, often, usually or almost always (Maree *et al.*, 1998). The following paragraphs describe the six fields of the original SOM.

1. The field **Study attitude** (SA) in mathematics comprises 14 statements and deals with feelings (subjective but also objective experiences) and attitudes towards mathematics and aspects of mathematics that are manifested consistently and which affects students' motivation, expectation and interest with regard to mathematics.

2. The field **Mathematics anxiety** (MA) comprises 14 statements. Panic, anxiety and concern are manifested in the form of aimless, repetitive behaviour (like biting nails, excessive sweating, playing with objects, exaggerated need to visit the toilet, scrapping of correct answers and an inability to speak clearly).

3. The field **Study habits** (SH) in mathematics comprises 17 statements and includes: displaying acquired, consistent, effective study methods and habits like planning time and preparation, working through previous tests and exam papers, working through more than just familiar problems, as well as following up problems in mathematics.

4. The field **Problem solving behaviour** (PSB) in mathematics comprises 18 statements and includes cognitive and meta-cognitive learning strategies in mathematics. It includes planning, self-monitoring, self-evaluation, self-regulation and decision making during the process of problem solving in mathematics. It is 'thinking about thinking' in mathematics.

5. The field **Study environment**[47] (SE) in mathematics includes aspects relating to the social, physical and experience environment. This field comprises 13 statements regarding students' level of frustration, restrictive circumstances at home, non-stimulating learning and study environments, physical problems like an inability to see or hear well, reading problems and language problems.

6. The field **Information processing** (IP) comprises 16 statements reflecting on general and specific learning, summarising and reading strategies, critical thinking and understanding strategies like the optimal use of sketches, tables and diagrams.

For the purposes of this study and to ensure that the POSC students do not regard the instrument as one that is not relevant in a tertiary setting, the original SOM questionnaire was edited as follows for the first implementation (as a pre-intervention instrument) in 2000 and 2001. In Table 4-10 the existing wording in the original version of the SOM and

[47] In the original text (Maree, 1996 & 1997; Maree *et al.*, 1998) this field was termed "Study milieu". For greater clarity the revised term "Study environment" was adopted for the questionnaire in this study.

the edited version are given. It should be pointed out that these changes in no way have any effect on the scoring of the instrument.

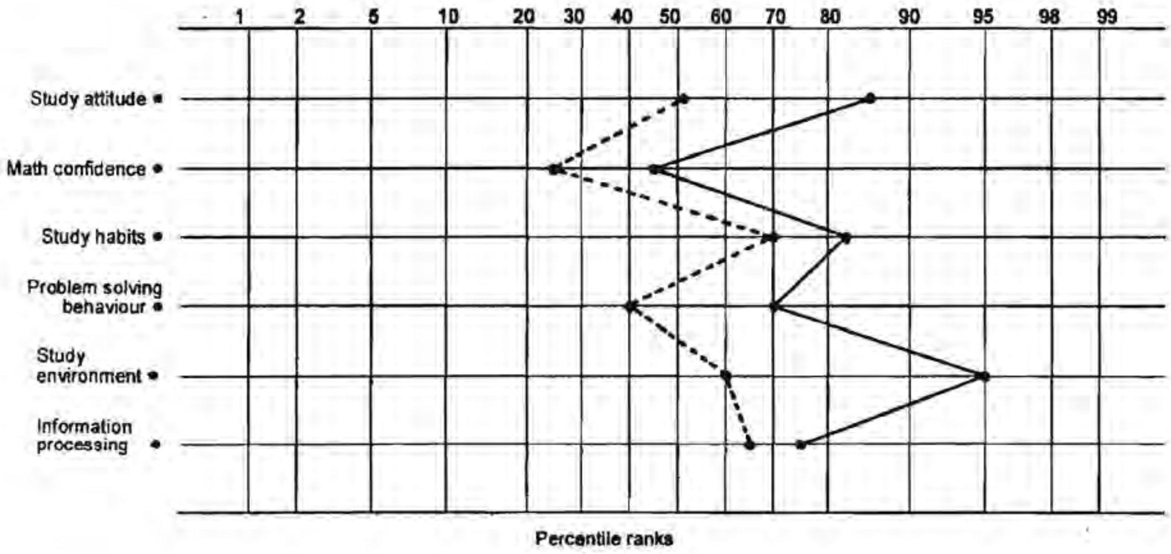
Table 4-10 Edits in the original SOM for use with tertiary students

Page	Existing wording in the original SOM	Edited version
1	There are 76 statements for grades 7, 8 and 9 and 92 statements for grades 10, 11 and 12.	There are 92 statements.
7	PUPILS IN GRADES 5, 6 AND 7 STOP HERE. DID YOU ANSWER ALL THE QUESTIONS? CHECK AND SEE. WAIT UNTIL YOU ARE TOLD WHAT TO DO. THIS PART TO BE COMPLETED ONLY BY PUPILS IN GRADES 10, 11 AND 12	Fully blocked out.

The original SOM including the editing done as indicated in Table 4-10 was used as a pre-intervention instrument with both the 2000 POSC and the 2001 POSC groups in 2000 and 2001 respectively.

The original SOM comprises a booklet with instructions and the 92 questions. It is answered on a preset form and scored by a tester according to the instructions given in the SOM manual (Maree *et al.*, 1997). Answers to the SOM are converted to percentile ranks after which a study orientation profile can be drawn. If, for example, an individual's raw score in a particular field, for example in the field Study attitude, is 47 in the questionnaire, it corresponds to a percentile rank of 85. This means that 85% of the norm group obtained lower scorers than the score concerned. Percentile ranks for the questionnaires range from 1 to 100 and for each field a different percentile ranking applies to the scores in that field (Maree *et al.*, 1998). Figure 4-5 illustrates the study orientation profiles of a student at the beginning of the POSC and at the end of the course.

Figure 4-5 Examples of a student's study orientation profiles



·················· Course beginning ———— Course end

Profiles from data pertaining to research in the current study

According to Maree *et al.*(1997) a high score on the SOM indicates a positive study orientation (or an aspect of it) whereas a low score indicates a negative orientation (or an aspect of it). However with regard to the field mathematics anxiety, it should be pointed out that a high percentile ranking for this field points to the relative absence of mathematics anxiety (Maree *et al.*, 1997:15).

As a broad guideline for the interpretation of a SOM profile the following division according to the percentile rank is suggested (Maree *et al.*, 1997:15):

- A score of 70–100% clearly indicates a positive study orientation or aspect of it.
- A score of 40–69% is neutral but can contribute to a positive or negative study orientation or aspect of it.
- A score of 0-39% clearly indicates a negative study orientation or aspect of it.

For the purpose of the research reported in this thesis, the author of this thesis prefers the term "favourable" (instead of "positive") and "unfavourable" (instead of "negative") to describe a study orientation associated with a score of 70-100% and 0-39% respectively.

Concerning the SOM profiles in Figure 4-5, it can be deduced this learner has a favourable study environment and a low level of anxiety for mathematics. This learner is fairly competent with regard to information processing in mathematics but has a neutral attitude toward mathematics. However, this learner clearly displays a unfavourable orientation in problem solving behaviour with regard to mathematics.

4.6.5 The Study Orientation Questionnaire in Mathematics Tertiary (SOMT)

4.6.5.1 Adaptation of the Study Orientation Questionnaire in Mathematics for tertiary mathematics

Although the original SOM was developed for use in a school environment, the fields as measured in the SOM are applicable to first year tertiary students (Maree *et al.*, 1997; Maree, 2000; Claassen, 2001). The scope of the fields as discussed in the previous section is accepted for the SOMT.

The researcher adapted the name of the second field from Mathematics anxiety (MA) to Mathematics confidence (MC). This change in no way affects the questions in the field or the scoring thereof. In the original interpretation of a profile the percentile rank for mathematics anxiety (for example, a score of 45 as in Figure 4-5) indicates that a learner is **less anxious** than 45% of the norm group. Using the term "mathematics confidence" in stead, the learner is **more confident** than 45% of the population. Furthermore, using the term "mathematics confidence" also correlates with the notion that a SOMT profile further to the right side indicates a more favourable study orientation.

The questions in the original SOM were formulated to determine study orientation in mathematics within a school environment and the wording of some of the questions strongly reflects this focus. The researcher carefully considered all the questions and reasoned that the wording could be changed, where necessary, to reflect a tertiary environment without affecting the scope or scoring of the questions. The researcher consulted with the authors of the SOM who confirmed that these changes will not effect the validity or reliability of the instrument (Claassen, 2001; Maree, 2000).

The author then adapted the original SOM for tertiary mathematics by doing appropriate language editing as well as further adaptations to five questions in the sixth field of the original SOM to reflect a focus on tertiary mathematics. This adapted version is referred to as the Study Orientation Questionnaire in Mathematics Tertiary (SOMT). In the following paragraphs the changes that were made to the wording and format of the original SOM are detailed.

Terms (words) that are used throughout the original SOM and that solely reflect a school environment were changed to terms that describe a tertiary environment. These changes are listed in Table 4-11.

Table 4-11 Changes of terms to reflect a tertiary environment

Original SOM	SOMT
lesson	lecture
teacher	lecturer
parents	friends
class (some cases)	lecture
home	residence (where I stay)

The wording of the following questions were changed to convey the meaning of the questions more clearly. These changes also do not affect the scoring of the questionnaire. The questions as in the original SOM and the reworded questions for the SOMT are given in Table 4-12.

Table 4-12 Rewording of questions in the original SOM for the SOMT

Question number	Original SOM	SOMT
50	I make sure that my sketches in Geometry are big and clear; I use colour pencils to make the sketches more clear to me.	I make sure that my freehand graphs and diagrams are clear; I use colour pencils to make them more clear to me.
56	In the maths lecture I perspire more than in other lectures.	In the maths lecture I perspire (sweat) more than in other lectures.
63	I talk to my friends about maths and we discuss mathematical terms and concepts (ideas).	I talk to my friends about maths and we discuss mathematical terms and concepts.
64	Personal problems are why I cannot do my best in maths.	Personal problems are the reason why I cannot do my best in maths.
80	I only find that I do not understand the sums when the teacher goes through the solutions (gives the answers).	I only realised that I had not understood the sums when the lecturer goes through the solutions.
83	I make use of tables, sketches and diagrams to solve maths problems.	I make use of tables, sketches and /or diagrams to solve maths problems.

In the sixth field of the original SOM (Information processing) three questions concern geometry. These three questions were analysed, their context, scope and aim determined in collaboration with Maree (2001) and changed to reflect the same scope and aim but in a tertiary context. The context of the original questions is geometry whereas the context of the adapted questions is introductory calculus.

Question 77 deals with "wrong assumptions" and this wording is the same in the adapted question. The reference to "Geometry" was changed to "real world problem".

Question 78 deals with "attribution of properties" and the scope of the adapted question is the same but the reference to "Geometry .... Sketches" were replaced with "graphical representation (of a function)" where the latter notion typical reflects on content in introductory calculus.

In question 81 the reference to "geometry' was changed to "maths" and as the scope of the question "cannot apply certain theorems" remained the same, this wording was not changed.

The mentioned three questions as in the original SOM and their adaptations for the SOMT-1 are given in Table 4-13.

Table 4-13 Changed questions of the original SOM for the SOMT-1

Question number	Original SOM	SOMT-1
77	I do badly in geometry because I make wrong assumptions; erroneously accepting, for example, that any point O within a circle must necessarily be the center of the circle.	I do badly when I have to solve a real world problem in mathematics because I make wrong assumptions from the given data.
78	I find, especially in Geometry, that I attribute properties to sketches while it does not have the properties.	I find that I attribute properties to a graphical representation (of a function) without properly organising what I see.
81	My mark for geometry is lower than it should be because I cannot apply certain theorems during maths tests and exams.	My mark for maths is lower than it should be because I cannot apply certain theorems during maths tests and exams.

The first adapted version of the SOM, namely the SOMT-1, was used as a post-intervention instrument with both the 2000 POSC and the 2001 POSC groups in 2001. An item analysis was performed on the SOMT-1.[48] Following up on the results of the final item analysis, further adaptations were done to three questions of the SOMT-1. These changes did not concern the questions that were already adapted from the original SOM for the SOMT-1. The wording of the three questions were changed to convey the meaning of the questions more precisely. Again these changes do not affect the scope of the questions or the scoring of the questionnaire (Claassen, 2002; Maree, 2002). The questions as in the original SOM and in the SOMT-1 and the reworded questions are given in Table 4-14. This second adapted version of the SOMT is referred to as the SOMT-2.

[48] See Chapter 6 section 6.1.

Table 4-14 Rewording of questions in the SOMT-1 for the SOMT-2

Question number	SOMT-1	SOMT-2
32	It is my friend's or lecturer's fault that I do not work hard in maths.	My friends, lecturer or circumstances beyond my control are to blame when I do not work hard at maths.
44	Even though I know that certain sums are incorrect, I mark them correct.	Even though I know that certain sums are incorrect, I do not bother to find out why I made a mistake.
49	In the maths lecture, I find that I have to visit the toilet.	In the maths lecture, I feel uncomfortable.

The SOMT-2 was used as a pre-intervention instrument with the 2002 POSC group. Again an item analysis was performed.[49] Following up on the results of this item analysis on the SOMT-2, two further questions were adapted. Question 11 had not been adapted previously, but question 49 was adapted for the second time. Again the wording of the questions were changed to convey the meaning of the questions more precisely and again these changes do not affect the scope of the questions or the scoring of the questionnaire (Claassen, 2002; Maree, 2002).

The questions as in the SOMT-2 and the reworded questions are given in Table 4-15. This third adapted version of the SOMT is referred to as the SOMT-3. The SOMT-3 was used as a post-intervention instrument with the 2002 POSC group.

Table 4-15 Rewording of questions in the SOMT-2 for the SOMT-3

Question number	SOMT-2	SOMT-3
11	If the maths lecture is boring, I do something else which interest me more.	I find the maths lectures boring.
49	In the maths lecture, I feel uncomfortable.	In the maths lecture, I feel uneasy.

[49] See Chapter 6.

4.6.5.2 Format of the Study Orientation Questionnaire in Mathematics Tertiary

The format of the questionnaire for the SOMT was changed and the version used in 2001 differs significantly from that of the original SOM. For the purpose of this study the format of the SOMT was designed to be used either as a paper based questionnaire or to be done on a computer. Examples of questions in the SOMT are attached in Appendix C.

On the first page of the SOMT the aim of the questionnaire is clearly spelled out, instructions for completing it are given as well as a description of the five categories that are used to answer the questionnaire. The five categories that are used for answering the questions of the original SOM namely, rarely, sometimes, frequently, usually or almost always are also used to answer the questions of the SOMT. The layout and format of the SOMT differ significantly from that of the original SOM in that the five categories are given in full for each question and a separate answer sheet is not used.

Answers must be indicated directly below each question by choosing one of the given categories. In the paper based version the respondent has to indicate his/her choice with a tick mark and for the computer based version an X has to be typed in the space allocated for the answer.

The SOMT-3 is scored according to the same procedures as given in the original SOM manual (Maree *et al.*,1997). Answers to the SOMT-3 are converted to percentile ranks after which a study orientation profile can be drawn. A profile for the SOMT-3 is drawn on the same grid as used for the original SOM (see Figure 4-5).

The implementations of the adapted SOM and the versions of the SOMT during the 2000-2002 research reported in this thesis are summarised in Table 4-16.

Table 4-16 Implementations of the adapted SOM and SOMT during 2000-2002

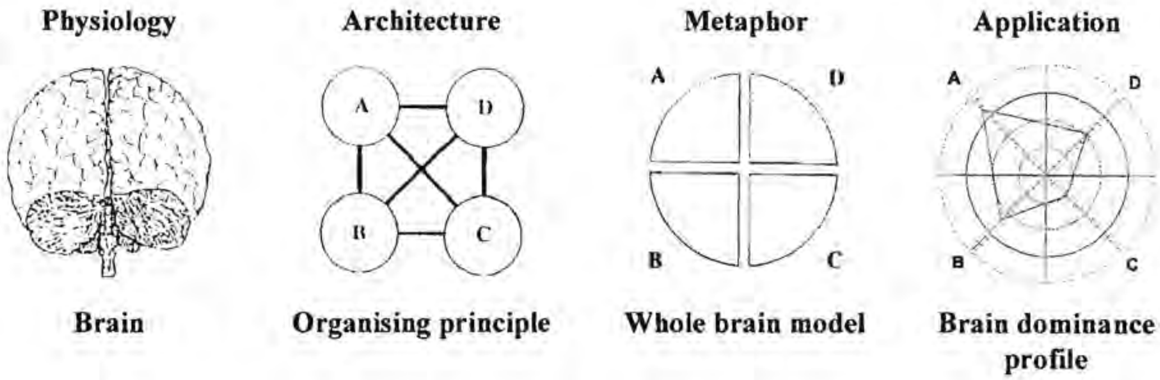
	Adaptation details in	Used for	Used as a pre/post intervention instrument	Date implemented
Original SOM adapted	Table 4-10	2000 POSC group 2001 POSC group	Pre-intervention Pre-intervention	March 2000 March 2001
SOMT-1	Table 4-11, Table 4-12 and Table 4-13	2000 POSC group 2001 POSC group	Post-intervention Post-intervention	June 2001 September 2001
SOMT-2	Table 4-14	2002 POSC group	Pre-intervention	March 2002
SOMT-3	Table 4-15	2002 POSC group	Post-intervention	August 2002

4.6.6 The Herrmann Brain Dominance Instrument (HBDI)

The Herrmann Brain dominance Instrument (HBDI) is an assessment tool that quantifies a person's relative preference for thinking modes that are based on the task-specialised functioning of the human brain. The HBDI was developed during the late 1970s and evolved form Herrmann's metaphoric whole brain model[50] which is based on the four quadrant organising principle of the physiological functioning of the human brain. Figure 4-6 illustrates the origin of the HBDI. The principles of left/right hemispheric and cerebral/limbic divisions of the brain are used and these are viewed as interconnected structures. From this premise the four-quadrant whole brain model was derived that lead to the development of the HBDI.

[50] See Chapter 2 section 2.3.4 regarding the Herrmann whole brain model.

Figure 4-6 Origin of the HBDI



Adapted from Herrmann (1995:413)

The HBDI comprises a survey that has to be completed by an individual. The survey is available as a paper and pencil version[51] obtainable from a certified HBDI practitioner[52] or it can be completed online at the website[53] of Herrmann International. All South African surveys are currently electronically scored at Herrmann International in the USA and the results added to the HBDI database of Herrmann International. Individual practitioners also have their own database of the surveys processed by them. To date, more than one million profiles have been done worldwide (Herrmann-Nedhi, 1999; Lumsdaine *et al.*, 1999).

Processing of HBDI surveys is done at a cost. In return the respondent receives a package containing a profile as well as extensive documentation that explains how to interpret the profile. An example of such a profile (without the documentation) is included in Appendix D.

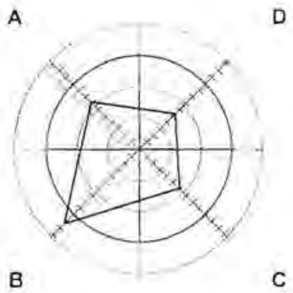
The HBDI comprises 120 items. The items include biographical data as well as questions on topics of handedness and secondary (high) school performance in mathematics and language. In a section on adjective pair data, forced choices have to be made between two different terms. The adjective pair data describes the thinking style distribution most instinctive for the individual. A section on key descriptors represents general preferences where an individual has to select adjectives that describe the way the self is seen. In a section on work (study) elements, the individual has to rank aspects form 1 (work or study done least well) to 5 (work or study done best). Information on preferred hobbies provide

[51] Examples of questions in the HBDI are included in Appendix D.
[52] The author of this thesis acquired certification in February 1999.
[53] *www.hbdi.com*

additional clues about preferred thinking styles. An individual has to rate his/her own degree of introversion/extraversion on a continuum scale. The survey also includes questions relating to motion sickness and on energy level. Energy level refers to preferred times for activities requiring metal alertness and these are categorised as either day or night time or both day and night time

A preference profile, developed from scores on the instrument, is displayed on a four quadrant grid. The higher the score in a quadrant, the stronger the preference for the thinking style related to that quadrant. Figure 4-7 gives an example of a thinking preference profile.

Figure 4-7 Example of a thinking preference profile according to the HBDI



Quadrant	A	B	C	D
Profile score	72	114	59	53
Preference code	1	1	2	1

Example of a profile from the database of the author of this thesis (2000)

The score for each quadrant can range from under 10 to over 150. The higher the score is in a quadrant, the stronger the preference for thinking in that quadrant. A preference code is determined by the magnitude of preference in each quadrant. The preference codes are defined as follows.

The preference code '1' or 'primary' is indicated by a score of 67 or above. A score of 67-100 indicates a strong preference for thinking in that quadrant. A score of above 100 indicates a very strong preference.

The preference code '2' or 'secondary' is indicated by a score of 34-66. This indicates a secondary or intermediate preference representing thinking modes that are comfortable and available as necessary.

The preference code '3' or 'tertiary' is indicated by a score of less than 34. A tertiary or low preference indicates a lack of interest or even an avoidance in that mode of thinking.

The four quadrants according to the HBDI emulate the four principle thinking structures in the brain. The thinking preferences associated with each quadrant can be organised as follows. In the left/right positions are those preferences that are commonly referred to as left brain/right brain ways of thinking. In the top/bottom positions are those ways of thinking that are referred to as more cerebral in the top and more limbic in the bottom. The profiles in Figure 4-8 are examples of profiles pertaining to the research reported in this thesis.

Figure 4-8 Examples of individual profiles showing thinking preferences according to the HBDI

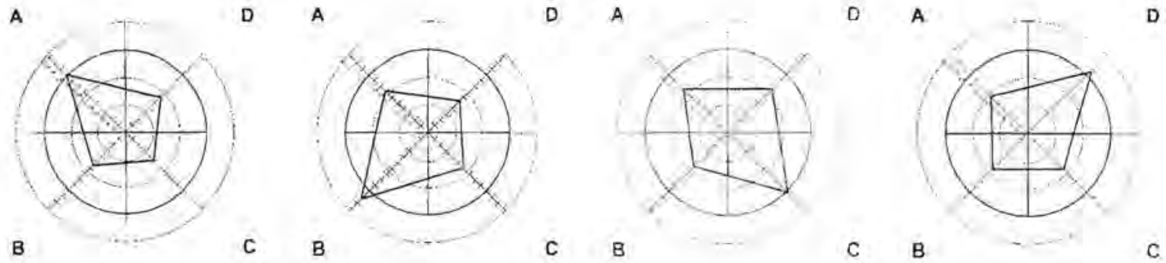


Figure 4-8 A
Profile showing an A-quadrant thinking preference

Figure 4-8 B
Profile showing a B-quadrant thinking preference

Figure 4-8 C
Profile showing a C-quadrant thinking preference

Figure 4-8 D
Profile showing a D-quadrant thinking preference

Examples of profiles from the database of the author of this thesis (2000)

The profile in Figure 4-8 A displays a strong preference for the thinking modes of the A-quadrant as well as a preferences for the thinking preferences associated with the linear hemisphere. The profile displays a moderate preference for the thinking modes associated with the D-quadrant and a low preference for the thinking modes associated with the C-quadrant.

The profile in Figure 4-8 B displays a strong preference for the thinking modes associated with the B-quadrant as well as an overall preference for the thinking modes associated with the linear hemisphere and a moderate preference for the thinking modes associated with global hemisphere.

The profile in Figure 4-8 C displays a noticeable strong preference for the thinking modes associated with the C-quadrant whereas he profile in Figure 4-8 D displays a strong preference for the thinking modes associated with the D-quadrant.

Interpreted according to the HBDI profile, the cerebral mode consists of cognitive and intellectual ways of thinking. The limbic mode encompasses visceral, structured and instinctive ways of thinking. The HBDI displays mental preferences and not abilities or competencies. A preference for a particular thinking style or an avoidance of another style are of equal consequence to an individual. The thinking and learning styles associated with Herrmann's model and the HBDI are detailed in Chapter 2 and results pertaining to the current research are given in Chapter 6 and discussed in Chapter 7.

It must be borne in mind that the HBDI is not a test for competencies but an indication of preferences and potential competencies. In this regard Herrmann (1995:76) points out that

> *Profiles are neither good not bad, right nor wrong; the instrument measures preferences for mental activity, which is entirely different from competence in performing it and profiles tend to remain constant, but they can and do change.*

4.6.7 The Lumsdaine and Lumsdaine learning activity survey (LAS)

The LAS[54] used in this research was adapted from student activity sheets in a textbook (Lumsdaine & Lumsdaine, 1995a; Lumsdaine *et al.*, 1999) that are used to give an indication of students' learning activity preferences. Each of the mentioned four activity sheets comprises statements (items) that reflect on activities associated with a specific quadrant of the Herrmann whole brain model. The LAS is essentially based on the Herrmann four quadrant whole brain model. A respondent has to circle the dot in front of each statement (item) that he/she finds easy and enjoy doing. The survey is thus not a forced choice between options and a respondent can circle a little or as many items he/she finds applicable. However, no conclusions can be drawn from insufficient or superfluous data points.

Using the original activity sheets (Lumsdaine & Lumsdaine, 1995a; Lumsdaine *et al.*, 1999) a calculation of learning preference distribution is done by considering all four

[54] An example of the LAS is included in Appendix E.

activity sheets and calculating the percentage contribution of each. As the items in each sheet represent activities in the different quadrants of the Hermann whole brain model, the learning preference distribution is associated with the different quadrants of the Herrmann model. Lumsdaine and Lumsdaine (1995a) and Lumsdaine *et al.* (1999) caption each of the four activity sheets with a reference to the quadrant being represented, for example "Quadrant A Learning activities and Behaviour". The researcher feels that this may give respondents a bias towards a specific quadrant.

The author of this thesis adapted the four activity sheets and compiled the questions in a single questionnaire. In the adapted survey, the items are grouped as in the original activity sheets (Lumsdaine & Lumsdaine, 1995a; Lumsdaine *et al.*, 1999). Each group consists of 15 items. In the original activity sheets captions indicate the quadrant according to the Herrmann model[55] to which the items relate. In some of the questions the wording also reflects the thinking modes associated with the Herrmann model. These references to the associated quadrant of the Herrmann model were omitted or reformulated so that any bias towards a specific group of questions (representing a quadrant in the Herrmann model) could be eliminated or restricted. Furthermore, the wording in some items were changed to reflect a South African context.

The adapted LAS questionnaire is a self-scored survey and instructions on the scoring are given with the survey. A diagram indicating one's preferences can be completed. Information is also given on how to interpret the scores. The adapted survey is presented with instructions that clearly indicate that the survey is **not a test.** It is merely a survey to get an indication of the activities that you find easy and like doing.

4.6.8 The Felder Soloman Index of Learning Styles (ILS)

The Felder Soloman Index of Learning Styles (ILS) is an instrument used to assess preferences on four dimensions of a learning style model originally formulated by Felder and Silverman.[56]

Since the middle 1990s engineering educators have used the ILS successfully to redesign engineering instruction so that the learning needs of individual students could be

[55] See Chapter 2 Figure 2-12.
[56] See Chapter 2 section 2.5.3 for details on the Felder Silverman model and the Soloman Felder Index of Learning Styles.

met (Felder, 1996). As the participants in the study reported in this thesis come from the domain of engineering education the possible use the Solomon Felder instrument with first engineering year students on the POSC is explored and for the purposes of this thesis the administration of the instrument is only qualitatively assessed.

The ILS comprises a 44-item questionnaire and is available as a web-version or a paper and pencil version. It can be viewed and downloaded free of charge (Felder, 2001). The web-version can be submitted online, is then scored automatically and feedback given immediately.[57] The downloadable version is accompanied by a response form and instructions for self-scoring.[58] A concise handout explaining the dimensions of the ILS (Felder & Soloman, 2001) is also available on the web-site.[59] Felder (2001) advises that students must consult the handout to interpret their scores once they have completed the instrument. A student's preference on a given scale may be strong, moderate or almost nonexistent, may change with time, and may vary from one subject or learning environment to another.

Felder (2001) stresses the point that a student's learning style profile is an indication of probable strengths and possible habits and that it does **not** reflect a student's suitability for a particular subject, discipline or profession.

The ILS assesses four dimensions namely active/reflective; sensing/intuitive; visual/verbal and sequential/global. To use the Felder Silverman model and the ILS in the context of the present study for discussion and feedback purposes,[60] the author adapted the order of the categories in two of the dimensions. The categories "active"/"reflective" were changed to "reflective"/"active" and "visual"/"verbal" were changed to "verbal"/"visual". This order reflects the brain-based organizing principle for thinking and learning identified by "linear"/"global" in the present study.

4.7 Research design: Experimental design

Following on the collection of the data, suitable procedures need to be used to process the data. Empiric-analytical research is possible if the data can be quantified. If derived

[57] A printout of the web version of the ILS as well as the feedback form is given in Appendix F.
[58] This version of the ILS is also included in Appendix F.
[59] A copy of this handout is included in Appendix F.
[60] See Appendix G for the template by means of which feedback was given during the 2001 activities.

conclusions are of possible relevance to a wider population than the sample involved in the research, appropriate statistical procedures need to be applied that can contribute to the external validity of a study (McMillan & Schumacher, 2001; Mouton & Marais, 1992). In the case of an action research approach as in the present study external validity is not necessarily implied.[61]

The data concerning the thinking style preferences as measured by the HBDI are processed to determine the thinking style preferences of the participatory group and interpreted quantitatively as well as qualitatively. The data concerning learning preferences as measured by the LAS questionnaire as well as the data concerning thinking style preferences as measured by the ILS are processed and analised only qualitatively. Results pertaining to the HBDI and LAS are compared to determine if the LAS could be used in stead of the HBDI.

The data concerning the study orientation in mathematics of the participating POSC students are processed to determine the applicability of the items in the SOMT for first year tertiary students; to analise the data pertaining to the different fields of the SOM and SOMT and to determine the relationship between the study orientation of the learners and performance in the regular first semester course in mathematics.

4.7.1 Hypotheses

The focus in the present study, on the one hand, is to propose a learning facilitation strategy for mathematics for first year engineering students on a support course. On the other, it is to compile a profile of the learners' thinking style preferences, their study orientation towards mathematics and their performance in mathematics. The study may thus be viewed both as of a hypotheses-generating nature and as of a hypotheses-testing nature.[62] The primary hypotheses concern the study orientation of the learners in mathematics at the beginning of the POSC and after the POSC as well as the nature of the thinking style preferences of these students.

The following hypotheses are addressed in the present study.

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[61] See Maxwell's notion of "generalisability" in Chapter 1, section 1.6.5 where he indicates that internal validity can have a greater focus than external validity.

[62] See Chapter 1 Figure 1-2 regarding the hypotheses framework of the study.

1. A relationship exists between the fields of the Study Orientation Questionnaire in Mathematics and performance in the standard first semester course in calculus.
2. Significant differences exist between the arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics at the beginning of the POSC and after the POSC.
3. No significant differences (post- minus pre-intervention) exist in the means of the three POSC groups for the fields of the Study Orientation Questionnaire in Mathematics.
4. The average mark achieved by the POSC group in a standard first semester calculus course is higher than the average mark of students not enrolled for the POSC.
5. The thinking style preferences of first year engineering students enrolled for a support course represent preferences distributed across all four quadrants of the Herrmann whole brain model.

In Table 4-17 a summary is given of the stated hypotheses, the relevant sub hypotheses, the applicable groups and variables and the statistical procedures used to investigate the hypotheses. The results of the statistical procedures regarding the main hypotheses as well as related sub-hypotheses are given in Chapter 6.

Table 4-17 Hypotheses for the empirical part of the study

Main hypothesis	Sub-hypothesis	Independent variable	Dependent variable	Statistical procedure
Main hypothesis 1: A relationship exists between the fields of the Study Orientation Questionnaire in Mathematics and performance in the standard first semester course in calculus.	The scores in the different fields of the SOM can be regarded as predictors of students' marks in mathematics	Scores in the different fields of the SOM	Mark in the standard first semester course in calculus for the 2000 POSC group 2001 POSC group	Regression analysis
	The scores in the different fields of the SOMT can be regarded as predictors of students' marks in mathematics	Scores in the different fields of the SOMT	Mark in the standard first semester course in calculus for the 2000 POSC group 2001 POSC group 2002 POSC group	Regression analysis
	Significant correlations exist between the different fields of the SOMT and the performance in the standard first semester course in calculus.	Scores in the different fields of the SOMT	Mark in the standard first semester course in calculus for the 2000 POSC group 2001 POSC group 2002 POSC group	Pearson correlation

Table 4-17 continues on the next page.

Table 4-17 Hypotheses for the empirical part of the study (continued)

Main hypothesis	Sub-hypothesis	Group	Variable	Statistical procedure
Main hypothesis 2: Significant differences exist between the arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics at the beginning of the POSC and after the POSC	None	2000 POSC students 2001 POSC students 2002 POSC students	Arithmetic means for the different fields of the SOM / SOMT	Wilcoxon test
Main hypothesis 3: No significant differences (post- minus pre-intervention) exist in the means of the three POSC groups for the fields of the Study Orientation Questionnaire in Mathematics.	None	2000 POSC students 2001 POSC students 2002 POSC students	Differences between the arithmetic means of the different fields of the SOM/SOMT	ANOVA

Table 4-17 continues on the next page.

Table 4-17 Hypotheses for the empirical part of the study (continued)

Main hypothesis	Sub-hypothesis	Group	Variable	Statistical procedure
Main hypothesis 4: The average mark achieved by the POSC group in a standard first semester calculus course is higher than the average mark of students not enrolled for the POSC.	None	2000 POSC students 2000 Other 5YSP students 2000 4YSP students 2001 POSC students 2001 4YSP students 2001 Other 5YSP students 2002 POSC students 2002 4YSP students 2002 Other 5YSP students	Performance in the first semester course in calculus	Mean, standard deviation

Table 4-17 continues on the next page.

Table 4-17 Hypotheses for the empirical part of the study (continued)

Main hypothesis	Sub-hypothesis	Group	Variables	Statistical procedure
Main hypothesis 5: The thinking style preferences of first year engineering students enrolled for a support course represent preferences distributed across all four quadrants of the Herrmann whole brain model.	Significant differences exist in the arithmetic mean of the scores for the quadrants of the HBDI between the POSC group and the civil engineering group.	2000 POSC group 2000 First year civil engineering students	Four different Quadrants of the HBDI	Kruskal-Wallis test
	Significant differences exist in the arithmetic mean of the scores for the quadrants of the HBDI between engineering students on a support course and science students on a support course.	2000 POSC group 1999 First year science students	Four different Quadrants of the HBDI	Kruskal-Wallis test
	Significant correlations exist between the quadrants of the HBDI and the corresponding sections of the LAS	2000 POSC group 2000 First year civil engineering students	Four different Quadrants of the HBDI Four sections of the LAS	Pearson correlation

4.7.2 Descriptive statistics

Different descriptive measures are used to report the quantitative data. The SAS program, Version 8 (SAS, 1990) was used to process the data. The statistical measures used in the study are summarised in the following sections. The results of the statistical procedures pertaining to the data in the current study are reported in Chapter 6 and interpreted in Chapter 7.

4.7.2.1 Arithmetic mean ($\bar{x}$)

The arithmetic mean is an important measure that describes the location of the data However, the arithmetic mean does not give an indication of the extent of the range of the data and therefore the standard deviation is used to describe the spread of the data.

4.7.2.2 Standard deviation (s)

The standard deviation determines the average deviation of values from the central value (arithmetic mean). If the value of the standard deviation is small the data are spread near the arithmetic mean and as the value of the standard deviation becomes larger, the data are more spread out. The terms "small" and "large" have to be interpreted relatively to the data set under consideration (Grimbeek, 2001). For the purposes of this study and in order to compare the arithmetic mean and standard deviation when applicable, the coefficient of variation (cv) is used as a norm to compare the relative deviation from the arithmetic mean.

4.7.3 Inferential statistics

Inferential statistics facilitates presenting, reporting, analysing and interpreting data so that deductions can be inferred. In order to test the hypotheses stated in Table 4-17 the following procedures are followed.

4.7.3.1 Reliability of results

The reliability of a psychological test can be defined as the extent to which it measures consistently whatever it measures (Owen, 1995). The reliability of a test indicates how much trustworthiness can be attached to a specific score in a test. It is therefore essential to determine the level of reliability of a test or questionnaire. Owen (1995) stresses the fact that the implementation of a test for a particular purpose influences the specific value of the reliability coefficient that is accepted for that particular case.

The reliability for the different fields of the SOM and the SOMT was determined using the Cronbach alpha coefficient.

It should be pointed out that reliability coefficients were not calculated for the HBDI, LAS and the ILS. The HBDI has been validated in numerous studies (Herrmann, 1995 & 1996; Lumsdaine & Lumsdaine, 1995a; Lumsdaine *et al.*, 1999). The results concerning the LAS and the ILS are interpreted qualitatively only.

4.7.3.2 Validity of the results of the current study

Criterion related validity provides an indication of the accuracy with which the scores obtained by means of a measuring instrument predicts scores in a criterion (Madge in Maree *et al.*, 1997). Criterion related validity thus concerns the calculation of the correlation between scores in one test and the performance in another (the criterion). In this regard two types of validity can be distinguished, namely simultaneous validity and predictive validity. Both simultaneous validity and predictive validity refer to an association between scores on the instrument and a specific variable on the one hand and the accuracy with which the scores in the test predict the relative position of the individual with regard to the variable on the other.

Concerning simultaneous validity in this study, Pearson correlation coefficients were determined. Correlation indicates the degree of the linear relationship between two (or more) sets of data. The following conventions are followed with regard to the interpretation of the correlation coefficients in this study:

For the statistical interpretation of correlation, the convention (Grimbeek, 2001) is followed that an arbitrary criterion is taken for r, namely $|r| \leq 0.25$ with the distinction that:

if $-0.25 \leq r \leq 0.25$, the correlation is regarded as poor;

if $-0.75 \leq r < -0.25$ or $0.25 < r \leq 0.75$, the correlation is regarded as acceptable;

if $|r| > 0.75$, that is $r < -0.75$ or $r > 0.75$, the correlation is regarded as very good.

In this study Pearson correlation was used to determine the simultaneous validity between the different fields of the SOM and the SOMT respectively and mathematics performance as well as the possible correlations between the quadrants of the HBDI and the corresponding sections of the LAS.

Predictive validity involves the combined or separate influence of two or more independent variables on a dependent variable. Multiple or step-wise regression analysis predicts the variance in the dependent variable by determining the relative contribution of the two or more independent variables. In the present study regression analysis was used to determine the predictive validity of fields of the SOM and SOMT for mathematics performance.

4.7.3.3 Comparing means

Wilcoxon test

The non-parametric Wilcoxon rank-sum test (BMDP3D, 1993) was used to compare the arithmetic means of the different fields of the SOM and SOMT for each of the research groups separately. Howell (1997:647) remarks that the Wilcoxon rank-sum test *is often thought of as the distribution-free analogue test of the t-test for two independent variables, although it tests a slightly different, and broader, null hypothesis.*

Kruskal-Wallis test

The Kruskal-Wallis test (BMDP3D, 1993) was used to compare the arithmetic means between the different research groups for each of the four quadrants of the Herrmann whole brain model as measured by the HBDI. According to Howell (1997:658) the Kruskal-Wallis one-way analysis of variance *is a direct generalization of the Wilcoxon rank-sum test to the case in which we have three or more independent groups.*

Analysis of variance and post hoc test

In the present study one-way analysis of variance (ANOVA) was used to analyse the differences between the arithmetic means of the different fields of the study orientation for the 2000, the 2001 and the 2002 POSC groups.

Where differences between the mentioned groups in this study were found with ANOVA, the GLM procedure of the SAS (SAS, 1990) was used as a post hoc test to determine which means differ significantly. Hurlburt (1994:281) describes post hoc tests as:

Hypothesis tests performed after a significant ANOVA to explore which means or combinations of means differ from each other.

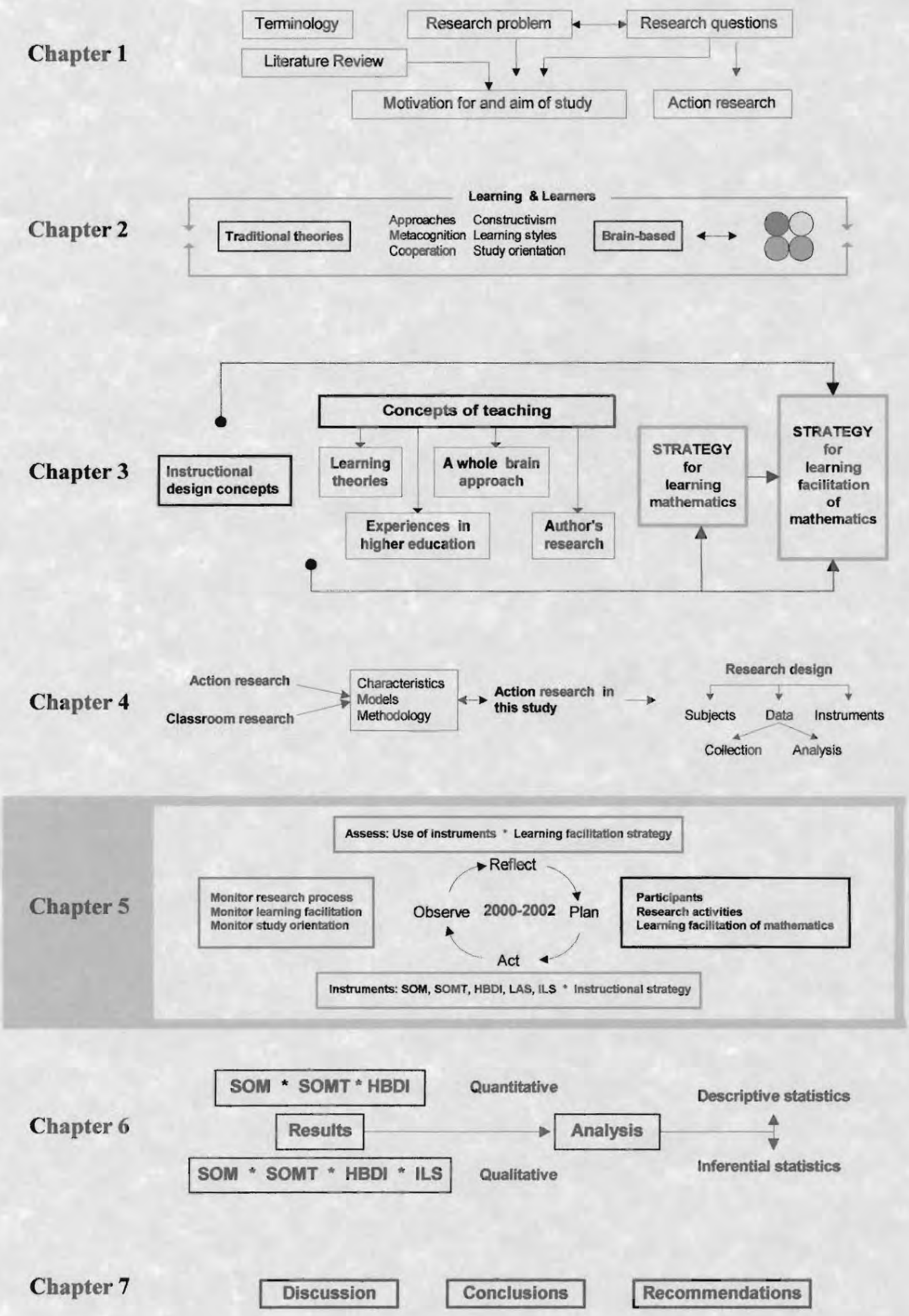
4.8 Research design: Qualitative strategy

Various strategies were used to collect data that are qualitatively interpreted. Participant observation included prolonged data collection through observation, communication, informal interviews and the researcher's notes as well as written feedback from some of the participants.

4.9 Summary

In Chapter 4 the philosophy underpinning the research approach of the present study was discussed and the research design of the study is presented with reference to ethical considerations, the validity and generalisability of the research, the subjects in the study, the data collection strategies and the data processing procedures. The choice of the instruments is motivated and their scope, validity and reliability are considered. The hypotheses that are addressed in the empirical part of the study are presented and the applicable statistical procedures indicated.

In the Chapter 5 the action research studies of 2000, 2001 and 2002 are detailed and the results pertaining to the quantitative and qualitative data are presented in Chapter 6 and further discussed and interpreted in Chapter 7.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Chapter 5

Research studies 2000 – 2002

5. Introduction

In November 1999 the author joined the Five Year Study Programme (5YSP) in the School of Engineering as lecturer responsible for the Professional Orientation Support Course (POSC). This posed the opportunity to implement strategies that are based on experiences and results gained during the author's involvement with students in the School of Science since 1991 and research conducted during 1993-1999 in the Gold Fields Computer Centre for Education in the School of Science. Selected results of these research studies have been reported by Steyn (1998), Steyn and De Boer (1998), Steyn, Carr and De Boer (1999) and De Boer and Steyn (1999).

In order to place the action research studies during 2000, 2001 and 2002 in context, an overview is firstly given of the 5YSP, the admission requirements for engineering study at the University of Pretoria and the POSC.

5.1 The Five Year Study Programme

The regular university engineering programme in South Africa requires four years of full time study as regulated by the Engineering Council of South Africa (ECSA). In 1994 the 5YSP was introduced in the School of Engineering at the University of Pretoria. This programme increases the duration of the standard engineering study from four to five years. This is arranged in such a way that the academic courses of the first two years of the regular four year programme are spread over the first three years of the 5YSP. The purpose of the 5YSP is to create an opportunity for students who have the potential to become engineers but who do not meet the entrance requirements for the regular four year programme and/or who are academically at risk because of their educational background.

The data in Table 5-1 summarises the retention of black students on the 5YSP during 1994 to 2001 (Du Plessis, 2001; Du Plessis, 2002).

Table 5-1 Retention of black students on the 5YSP during 1994-2001

Year of enrolment	1994	1995	1996	1997	1998	1999	2000	2001
Number of students	21	55	55	23	25	36	34	45
POSC students	21	55	55	23	25	36	33	40
Graduated in 5 years		2	3	3				
Graduated in 6 years	1	7	7					
Graduated in 7 years	1	4						
Registered for engineering in 2002	1 (5%)	1 (2%)	5 (9%)	7 (30%)	13 (52%)	18 (50%)	30 (88%)	40 (88%)

The total admissions of black students for engineering study during 1994-2001 is 294. Of these students 28 (18%) out of a possible 154 (representing the 1994-1997 intake) have graduated. In 2002, 115 students (39% of the 1994-2001 intake) are still registered for engineering and 151 students (51% of the 1994-2001 intake) have either migrated to another faculty or discontinued their studies. Most of the black students on the 5YSP are also enrolled for the POSC.

From the data it is noticeable that the retention rate of black students on the 5YSP is increasing, for example, from the 1998 intake a possible 52% of the students may graduate in the minimum five years.

The figures in Table 5-1 give an indication for the need of support to increase the tertiary survival of prospective black African graduates in engineering. Du Plessis and Quagraine (2000:27) point out that *a mere extension of the period of study has proved to be only partially successful. A more holistic approach to the needs of the student at risk in engineering seems imperative.* According to Du Plessis and Quagraine (2000) engineering educators in South Africa should reconsider what they want to achieve; cognisance must be taken of the diverse educational, social and environmental factors that influence academic achievement and special plans of action should be taken to secure academic success of prospective (black) engineering students.

The focus of the research presented in this thesis specifically addresses one of the cornerstones of engineering study namely the thorough understanding of the fundamental concepts underpinning a study of calculus. The learning facilitation strategy for mathematics proposed in this thesis can thus be viewed as a reconsideration of the structure of support for mathematics in a first course in calculus. In this way the research supports the afore mentioned views of Du Plessis and Quagraine (2000) regarding engineering education.

5.2 Admission requirements for engineering study at UP

During 1994-2002 the admission requirements for engineering study at the UP are a minimum M-score of 18 and a score of at least 60% (C-symbol) for both Mathematics and Physical Science on Higher grade in the final examination in Grade 12. The M-score is calculated according to the values given in Table 5-2. If a candidate does not comply with these requirements but has minimum M-score of 12 as well as one of the combinations given in Table 5-3, he/she may be permitted to write an admission test. The system of writing an admission test was introduced in 1996.[63] Admission to the 5YSP is then considered on ground of the results of the test (School of Engineering Regulations and Syllabi, 2001).

Table 5-2 Calculation of M-score at the University of Pretoria

Symbols	Higher Grade	Standard Grade
A-symbol (80% and higher)	5	4
B-symbol (70%-79%)	4	3
C-symbol (60%-69%)	3	2
D-symbol (50%-59%)	2	1
E-symbol (40%-49%)	1	0

[63] Referring to Table 5-1 on the previous page, it should be pointed out that the decline in numbers of enrolment between 1996 and 1997 may be due to the implementation of the admission test and more stringent admission requirements (Du Plessis, 2002).

Table 5-3 Alternative combinations of scores for admission to the Five Year Programme

Grade 12 Mathematics (Higher grade)		Grade 12 Physical Science (Higher grade)		M-score
D-symbol	+	D-symbol	+	12
A-, B- or C-symbol	+	D-symbol	+	12
D-symbol	+	A-, B- or C-symbol	+	12

5.3 The Professional Orientation Support Course (POSC)

Throughout their study, students on the 5YSP enrol for the same courses as students on the 4YSP and they attend the same classes. However, all the students on the 5YSP are given additional academic support in their first year engineering courses by means of a tutoring system. Tutors are usually senior (engineering) students who are appointed by the School of Engineering. The supervision of tutors is the responsibility of the lecturers who teach the courses where the tutoring is done.

In spite of this tutoring support, some of the students enrolled for the 5YSP are still at risk due to the fact that in the late 1990s early 2000s secondary schooling in South Africa represents varying levels of educational competency. In order to accommodate these varying levels of competency in educational background a two semester credit-bearing course,[64] the POSC, has been presented as part of the 5YSP since 1994.

The POSC is presented as two semester modules during the first year of study. The module code in the first semester is JPO110 and in the second semester it is JPO120. Students obtain eight credits[65] for each of the modules. The aims of the POSC are to provide learning opportunities for the development of academic, personal, communication and information skills within an engineering context and to facilitate students' competency in mastering the fundamental concepts that underpin a study in calculus. In pursuing these

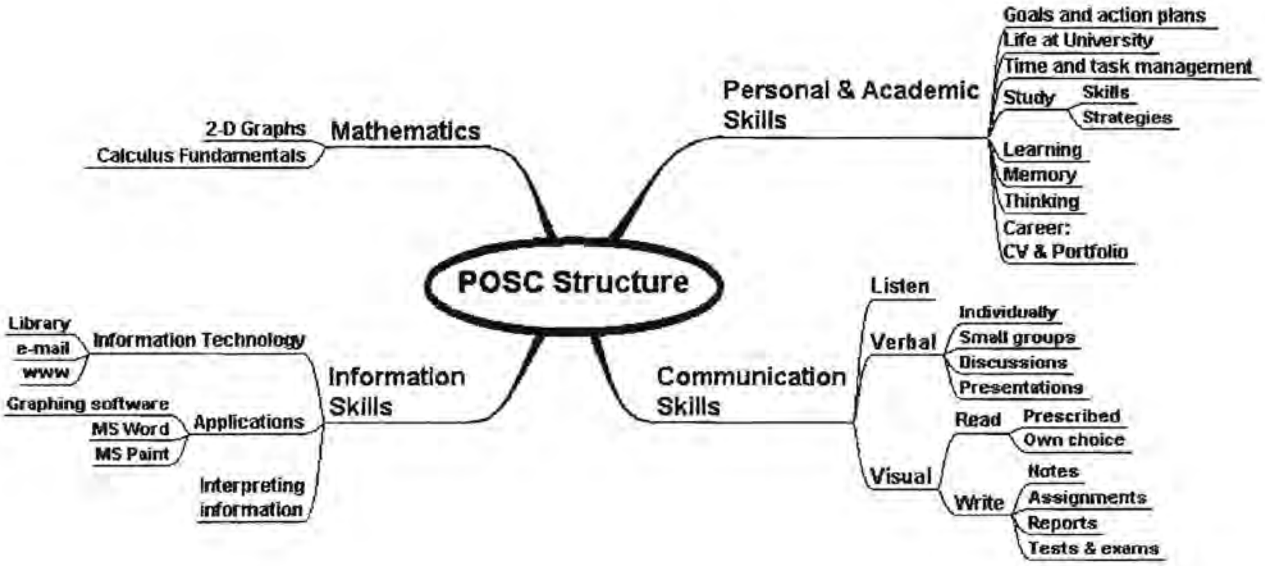
[64] Since 2001 the term "module" is used instead of "course". For the purpose of this thesis the term "module" is also used for the two modules comprising the POSC.

[65] Eight credits is a regular weighting for a semester module in the School of Engineering at UP although some modules, such as the standard first semester calculus module, have a higher weighting – the credit weighting for this calculus module is 16.

aims the primary focus is the development of each student's academic potential in order for him or her to pursue engineering studies successfully.

The diagram in Figure 5-1 gives an overview of the structure of the POSC as it was presented during 2000, 2001 and 2002. The content of the course focuses on two broad themes, namely the development of skills and mathematics.

Figure 5-1 Overview of the Professional Orientation Support Course (POSC)



Compiled by the author of this thesis

In complying with the outcomes based educational policy of South Africa in the early 2000s (Department of Education, 1995 & 1997; Olivier, 1998), the two themes, skills development and mathematics, can be interpreted in terms of **general (critical) learning outcomes** as follows.

1. Organising and managing own activities responsibly and effectively.
2. Working effectively with others as a member of a group and a class.
3. Communicating effectively using visual, mathematical and/or language skills in the modes of oral and/or written persuasion.
4. Collecting, analysing, organising and critically evaluating information.

5. Using science and technology effectively and critically, showing responsibility towards the environment and health of others.
6. Contributing to the personal development of the learner.

The general (critical) outcomes of the educational policy in South African are complemented by **specific learning outcomes** (Olivier, 1998). The following **specific learning outcomes** result from the activities of the POSC course.

To reach the specific learning outcomes for the **mathematics component** of the POSC, students

1. Revise fundamental mathematical concepts.
2. Identify possible gaps in their own mathematical background.
3. Use the graphing software package *Master Grapher for Windows*
4. Visualise 2-D mathematical functions through their graphs using *Master Grapher for Windows*.
5. Explore and interpret the characteristic features of 2-D functions using a graphical representation.
6. Identify when they do not understand concepts introduced in their main stream mathematics courses.
7. Clarify (on the own and/or with the help of others) those concepts that are unclear.
8. Understand the fundamental mathematical concepts that underpin a study of calculus.

With regard to the specific learning outcomes for the **skills components** of the POSC, students overall learn to

- Think and function within an academic, engineering environment.
- Use the English language to communicate effectively.
- Solve problems from a scientific point of view.
- Use technology to access, process and present information effectively.

Following are specific learning outcomes resulting from the different skills categories.

With regard to specific learning outcomes for **personal skills** students learn to:

1. Set goals for personal development and focus on achieving these goals.
2. Develop and maintain healthy interpersonal relationships.

3. Develop a realistic self-concept and an understanding of one's personal strengths and weaknesses.
4. Gather the relevant information, seek help and support from people within and outside of one's immediate circle, in order to make decisions and solve problems on a personal level.
5. Apply the principles of effective task management.
6. Develop and maintain a healthy, balanced lifestyle.

With regard to specific learning outcomes for **communication skills** students learn to:

1. Listen actively to the statements of fellow students, lecturers and experts in such a way that promotes effective communication.
2. Read attentively the statements of fellow students, lecturers and experts as presented in reports, notes and textbooks.
3. Express one's knowledge and ideas in unambiguous English, using correct grammar and the terminology that is customary in the fields of engineering.

With regard to specific learning outcomes for **information skills** students learn to:

1. Use the Microsoft WINDOWS operating system to manage applications and files.
2. Use application software including graphing software, word processing and a spreadsheet.
3. Use information technology to access and process information.

The development of observation skills and problem solving skills within an academic and engineering content are integrated within the learning content and the learning process of the course. The specific learning outcomes associated with these are subsequently given.

When performing the tasks in the POSC course, the following specific learning outcomes relate to **observational skills**:

1. Giving oral and/or written descriptions of scientific or technological phenomena, theories and methods and distinguishing the facts described.
2. Analysing scientific information for relevancy in terms of the following:
   - Comprehensiveness – showing what information is lacking or superfluous.
   - Accuracy – showing whether the information used is sufficiently accurate.
   - Significance – showing that the information is significant.

3. Establish the meaning of scientific information in terms of the following:
   - Valid deductions that can be made from the information.
   - Logical steps that lead to each deduction.

When given a problem in the POSC (and eventually in engineering practice), students must demonstrate their ability regarding the specific learning outcomes relating to **problem solving skills** and act as follows:

1. Identify the problem.
2. Generate one or more alternative solutions to the problem.
3. Distinguish between relevant and superfluous information and identify additional information to be gathered.
4. Evaluate the alternatives with regard to what is given and what is required and select the best solution.
5. Implement the solution.
6. Evaluate the solution.

Emphasis in the POSC course is on the **learning content** as well as on the **learning process**. It is imported to note that, where possible, an integrated approach is followed in the presentation and assessment of the course content. This is done in order to give the students an idea of the skills and knowledge an engineer needs in a real world situation. For example, when the students do a project during the second semester, they have to do research and use technology (information skills), they have to apply mathematical knowledge (academic skills) and have to compile a report (communication and information skills). Observational and problem solving skills are a vital part of the activities. Furthermore, working in small groups and using time effectively are just some of the other skills needed and practised for the successful completion of the project.

The learning facilitation philosophy of the POSC indeed exhibits the view expressed by Olivier (1998:39), namely that:

The challenge involved in outcomes-based learning is the rationale of achieving outcomes within a learning programme while developing within learners the capability to think, reason, criticise, deliberate, think, socialise and apply knowledge and skills within a specific context, rather than just acquiring it ... there is a strong focus on conceptual thinking, problem solving and insight abilities, which is coupled with strong adaptability to change and develop. This approach implies that the ways learning take place are as important as how mastering and integrating and manipulating information take place or occur.

In addition to complying with the general educational policy in South Africa of outcomes-based learning, the training of engineers in South African also have to comply with outcomes set by ECSA. These outcomes are summarised in Table 5-4. Those outcomes that are specifically addressed in the POSC (with relevance to the course content of the POSC) are indicated with a tick mark.

Table 5-4 Engineering degree outcomes required by ECSA

	ECSA outcomes	Addressed in the POSC
1	An ability to identify, formulate and solve engineering problems.	✓
2	An ability to apply knowledge of mathematics, science and engineering.	✓
3	An ability to design a system, component or process to meet desired needs.	
4	An ability to apply research methods, plan and conduct investigations and experiments	
5	An ability to use appropriate engineering methods, skills and tools and assess the results they yield.	✓
6	An ability to communicate effectively, both orally and in writing, with engineering audiences and the community using appropriate structure, style and graphical support.	✓
7	A broad education necessary to understand the impact of engineering activity on the society and the environment.	✓
8	An ability to function as an individual and as a team member in a multidisciplinary environment.	✓
9	An ability to engage in life-long learning through well developed learning skills.	
10	To be critically aware of the need to act professionally and ethically and to take responsibility within own limits of competence.	✓

Compiled from ECSA Document PE-61 (1998)

Due to the extent of the scope of the learning facilitation activities in a support course such as in the POSC outlined above, the opportunities for utilising learning facilitation as action research endeavours are abundant. The focus in this thesis is therefore narrowed to the development of a learning facilitation strategy for mathematics. As the learning facilitation of mathematics is the primary focus in the POSC during the first semester, the action research reported in this thesis concerns the activities of the first semester module, JPO110, of the POSC. For the purposes of this thesis the action research activities during 2000 and 2001 are the main focus. During 2002 a limited action research study was also conducted with a restricted focus on two aspects that were also addressed in the 2000 and 2001 studies. This included the implementation of the SOMT both as a pre-intervention instrument at the beginning of the POSC and as a post-intervention instrument after the POSC. These results are quantitatively and qualitatively analysed together with the comparable results for 2000 and 2001. Furthermore, the ILS was also implemented in 2002 and the results hereof is qualitatively analysed together with those of 2001.

In sections 5.4 to 5.8 the research studies of 2000 and 2001 are detailed. The research study of 2002 is discussed in section 5.9.

5.4 Overview of the 2000 and 2001 research

The diagram in Figure 5-2 illustrates the action research cycles of 2000 and 2001 and indicates that the research is based on the results and insights gained from the 1993-1999 research activities. For the purpose of this chapter the action research terms of **act**, **observe** and **reflect** are interpreted as **implement**,[66] **monitor**[67] and **assess**[68] as these, in the opinion of the writer, convey the essence of the research activities reported in this thesis.

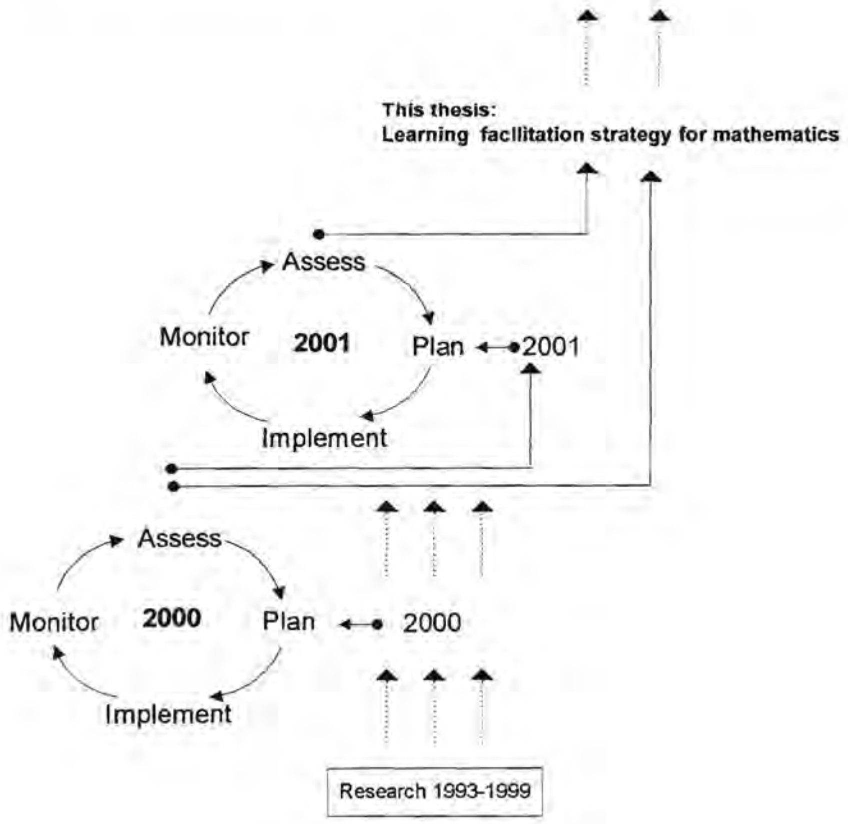
Two aspects regarding the format in which the action research activities are reported here need to be pointed out. Firstly, the details of the research activities of 2000 and 2001 regarding the POSC students are reported simultaneously as most of them were similar in scope. Wherever differences, changes or adaptations occurred between the activities of 2000 and 2001, they are indicated and treated separately. Secondly, the level of detail in which the action research activities are reported was determined by identifying those

[66] The term "implement" is viewed as *to put into effect* (Thompson, 1995:681).
[67] The term "monitor" is viewed as *to watch and check something over a period of time* (Crowther, 1995:753).
[68] The term "assess" is viewed as *to determine the importance, size or value* (Woolf, 1977:67).

principles and activities that can be regarded as essential information for any other interested researcher who may wish to duplicate the study or an aspect thereof.

In Figure 5-3 an overview is given of the content of the phases plan, implement, monitor and assess of the action research cycles.

Figure 5-2 Action research cycles 2000 and 2001



Compiled by the author of this thesis

Figure 5-3 Action research activities 2000 and 2001

Compiled by the author of this thesis

In Chapter 4 (Table 4-1) some general characteristics of action research were listed. All of these characteristics except one, namely collaborating with other researchers, are relevant to the present study. With regard to the necessity of collaboration, Cohen and Manion (1994) point out that collaboration in action research is not essential and Zuber-Skerritt (1992b; 1997) strongly argues that teachers in higher education themselves should conduct action research on their own teaching practices. The characteristics of the action research activities as applicable to this study are summarised in Table 5-5.

Table 5-5 Common characteristics of action research in the current study

1 Situational	This study is concerned with learning facilitation in a specific context and attempting to explore it in that context.
2 Collaborative	This study did not involve teams of practitioners and researchers.
3 Participatory	In this study the researcher is not an outside expert conducting an enquiry with 'subjects', but a co-worker doing research with and for the learners concerned.
4 Critical	In this study participants (lecturer and learners) search for practical improvements in their work and strive to change their environment as necessary and they themselves are changed in the process.

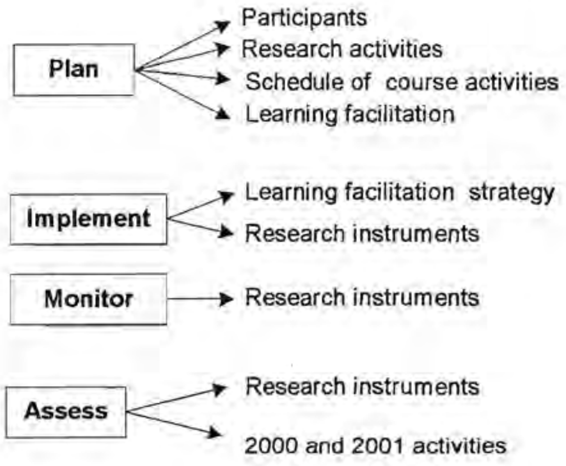
5 Self-evaluative	In this study adaptations are continuously being evaluated and the ultimate objective is to improve practice in some way or other.
6 Accountability	In this study the researcher (lecturer) remains committed to continuous quality improvement that is fostered by the nature of the action research approach.
7 Practical and theoretical	This study seeks to unite two central concerns in educational research, namely improvement in practice and increased knowledge.
8 Interpretative	This study is not assumed to result in the researcher's positivist statements based on right or wrong answers to the research questions, but in contributions to improve learners' experience in mathematics based on the interpretation of the outcomes of the study.
9 Research into teaching	This study is action research conducted by the practitioner on the own teaching practice and is also informed by theory, but not confined by abstract theories.
10 Professional development	In this study the researcher is truly involved in educational research on which the own practice is based and the study contributes to the professional development of the researcher.
11 Continuous	The task is not finished when the report on the research activities of 2000-2002 has been documented in this thesis. Improvement of support in learning facilitation of tertiary mathematics in a support course is an ongoing process.

Compiled by the author of this thesis and based on the contents of Table 4-1 on pages 138-139

In the following section the planning phases of the 2000-2001 research are discussed. Then the schedules for the implementation of the activities are given and finally the remaining three phases (implement, monitor and assess) are discussed.

The report on the phases implement, monitor and assess are treated in the following way. Firstly the implementation of the learning facilitation strategy for mathematics (proposed in Chapter 3) is discussed. Then the implementation of the research instruments and the monitoring thereof are discussed. The final phases of the research cycles are discussed by assessing the 2000 and 2001 studies with regard to the instruments used and the effect of the learning facilitation strategy that was followed. The diagram in Figure 5-4 illustrates the structure of this discussion.

Figure 5-4 Structure of the discussion of action research activities in 2000-2001



Compiled by the author of this thesis

5.5 Planning the 2000 and 2001 research

The action research studies during 2000 and 2001 were conducted as an integral but unobtrusive part of the POSC. During everyday course activities students were not deliberately made aware of the fact that they were participating, together with the lecturer, in an action research study. Exceptions to this were when questionnaires were administered or surveys conducted. In these cases the lecturer (researcher) explained to the students that their contributions would, on the one hand aid research to improve the instructional approach of the POSC and on the other, their participation could enhance their own personal and academic development. It should be borne in mind that although the focus in this thesis is on the **development of the mathematics potential** of the learners, the overall challenge of learning facilitation in the POSC is to develop the academic potential of the learners.

The activities undertaken to plan the research (and structure the POSC) are listed Table 5-6 for 2000 and in Table 5-7 for 2001.

Table 5-6 Action plan 2000

Planning	Activities	
Course schedule	Plan POSC activities according to the schedule on the official timetable Schedule SOM[69] (Pre intervention, paper based) Schedule HBDI[70] (Computer based online) Schedule LAS[71] (Paper based)	
Research schedule	Semester 1:	SOM administer SOM feedback HBDI online
	Semester 2:	LAS administer LAS feedback HBDI feedback SOMT (Computer based) [72]
	Qualitative assessment:	Researcher's self-reflection Student feedback
	Quantitative assessment:	HBDI LAS instead of HBDI? SOM and SOMT (Pre- and post-intervention) WTW 114
Computer and lecture facilities	Reserve computer laboratory for all scheduled periods Reserve lecture hall for all schedules periods	
Facilitation aid	Search for and appoint tutors who are able and committed to the aims of the POSC	
Instructional material	Acquire a copy of the instructional package *Fundamentals of 2-D Function Graphing* for each student Compile the study manual for the POSC	
Course assessment[73]	Continual assessment throughout Weekly marking of mathematics answer sheets Class tests (paper based) and using the graphing utility *Master Grapher* Semester 1 (JPO110): No formal semester tests, June exam Semester 2 (JPO120): No formal semester test, November exam	
Questionnaires	Adapt SOM HBDI online Adapt the LAS	

[69] See Chapter 4, section 4.6.4 for information on the SOM.
[70] See Chapter 4, section 4.6.6 for information on the HBDI.
[71] See Chapter 4, section 4.6.7 for information on the LAS.
[72] Although this activity was done in 2001, the results thereof pertain to the 2000 study and thus the inclusion of it in this table.
[73] The mathematics component of the POSC in the first semester counts 65% of the total mark for this module. The other 35% is allocated to skills development and introductory research activities.

Table 5-7 Action plan 2001

Planning	Activities	
Course schedule	Plan POSC activities according to schedule on official time table Schedule SOM (Pre intervention, paper based) Schedule LAS (Paper based) Schedule ILS[74] (Paper based) Schedule SOMT[75] (Post-intervention, computer based)	
Research schedule	Semester 1:	SOM administer LAS administer ILS administer Individual feedback on all the questionnaires
	Semester 2:	SOMT administer SOMT feedback
	Qualitative assessment:	Researcher's self-reflection Student feedback
	Quantitative assessment:	SOM and SOMT (Pre- and post-intervention) WTW 114 marks
Computer and lecture facilities	Reserve computer laboratory for all scheduled periods Reserve lecture hall for all schedules periods	
Instructional material	Acquire a copy of the instructional package *Fundamentals of 2-D Function Graphing* for each student Edit and adapt the 2000 Study Manual of the POSC for 2001	
Facilitation aid	Search for and appoint tutors who are able and committed to the aims of the POSC	
Course assessment	Continual assessment throughout Weekly marking of mathematics answer sheets Semester 1 (JPO110): No formal semester tests, June exam Semester 2 (JPO120): Two semester test during scheduled test week, no November exam	
Questionnaires	SOM Adapt SOM for tertiary students (referred to as SOMT) Adapted LAS ILS	

[74] See Chapter 4, section 4.6.8 for information on the ILS.
[75] See Chapter 4, section 4.6.5 for information on the SOMT.

5.5.1 Participation

The participation in the action research activities during 2000 and 2001 mainly involved the researcher and the students enrolled for the POSC. During 2000 the research activities also involved a group of first year civil engineering students. Their inclusion in the research concerned comparing the thinking style preferences the engineering students on the POSC to those of a group of first year civil engineering students (in the School of Engineering).

It should be pointed out that an additional set of data concerning thinking style preferences and study orientation is also included in the results given in Chapter 6 and discussed in Chapter 7. This data on thinking style preferences is from a study in 1998 (De Boer & Steyn, 1998) concerning the thinking style preferences of a group of science students on a support course (in the School of Natural Sciences) and it is used in the current report to compare the thinking style preferences of these science students to those of the engineering students mentioned above.

In the following sections detail is only given of the POSC students as their involvement form the main focus of the current study.

5.5.1.1 Participants of 2000

The POSC class of 2000 comprised 33 students in the first semester of whom five were females and 31 were black. An African language is the mother tongue of 31 students and Afrikaans the mother tongue of two students. English is the second (or third) language of all the students. The language of instruction for mathematics in secondary school was English for 21 of the students, 8 received instruction in English as well as in their mother tongue and four received instruction in their mother tongue. The average M-score of this group was 17.9 out of a possible 30.

Only 19 of the students had had limited previous experience with computers and none of them had used a computer for mathematics before. This limited experience comprised, on average, one to two hours of computer use that was scheduled as a computer literacy period in the formal school timetable in their final year of secondary schooling.

All 33 students completed the HBDI and 32 completed the adapted LAS. The adapted SOM was completed by 30 of the students and 26 students completed the SOMT.[76]

These identifying attributes of the POSC participants in 2000 are summarised in Table 5-8.

In addition to the POSC students, 30 first year civil engineering students also completed the HBDI and the LAS questionnaire during 2000.

5.5.1.2 Participants of 2001

The POSC class of 2001 comprised 40 students in the first semester of whom 13 were females. During the second semester there were 38 students including the 13 females. All the students were black. An African language is the mother tongue of 37 students, English is the mother tongue of two students and one student has Portuguese as mother tongue. English is the second (or third) language of all but two students. The language of instruction for mathematics in secondary school was English for all the students. The average M-score of this group was 17.1 out of a possible 30.

Of these 40 students, 17 had had no previous exposure to computers. Twenty students indicated that they had had previous experience with computers that was limited to introductory usage skills, some word processing and spread-sheet use.[77] Three students indicated that they had computers at home of which two have Internet access. Again none of the students had used a computer for mathematics before.

The HBDI was not used in the 2001 study but all the students completed the LAS as well as the ILS. The SOM was done by 40 students and all 38 students enrolled for the second semester completed the SOMT.

The identifying attributes of the POSC participants in 2001 are summarised in Table 5-8.

[76] For the discussion in this chapter, no distinction is made between the different versions of the SOMT.

[77] Although the students with 'limited' computer knowledge indicated that they had skills with regard to word processing and spreadsheet use, the researcher found during course activities in the second semester of both 2000 and 2001 that none of these students were proficient users of any application program.

Table 5-8 Attributes of the POSC participants of 2000 and 2001

		Number of students		
		2000	2001	Total
Male		28	27	55
Female		5	13	18
Total per group		33	40	
Mother tongue:				
	African language	31	37	68
	Afrikaans	2	0	2
	English	0	2	2
	Portuguese	0	1	1
Language of high school instruction in mathematics:				
	English	20	40	61
	Mother tongue	4	0	4
	English and mother tongue	8	0	8
Average M-score:				
		17.9	17.1	
Computer experience prior POSC enrollment:				
	No experience	14	17	31
	Limited experience	19	20	39
	Experience	0	3	3
	Used for mathematics	0	0	0
Participation in the:				
Herrmann Brain Dominance Instrument (HBDI)		33	0	33
Lumsdaine and Lumsdaine Learning Activity Survey (LAS)		32	40	62
Felder Solomon Index of Learning Styles (ILS)		0	40	40
Study Orientation Questionnaire in Mathematics (SOM)		30	40[78]	70
Study Orientation Questionnaire in Mathematics Tertiary (SOMT)		26	38[79]	62

[78] Of these 38 could be used for data analysis.
[79] Of these 36 could be used for data analysis.

5.5.2 Planning the research activities

Research activities were planned to address the research questions stated in Chapter 1.[80]

The research questions were explored and assessed against the background of the learning facilitation strategy followed in the POSC and within the context of the activities of the course. In order to explore the first two and the last research questions, appropriate instruments had to be chosen.[81]

The aim of the first research question was to explore the study orientation of the students towards mathematics. For this purpose the SOM and the version adapted for tertiary students, the SOMT[82] were used.

In the second research question the aim was to determine if the learning facilitation strategy followed in the support course has an effect on students' study orientation towards mathematics. In this case the results of the SOM (SOMT) as pre-intervention and post interventions are quantitatively and qualitatively compared.

In addressing the fourth research question, concerning the thinking style preferences of the students, the HBDI, the LAS and the ILS were used.

The third research question explores whether a learning facilitation strategy using graphical exploration of 2-D functions to enhance the learning of mathematics contributes to improved academic performance in the standard first semester course in calculus. This question addresses the performance of the POSC students in the standard calculus course compared to the performance of other students on the 5YSP who are not enrolled for the POSC and to the performance of students on the regular 4YSP.

5.5.3 Schedule of course activities

The diagram in Figure 5-1 on page 190 outlines the focus areas of the POSC. During the module in the first semester the primary focus is on mathematics. However, the learning facilitation strategy proposed in this thesis strongly advocates the development of the **mathematics potential** of the learner and this inevitably also involves the development of **personal, academic and communication skills**. The development of these skills is

[80] The research questions are stated in Chapter 1 section 1.4 on page 8.
[81] See Chapter 4 for details on the instruments used in this research.
[82] The adaptation to the SOM for tertiary use is discussed in Chapters 4 and 6.

therefore integrated into the learning facilitation strategy of mathematics in the POSC. Furthermore, the instructional material used for the learning facilitation of mathematics in JPO110 heavily relies on the use of a computer to generate the graphs of two-dimensional functions and this necessitates the acquisition of basic skills in the use of a computer and the graphing program *Master Grapher for Windows* (Carr & Steyn, 1998).

In scheduling the action research activities reported in this thesis as well as the course activities of JPO110 during 2000 and 2001 the researcher (lecturer) had to incorporate the administering of the questionnaires for the purposes of the research into the course activities in such a way that they would be appropriate for the course content and had to be given at a time when students would realise the need thereof and could benefit from the resulting information.

During 2000 a total of 60 periods of 50 minutes each was available for JPO110 and in 2001 there were 62 periods. In Table 5-9 the allocation of the periods to different course and research activities is summarised. For the purposes of this thesis it should be pointed out that 24 periods were scheduled for mathematics in 2000 whereas 33 periods were scheduled for mathematics in 2001. The number of periods used for academic and personal skills were almost equal (eight in 2000 and seven in 2001). Five periods were used for administering the research instruments in 2000 and four periods in 2001. In both cases the students had to do the SOMT questionnaire in their own time.

Table 5-9 Allocation of periods to the activities of the POSC during 2000 and 2001

	2000	**2001**
Total number of periods available	60	62
Total periods used for:		
Administrative and social matters	6 + 2	4 + 1
Hands on introduction to computer use	1	1
Mathematics, using computer graphing utility	20	30
Mathematics pen & paper	2	3
Mathematics test	2	0
Personal & academic skills	6	5
Additional skills	11	12
Mind Map video & information	2	2
Research questionnaires	5	4
Group feedback on questionnaires	3	0

It should be noted that the initial aim during the first four weeks of the first semester is to get the students doing the mathematics of the POSC as soon as possible and at the same time give them the basic skills to cope with the new academic environment. This is done to support them in their preparation for the first test week of the School of Engineering that is usually in the beginning of March.

During both the 2000 and 2001 research activities the administering of the research questionnaires was scheduled for the time between the first and second test weeks. In 2000 the SOM was scheduled in the week following the first test week. The HBDI was scheduled for the second week after the March-April recess. The LAS questionnaire was scheduled for the beginning of the second semester in mid July. The POSC 2000 students did the SOMT in June 2001.

In 2001 the SOM was also the first research instrument to be administered and was scheduled for the second week following the first test week. The LAS questionnaire was scheduled for the following week. The Felder Solomon ILS was scheduled for the week following the March recess. The SOMT was scheduled in the second semester at the beginning of September.

An information session on mind maps as a study tool was scheduled after the students had had some experience preparing for tests at university. In 2000 it was scheduled after the two test weeks but prior to the June exam. In 2001 the information on mind mapping was scheduled for the end of April after the first test week and prior to the second test week.

5.5.4 Planning the learning facilitation of mathematics in the POSC

Students who are enrolled for the POSC attend the same standard mathematics courses as the other first year engineering students. All the students enrolled for the standard calculus course during the first semester (coded as WTW114 during 2000-2001 and as WTW158 in 2002) have four 50 minute lecture periods and one 90 minute practical session per week. In addition to the lectures and practicum all the engineering students on the 5YSP (including the POSC students) attend two compulsory tutor sessions of 50 minutes each per week. These sessions are scheduled to fit into students' free lecture periods. Tutors[83] conduct the sessions and approximately ten students are allocated to a specific tutor. Students should preferably remain with the same tutor. These activities are presented and coordinated by the Department of Mathematics.

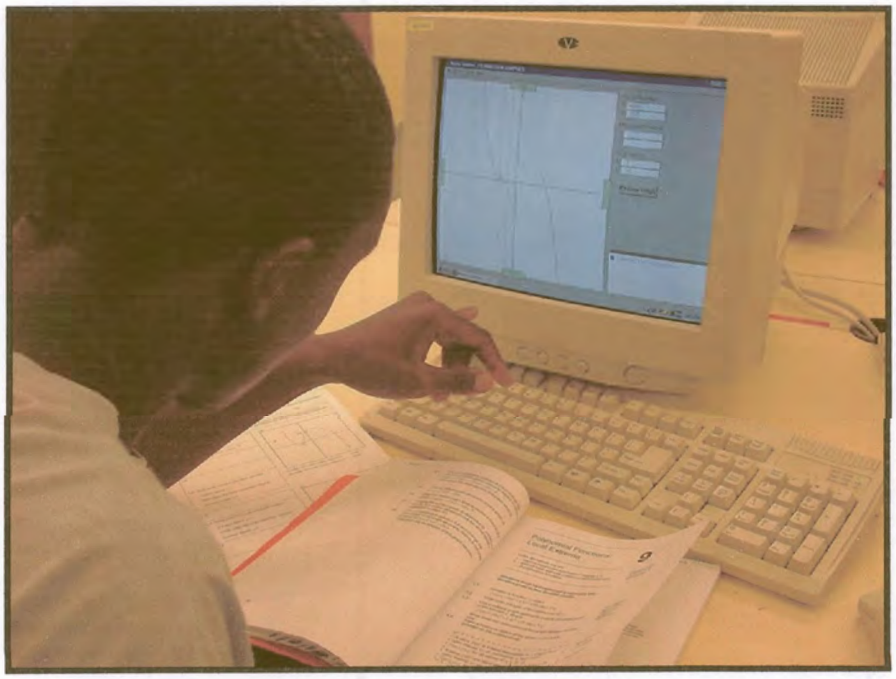
The mathematics component of the POSC is done independently from the standard calculus course but in addition to the above mentioned activities. The aim of the mathematics activities in the POSC is to ensure that students understand two-dimensional functions and their graphs as the fundamental concepts that underpin a study in calculus are embedded in a thorough understanding hereof (Finney, Thomas, Demana & Waits, 1994; Larson, Hostetler & Edwards, 1998).

The mathematical content of the POSC (in the module JPO110) includes the principles from pre-calculus that underpin a study of calculus, concepts related to the Cartesian coordinate system, two-dimensional functions, the concepts of limit, continuity and differentiation, the application of the first and second derivative and estimating the area under a curve. Figure 5-5 and Figure 5-6 illustrate the mathematic activities of the POSC.

[83] See section 5.1 above for information on the tutoring system.

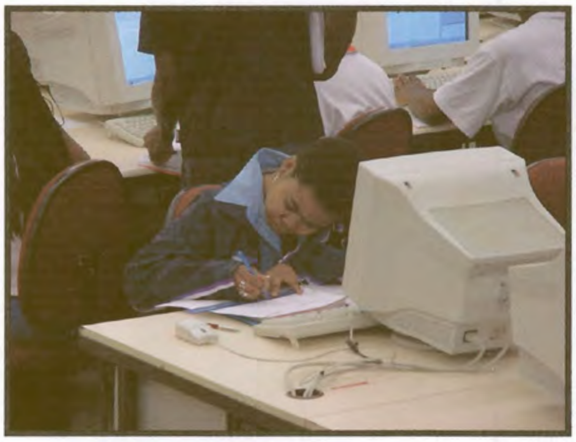
Figure 5-5 Mathematics activities in the POSC

Mathematics activities in the POSC take place in a computer laboratory which is illustrated in the photograph above. Exploration of mathematical concepts related to 2-D functions is done using a computer graphing tool, following structured activities in a work book, analysing the graphs of 2-D functions, making deductions and writing down answers on a formatted answer sheet. The photograph below illustrates a student engaged in these activities.



The following photographs illustrate three typical aspects of the learning facilitation strategy proposed in this thesis and followed in the POSC. Students work alone, there is frequent one-on-one interaction between facilitator and learner and students also engage in informal small group discussions for short periods.

Figure 5-6 Learning facilitation activities in the POSC



Student working alone.

One-on-one tutor and learner interaction.

Informal small group activities.

5.6 Implementing the learning facilitation strategy for mathematics

The diagram in Figure 5-9 on page 218 illustrates the implementation of the learning facilitation strategy proposed in this thesis. In the following sections the main aspects of the implementation activities, namely the tasks of the facilitator, the instructional media and the learning facilitation strategy are discussed.

5.6.1 Tasks of the facilitator

The following tasks of the facilitator are singled out and briefly discussed as they are specifically relevant for the learning facilitation of mathematics in the POSC. The tasks of the facilitator are associated with the implementation of "Learning Facilitation" as illustrated in Figure 5-9 on page 218.

The tasks of the facilitator include overseeing that the following principles, identified by Steyn (1998) for learning facilitation when a graphing utility is used, are addressed and implemented.

- **Structured exploration and interpretation**. Graphical explorations as an aid to mastering fundamental mathematical concepts need to be well structured. Learners need to be taught how to explore graphs and make meaningful interpretations. Disregarding this principle may result in graphical images becoming only 'nice to look at' and learners perceiving them as 'so what about it'. In order to structure learners' exploration activities, detailed step-by-step guidelines for the exploration activity need to be followed. The example in Appendix B illustrates the format of a worksheet that complies with this principle. The step-by-step instructions imply that students have to read, comprehend and use this instructional information to do the exploration activities. This promotes self-exploration by a learner and the activity is self-paced.

- A **whole brain approach** encompasses a combination of graphical exploration and graphical analysis that can be interpreted as a back and forth movement between right and left brain activities[84] Using the principle of structured exploration discussed above, and in particular, working through worksheets as in Appendix B, results in activities where the utilisation of cognitive functions, associated with the linear hemisphere, are promoted through the structured format and verbal information. This is followed by the utilisation of

[84] See Chapter 2 Table 2-7 on page 63 for key brain characteristics, note the explanation of the "iterative" characteristic.

cognitive functions associated with global hemisphere in the actual exploration activity, which is then followed by linear hemisphere utilisation in analysing, formulating and writing down of the solutions to the problem. The incorporation of both exploration and analysis contribute to the mastering of fundamental mathematical concepts when a graphing utility is used.

- **Verification and illustration**. To aid in mastering fundamental mathematical concepts, graphical interpretation should be accompanied by algebraic verification (orally and/or in writing) and algebraic results should be illustrated graphically. Students should be encouraged to 'speak mathematics' and explain the visual images on the screen. The task of the facilitator in this regard is to listen and prompt students to (re-)formulate mathematically correctly. Having formulated the concept verbally, they then need to write it down in mathematical symbols. This coherence between exploration and verification promotes the utilisation of linear as well as global hemisphere cognitive activities and promotes deeper understanding of the concepts involved.

- The **left-to-right principle**. Graphical exploration and interpretation should be done starting from the left side of the screen (following the curve displayed on the screen) and working towards the right side. This is important, as analytical mathematical theorems that reflect on two-dimensional functions postulate concepts for increasing values of x. There is one exception to this principle, namely, when limits from the right, $\lim_{x \to a^+} f(x)$, are explored.

It should be pointed out that the researcher invariably experienced that learners do not know where to begin (the left side or right side) when they have to interpret a graphical image.

- **The principle of non-assumption**. Learners need to be taught how to explore graphs and make meaningful interpretations. Facilitators of learning should never assume that learners observe and deduce from graphical images what teachers expect students to observe and deduce. Fuchsteiner (1997:16) remarks that *we must start [our teaching] where students are rather than where we wish they were*. It is thus the task of the facilitator to ensure that the learner accomplishes what he/she is intended to master.

- The **tool principle**. It should be stressed that the facilitator should view technology (such as a graphing utility) as a tool to aid learning and enhance teaching. Technology should neither intimidate a learner nor dominate instruction.

- The **assessment, grading and feedback of answer sheets** are done in order to ascertain that students write down mathematics correctly. The focus is thus not on numerically correct answers but on the way in which they are written down. The lecturer (researcher) regards the continual assessment, grading and feedback of the answer sheets as of primary importance in the learning facilitation strategy proposed in this thesis.

5.6.2 Instructional media

The instructional media[85] used for the facilitation of the mathematics in the POSC include graphing software and paper based instructional material. The arrangement of the instructional media in the implementation of the proposed learning facilitation strategy is illustrated in Figure 5-9 on page 218.

During 2000-2002 the package *Fundamentals of 2-D Function Graphing – a practical workbook for precalculus and introductory calculus* (Greybe, Steyn & Carr, 1998) was used.[86] This package consists of a workbook, accompanying answer sheets and graphing software, namely, *Master Grapher for Windows* (Carr & Steyn, 1998).

The software *Master Grapher for Windows* is a tool that generates the graphs of two dimensional functions and comprises a graphing utility, three computer based interactive tutorials and an online help.

- **The graphing utility**

The graphing utility represents a two-dimensional coordinate system and the main user interface is window where graphs are drawn and from which the other options of the software, needed for exploration, can be accessed. The main window is displayed in Figure 5-7. The equations of the functions to be drawn are entered in an equation editor which is displayed in Figure 5-8.

The software was designed to promote self exploration by a learner. The following technical features of the software support the exploration activities (Steyn, 1998):

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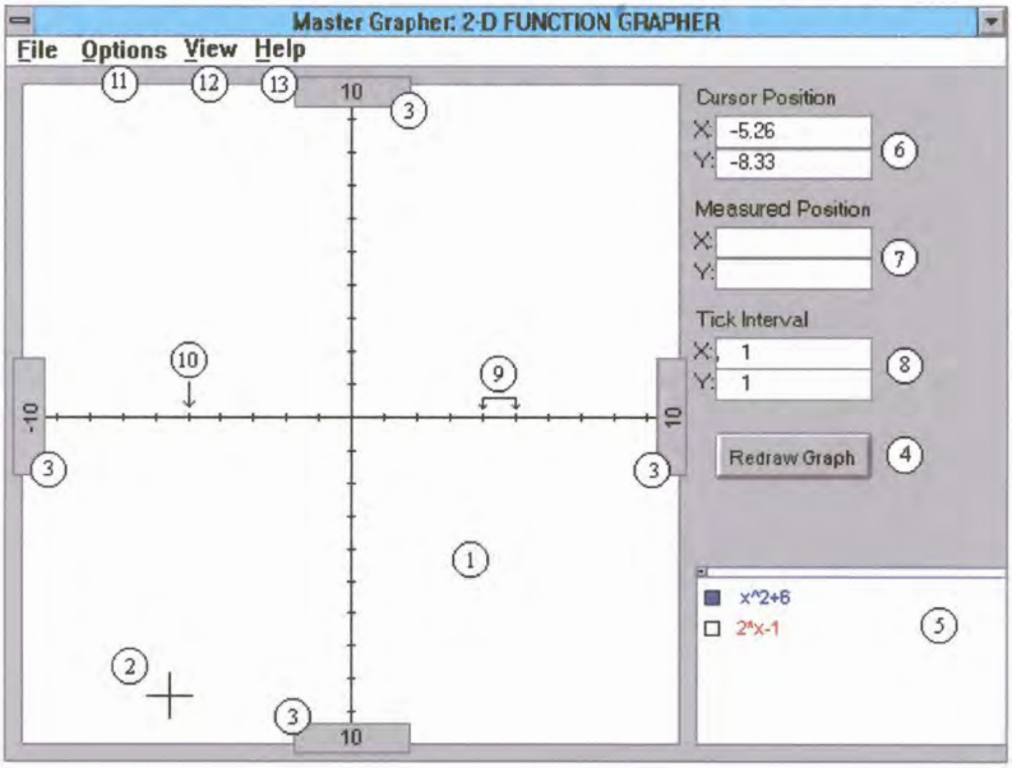
[85] The term "medium" refers to *the means by which something is communicated* (Thompson, 1995:847).
[86] The use of this package is a *sine qua non* in the learning facilitation strategy proposed in this thesis. Continual revision of the workbook remains an ongoing priority.

- The skill to use the software is acquired within 1-2 hours (even for inexperienced computer users).[87]
- Entering of functions is easy.
- Up to five functions can be displayed simultaneously.
- Functions are colour coded to aid in distinguishing displayed functions from each other.
- Entered functions can easily be displayed or not-displayed by clicking on the coloured box in the 'function display window' (see Figure 5-7).
- A cross-hair cursor as well as the 'cursor position block' indicate the current position on the two-dimensional plane (see Figure 5-7).
- Exploratory activities, e.g. following a curve 'physically', is done with a mouse.
- A right mouse click gives the measured position of the cursor and this position is indicated with blue dotted lines on the 'graph window' and displayed in the 'measured position' block.
- A 'tick interval' block indicates the scaling of the axes.
- The dimensions of the graph window[88] is easily changed by clicking on the 'axis limit' blocks or accessing the menu option 'Scaling of the axes' under the 'Options' menu. The default dimensions is [Xmin, Xmax] x [Ymin, Ymax] = [-10, 10] x [-10, 10] and is written in this notation.
- Toggling between two consecutive graph windows is easy. This option is accessed through the menu item 'View' (see Figure 5-7).
- Vertical and/or horizontal lines can be set (fixed) at required values for determining *x*- and *y*-values, respectively.
- Moving vertical and/or horizontal lines can be activated and used for exploration. This exploration is especially conducive for active and intuitive exploration of images.
- Repeated zooming is possible and is done by accessing the 'zoom' feature under the 'View' menu and using the mouse.
- The larger viewing area and better resolution of a computer screen (in comparison with that of a graphing calculator) is conducive to authentic graphical exploration.

[87] Refer to Table 5-8 for detail on the entry level of computer experience of the POSC students.
[88] In some graphing utilities and textbooks the phrase "viewing rectangle" is used to indicate the 'window' in which the 'graph' is displayed.

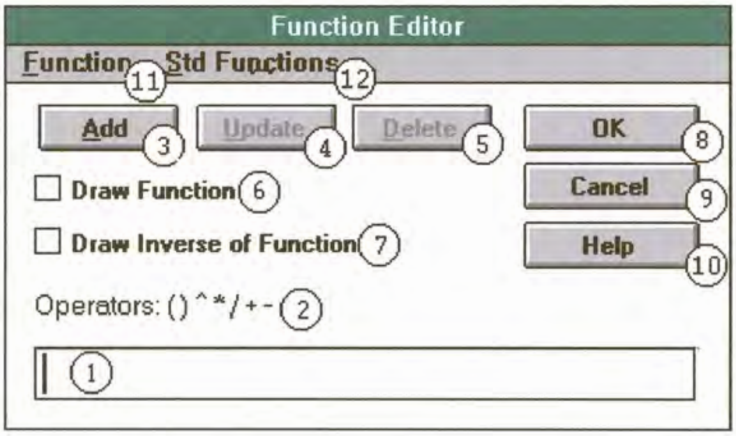
Figure 5-7 The main window of the software *Master Grapher for Windows*



- Functions are plotted in the **Graph Window** (also referred to as a **Viewing Rectangle)**
- **Cross-hair cursor** shows the current *x* and *y* coordinates. See also ⑥
- **Axis limit blocks** show the current [Xmin, Xmax] x [Ymin, Ymax]
- **Redraws** the graph(s) of the selected function(s)
- **Function Display Window** shows the current functions. See **Function Editor** on the next page.
- **Cursor Position** shows the *x* and *y* coordinates of the cross-hair cursor ②
- **Measured Position** fixes the current *x* and *y* coordinates of the cursor with dotted horizontal and vertical lines, and is set by clicking with the right button.
- **Tick Interval** shows the distance between ticks on the *X*- and *Y*-axes. Scaling on the two axes may differ.
- A tick interval is the physical distance between the ticks on the axes. See also ⑧
- **Tick marks**, together with **Cursor Position** ⑥, the **Tick Interval** ⑧ and the **Axis Limit Blocks** ③, replace a grid.
- Menu item: **Options** for options concerning the Graph Window, such as functions and scaling the axes.
- Menu item: **View** for options in exploring the behaviour of graphs.
- Menu item: **Help** gives information on using *Master Grapher for Windows* as well as information on some mathematical topics.

Adapted from Greybe, Steyn & Carr (1998:3)

Figure 5-8 The function editor of the software *Master Grapher for Windows*



- Use the **Function Typing Box** to enter functions.
- These are the allowed operators in *Master Grapher for Windows*.
- Button to **add** the function in the Function Typing Box ① to the list of saved functions.
- Button to **replace** a function with the one in the Function Typing Box ①
- Button to **delete** the function in the Function Typing Box ①
- Click on the **Draw Function** option to have *Master Grapher for Windows* plot the function in the Function Typing Box ① when the Function Editor is closed.
- **Draw Inverse of** (the) **Function** in the Function Typing Box ①. This option is only active if **Draw Function** ⑥ is active.
- The **OK** button is used to accept all changes made to functions in the Function Editor.
  The list of functions can only be modified through the **Add**, **Update** and **Delete** buttons.
- The **Cancel** button is used to discard any changes made.
- The **Help** button is used to access Help on the Function editor.
- Clicking on this menu option gives a list of the current functions. A function can be selected into the Function Typing Box ① by clicking on it.
- A list of standard functions available in *Master Grapher for Windows*. These can be selected into the Function Typing Box ① by clicking on them.

Adapted from Greybe *et al.* (1998:5)

- **The interactive tutorials**

The first tutorial, *The Cartesian Coordinate Plane*, covers the basics of a coordinate reference system, the fundamentals of the two-dimensional plane and introduces the student to the coordinate system of the graphing utility, *Master Grapher for Windows.*

The second tutorial, *Fundamentals of 2-D Graphing*, is aimed at giving the students the basic knowledge for using a graphing utility when exploring two-dimensional functions.

The third interactive computer tutorial, *Graphing Trigonometric Functions,* includes radian measure and the fundamentals of graphing the trigonometric functions sine, cosine and tangent.

- **The online help**

The online help explains the features and use of the software and includes extensive help on topics of fundamental mathematics that is related to two-dimensional function graphing.

- **The workbook**

The workbook is made up of worksheets, each focusing on a different topic. In each worksheet selected examples are explored through a sequence of activities. The results of these explorations are written up on answer sheets which are designed in a special format to correspond with the worksheets. The uniform structure of the answer sheets also eases the marking and grading of the learners' answer sheets. An example of a worksheet is attached in Appendix B.

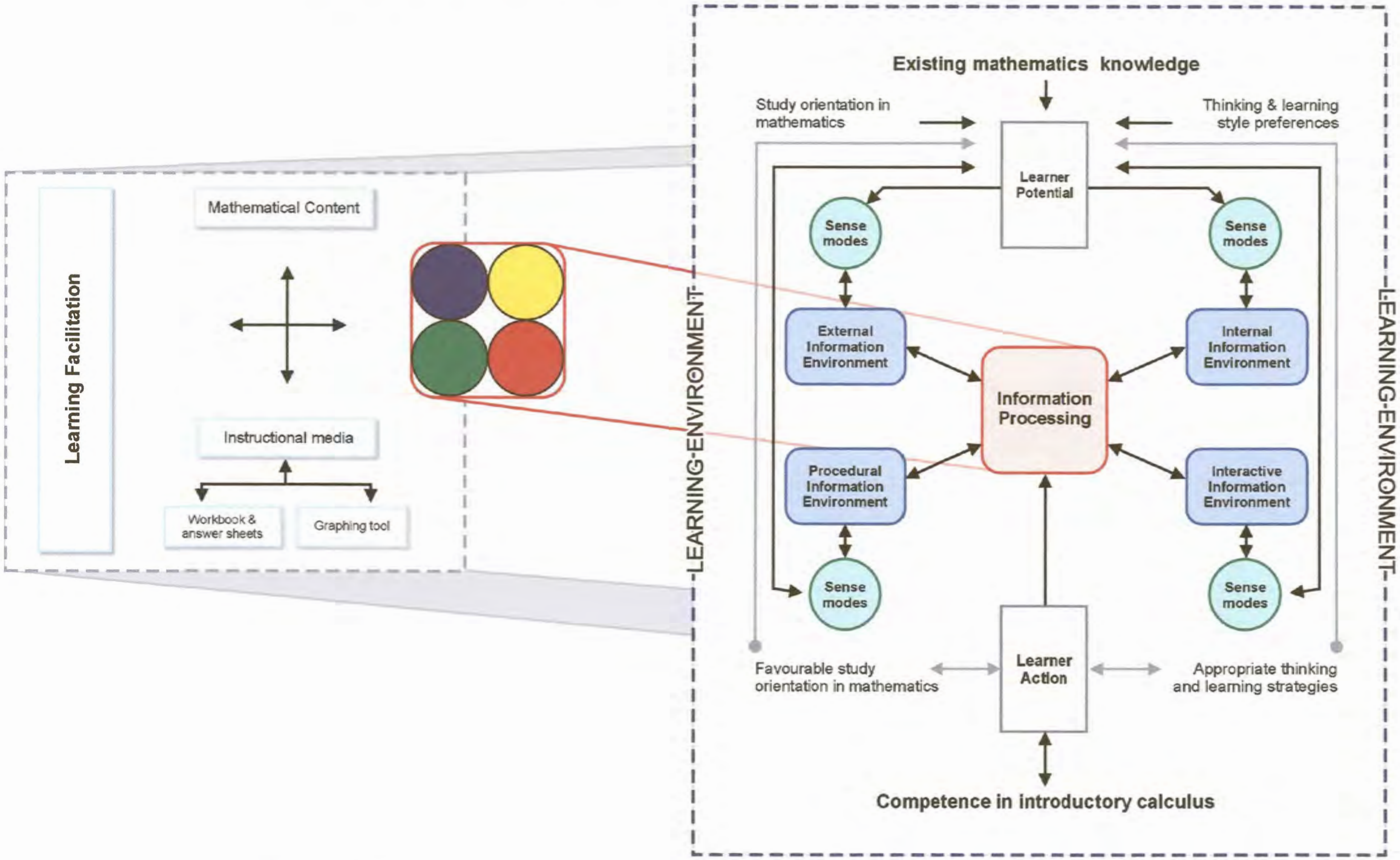
In Table 5-10 a summary of the main characteristics of the instructional package is given.

Table 5-10 A summary of the instructional media

Medium	Comprises of	Characteristics	Special features
Computer software	Graphing utility	Exploration tool Meaningful image	Large screen Ease of use Moving lines Fixed lines Easy zoom
	Tutorials	Fundamentals of a 2-D coordinate system Fundamentals of graphical exploration Trigonometric functions	Interactive Computer based Self-paced
	Online help	Help for user working alone	
Workbook	Worksheets	Structured explorations Read, understand and write mathematics	Practical workbook, not a textbook Clear lesson objectives Margin notes
	Appendices: Interpreting graphs	Awareness of limitations of technology	
Answer sheets	Formatted to accompany a specific worksheet	Ease of use for students Uniform format for marking	Fill-in format Exercises in writing mathematics Pen & paper graphs

Adapted from Steyn (1998:163)

Figure 5-9 Implementation of the proposed learning facilitation strategy



Proposed and compiled by the author of this thesis

5.6.3 Learning facilitation of mathematics

The learning facilitation of mathematics in the POSC can be described as composite and aimed at developing the mathematics potential of the learner. This implies that all the components of learning facilitation strategy illustrated in Figure 5-9 should ideally be addressed and functionally optimised.

Due to the very nature of the concept "support"[89] within the context of this study, the proposed learning facilitation strategy for mathematics does not focus solely on mathematical content but also includes the development of skills for learning mathematics. It should be stressed that the learners are not merely trained to use the skills as recipes for applications. The development of skills for learning (mathematics) is treated as an integral part of both the facilitation strategy for mathematics and of the philosophy underpinning all the activities of the POSC namely, the development of the mathematics potential of a learner following an integrated whole brain approach.

As the instructional strategy for mathematics learning facilitation strongly advocates a whole brain approach to learning and teaching, students need to be made aware of the concept of whole brain utilisation. Students also need to gain insight into their own thinking and learning style preferences and should realise that they need to develop skills to utilise their less preferred thinking and learning modes.

In addition to the development of the mentioned skills that are integrated in the strategy, mind mapping is introduced as a specific and recommended learning and study tool for mathematics. The motivation to include mind mapping is based on the premise that in the construction of a mind map the activity presupposes utilisation of diverse thinking (learning) preferences according to the four quadrant whole brain model. The researcher highly values mind mapping as a study tool as this gives students practice in developing gestalt (global) thinking activities. Although mind mapping is foremost a global approach, it also incorporates linear thinking activities that contribute to whole brain uitlisation.

Mind mapping seemingly has a positive effect on students' learning of mathematics (Steyn & De Boer, 1998). Melton *et al.* (2001:27) also report that results from an experiment with

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[89] See Chapter 1 section 1.2.6 for an explanation of the term "support" within the context of this thesis.

mind maps in a college algebra class *support the hypothesis that the use of mind maps by these students can improve their mathematical skills.*

5.7 Implementing and monitoring the research instruments

The researcher is of the opinion that a relationship of trust and understanding should exist between the lecturer (researcher) and the students (participants) before research instruments (such as questionnaires) are administered in any research done in a classroom. Furthermore, freshmen students need time to get used to their new environment and some time has to elapse between all the forms that students have to complete during registration at the university and the completion of research questionnaires. Therefore the first questionnaire for the purposes of this study was completed after five academic weeks in 2000 and 2001. It was done in the week following on the first test week of the School of Engineering.

In all instances where questionnaires were completed during the 2000-2002 studies, students were informed of the activity and the purpose of the instrument was explained. Students were also informed regarding the possible benefits of the instrument for themselves and they were assured that all data is treated anonymously. Furthermore, it was explicitly stated that although completing a questionnaire was part of the POSC activities, it was not compulsory.

The following sections describe the implementation of each of the instruments that were used during this research as well as the researcher's observations regarding the implementation of the instruments.

5.7.1 The Study Orientation Questionnaire in Mathematics (SOM)

5.7.1.1 Implementation of the SOM

The original SOM (Maree, 1996) and accompanying answer sheet were used as pre-intervention instrument during both the 2000 and 2001 research activities.

The lecturer (researcher) used the administering of the instrument as an opportunity to stress the importance of physical wellness and that a healthy diet and ample water intake

(Hannaford, 1995; Dennison *et al.*, 1989) are important while studying. The questionnaire was administered late morning and the researcher assumed that the students could be hungry and or tired. Therefore they each received a snack before doing the questionnaire. This hopefully conveyed the message of basic physiological needs to be met for sustained academic (brain) activity.

The lecturer (researcher) went through the instructions of the original SOM manual with the students, highlighting the meaning of the five categories used for answering the questions of the SOM. The researcher stressed the fact that the questionnaire was not a test and the students were told to ask whenever they encountered a word or question that they do not understand. Students were allowed to leave when they were finished.

The answers were processed and scored by the researcher according to the prescribed instructions and format. The SOM profile of each student was drawn.

In 2000 the lecturer (researcher) gave the feedback on the SOM to the class as a group. Due to the scheduling of the POSC activities, this was done three weeks after the instrument was administered. Every student got his/her own answer sheet with the SOM profile already drawn. An example of a SOM profile[90] was used to explain the interpretation of profile and the meaning of the six fields of the SOM. The lecturer (researcher) also encouraged the students to consult with her regarding any further queries they may have regarding their SOM profiles.

In 2001 the lecturer (researcher) gave the feedback on the SOM to students individually during 10-15 minute interviews that were conducted in the last two weeks of classes prior to the exam period. Each student's profile was explained and discussed with him/her. This feedback on the SOM was done together with feedback on the other instruments (the LAS and ILS).[91]

[90] See Chapter 4 Figure 4-5 for an example of a SOM profile.
[91] See sections 5.7.4.1 and 5.7.5.1.

5.7.1.2 Monitoring the implementation of the SOM

The time scheduling for doing the SOM was appropriate both during 2000 and 2001. No problems were encountered in the administering of the SOM and the students cooperated well. It took the students approximately 20-30 minutes to complete the questionnaire. In 2000 two students did not participate in the activity but in 2001 all the students attended the session. During 2000 three of the students were unfamiliar with the term "perspire" used in question 56 of the SOM. In 2001 the researcher pointed out that the term "perspire" means "sweat".[92]

The answer sheets were checked to ensure that only one answer per question was marked, that the maximum number of unanswered questions was within the range allowed and that no gross deviations occurred in the way the answers were given, for example all answers marked in the same position on the answer sheet. During 2001 one answer sheet could not be scored due to anomalies and the scoring of another required special attention. Both these cases were followed up during the individual feedback sessions.

The lecturer (researcher) experienced the group feedback during 2000 as unsatisfactory for the following reasons. Although students seemingly followed the explanation of how to interpret the SOM profile and what the fields of the SOM meant, it cannot be deduced that the students benefited from the activity. Furthermore, only four students followed up the invitation for further consultation. Of these, two students had an average SOM profile of above 90, one's average was 80 and the other 66. These students were not necessarily those in need of consultation and those who could have benefitted from consultation did not follow up.

As the focus of the learning facilitation strategy in the POSC strongly proposes a developmental approach, an educational research intervention such as the SOM should be utilised to aid learner support and development and not merely as another activity. Based on this experience, the feedback on the SOM during 2001 was done individually. During these individual sessions the interviewer (lecturer/researcher) made sure that the student was at ease. The student was asked whether it was in order if the interviewer made notes during the conversation and none of the students were disturbed by this request.

[92] In the SOMT version, the term "sweat" was added in brackets.

The individual feedback in 2001 comprised feedback on a student's SOM profile as well as feedback on the LAS and the ILS. Students received their SOM answer sheet with the SOM profile. A copy of this document is given in Appendix G.

The sessions were well-timed with regard to the students' own experience of university study. It so happened (without deliberately planning before hand) that the interviews were conducted after the students had done a mathematics worksheet[93] in which aspects related to problem solving behaviour and information processing (two specific fields addressed in the SOM) occurred. This posed the opportunity to ask the students how they had coped with the worksheet and this information was linked to the two fields (Problem solving behaviour and Information processing). Furthermore, the researcher (lecturer) found it meaningful to give feedback incorporating all the available information gained through the applied questionnaires. It is noteworthy that all the learners could identify with their SOM profile. These interviews also gave the students an opportunity to verbalise some aspects of their mathematics background and learning that seemingly concerned them. Overall, the lecturer (researcher) got the impression that the students appreciated the opportunity for this type of one-on-one discussion.

5.7.2 The Study Orientation Questionnaire in Mathematics Tertiary (SOMT)

In the initial planning of the 2000 research study the administering of the original SOM as a post intervention instrument was not precisely scheduled as the researcher felt that certain questions in the original SOM are too focused on mathematics within a school environment to be used with students after they had already completed a semester of tertiary study. Following on this reasoning, the researcher engaged in a series of adaptations of the original SOM that resulted in a version for use with tertiary students. The details of these adaptations are adressed in Chapter 4. The first version of the adapted questionnaire, the Study Orientation Questionnaire in Mathematics Tertiary (SOMT-1) was administered to both the 2000 and 2001 POSC students in the second semester of 2001.

[93] See Appendix B.

5.7.2.1 Implementing the SOMT in 2001

The students were again made aware of the fact that the questionnaire was not a test and that they should interpret it with regard to the standard mathematics course (and not the mathematics component of the POSC).

The POSC students of 2000 did the SOMT-1 at the beginning of the second semester, in June 2001. The questionnaire was e-mailed as an attachment (in a MS Word document format) and students had to complete it by typing an X in the appropriate space. They completed it in their own time and mailed it (as an attachment) back to the researcher. The students reported that it took about 20 minutes to complete the questionnaire. No formal feedback was given to these students.

During 2001 the SOMT was also e-mailed as an attachment to the POSC students of 2001 and they completed it early in September in a scheduled POSC period. Again it took about 20 minutes to complete. Feedback on the SOMT was again given to the students individually by way of a handout showing both the SOM and the SOMT profiles of the student and a short consultation. An example of the handout used during the feedback session is given in Appendix G.

5.7.2.2 Monitoring the implementation of the SOMT

As the POSC students of 2000 did the SOMT when they were no longer enrolled for the POSC, some logistics challenges arose. The SOMT questionnaires were mailed only to the 31 POSC students of 2000 who completed the SOM in 2000. Of these 27 replied. Efforts to contact the other four students were unsuccessful. For logistical reasons no feedback was given to the students which is an unsatisfactory outcome for an educational research activity.

During 2001 the administering and feedback of the SOMT were timed appropriately. Feedback was given individually in the last two weeks of the second semester. Students were seemingly interested in comparing their SOM and SOMT profiles. During the interviews they were encouraged to air any concerns they had. Again it seemed that the students appreciated the opportunity of one-on-one contact and the personal feedback. In this way the researcher felt that these final interviews wrapped up participant observation regarding this group of students.

5.7.3 The Herrmann Brain Dominance Instrument (HBDI)

5.7.3.1 Implementing the HBDI in 2000

Research activities concerning the HBDI in 2000 involved the POSC students as well as the freshman civil engineering students of 2000.

The civil engineering students did the HBDI during March 2000 and the POSC students at the end of April. Both groups of students did the HBDI online in a computer laboratory. The data was processed and electronically scored through Herrmann International in the USA.[94]

Feedback on the interpretation of a HBD profile as well as information regarding Herrmann's four quadrant whole brain concept were given to both groups of students separately. The researcher gave the feedback on the HBDI to the civil engineering students at the beginning of the second term (in April) and to the POSC students at the start of the second semester (in mid July). A copy of a thinking preference profile according to HBDI is included in Appendix D.

For the POSC students and the civil engineering students the individual results of the HBDI were used to organise them into groups of four. The aim was that each group should be balanced in terms of the represented quadrants of the Herrmann whole brain model. Such a balance ideally should result that the average profile of the group members represents a profile with evenly balanced preferences in all four quadrants.

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[94] See Chapter 4, section 4.6.6.

5.7.3.2 Monitoring the implementation of the HBDI in 2000

The implementation of the HBDI is a timely process. It is dependent on the availability of computer facilities to do the questionnaire or the questionnaire has to be done as a pen and paper version and the data then entered manually into the electronic system. Processing of the data is, amongst other things, dependent on the electronic connection with the scoring centre in the USA. During 2000 numerous technical problems were experienced in this regard. This eventually led to delay in the feedback to the POSC students.

5.7.4 The Lumsdaine and Lumsdaine learning activity survey (LAS)

5.7.4.1 Implementing the LAS

The research activities concerning the LAS in 2000 involved the POSC students as well as the freshmen civil engineering students of 2000. Both groups of students did the LAS before they were given information on the four-quadrant whole brain concept and before feedback on their results of the HBDI were given. The civil engineering students did the LAS towards the end of the first term (in April) and the POSC students did it at the beginning of the second semester (in mid July). As the LAS is an easy to do, self-scoring instrument, the students completed the LAS as homework and compiled their preference scores. An example of the LAS is attached in Appendix E.

During 2000 feedback on the LAS was given to the POSC students and the civil engineering student groups separately. The researcher gave feedback to the POSC students simultaneously with the feedback on the HBDI. For the civil engineering students the feedback on the LAS was given by their lecturer in the module Practical Orientation.[95]

During 2001 the research activities pertaining to the LAS reported in this thesis only included the POSC students. They had to complete the LAS as homework and submit it to the lecturer (researcher). In the following week the students were asked also to complete the ILS.[96] The lecturer (researcher) made a copy of each student's LAS survey and the ILS for use in follow up consultations with the students. The administering of these instruments was done towards the end of April between the two test weeks in the School of

[95] This module was presented to first year civil engineering students and was aimed at preparing them to function as professionals combining academic and professional proficiency, personal, interpersonal and communication skills. In 2001 the module was replaced by another, Innovation, that has similar focuses.

[96] See section 5.7.4.2.

Engineering. Feedback on these questionnaires was given to the class as a whole and the distribution of preferences for the group was indicated. Feedback was also given to the students individually during the mentioned interviews.

The researcher (lecturer) compiled a feedback sheet[97] for each student that included a photo[98] of the student, a section where the student had to write the results of the ILS and a section where the results of the LAS had to be written. The original copies of the students' completed LAS and the ILS were also handed back. The students transferred the data to his/her feedback sheet where after the researcher (lecturer) discussed the interpretation of the data.

This discussion started with information pertaining to the physical organisation of the human brain and students were introduced to the Herrmann four-quadrant whole brain concept. The information on whole brain utilisation and the different modes of learning according the Lumsdaine and Lumsdaine model[99] were discussed. Then the data for the group as a whole according to the LAS survey and the ILS was discussed. The distribution of learning preferences and learning styles for the class were discussed. Learners' expectations and possible constraints as proposed by the Herrmann model (and as indicated by the LAS) were pointed out using a handout containing the information as in Figure 5-10.

These activities took approximately an hour. Then the students were given a short (10 minute) break. To link the principle of whole brain utilisation to learning and studying the following hour was devoted to information on mind mapping as a study tool.

In addition to the feedback and information session to the class as a whole, feedback was also given to students individually towards the end of the first semester (in May). The lecturer (researcher) compiled a feedback sheet[100] similar to the one mentioned above for use in these interviews. The aim with these interviews was to deliberately make one-to-one contact with all the students; give them feedback on the SOM and integrate all the information presented by the instruments used so that the data made sense to the students.

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97 See Appendix G for an example of the feedback sheet.
98 The lecturer (researcher) compiles a photo class list at the beginning of the year. These are stored electronically and used as needed.
99 See Chapter 3 section 2.5.2
100 See Appendix G for an example.

The students also had the opportunity to communicate with the lecturer on any aspect pertaining to their tertiary environment and experiences to date. Once again the students seemingly appreciated the opportunity of one-to-one communication with the lecturer (researcher).

Figure 5-10 Learners' expectations according to the Herrmann model

Herrmann International (1999a)

5.7.4.2 Monitoring the implementation of the LAS in 2000 and 2001

The LAS survey is easy to administer and to score and students can easily do it on their own. To make the interpretation of LAS meaningful, information regarding the four quadrant whole brain model and the principle of whole brain uitilisation should be given.

5.7.5 The Felder Soloman Index of Learning Styles (ILS)

5.7.5.1 Implementing the ILS in 2001

The ILS was used in the 2001 study only. The students completed the pen and paper version of the ILS as homework and had to submit it the following day. The researcher then checked the students' scoring of the questionnaire and made a copy of each. These were kept as records to be used for feedback to the students as well as for the research reported in this thesis.

Each student's copy of his/her ILS was handed back during a follow up class information session and feedback was done as discussed in section 5.7.4.1 above. In addition to the mentioned feedback each student also got a copy of the explanation sheet (Soloman & Felder, 2001) accompanying the ILS.[101]

5.7.5.2 Monitoring the implementation of the ILS in 2001

The ILS is easy to administer as the questions are well formulated, easily understood and the students can score the ILS themselves. The ILS is also easy to interpret following the reasoning in the accompanying explanation sheet.

The researcher included the ILS instrument in the present study to determine its usefulness in enhancing students' awareness of their learning styles and to create an further awareness that they need to be able to function in all the categories of the ILS.

5.8 Assessing the 2000 and 2001 research

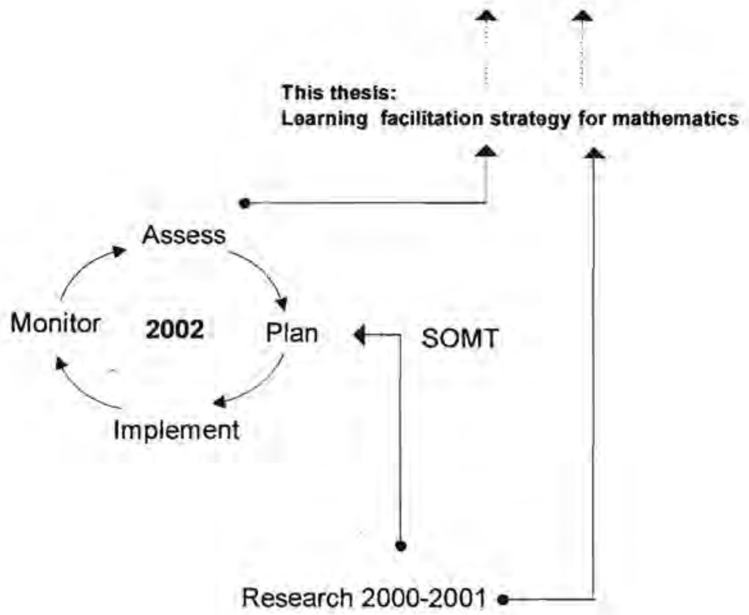
The assessment of the studies comprises the analysis of the research data and the quantitative and qualitative interpretation thereof. The research results are presented in Chapter 6 and discussed in Chapter 7 and the assessment of the 2000 and 2001 studies are included in these discussions.

[101] A copy of the explanation sheet is included in Appendix F.

5.9 The 2002 research

The main aim during the 2002 research was to further refine the adapted SOMT-1. It should, however, be pointed out that the activity of implementing the SOMT as a pre- and post-intervention instrument was totally integrated into the 2002 course activities. Furthermore, the learning facilitation strategy for mathematics, proposed in this thesis, was again implemented in the POSC. For the purpose of this thesis the action research cycle of 2002 concerning the SOMT is briefly discussed in the following sections. The diagram in Figure 5-11 illustrates the action research cycle of 2002.

Figure 5-11 Action research cycle 2002



Compiled by the author of this thesis

5.9.1 Participants of 2002

The POSC class of 2002 comprised 52 students in the first semester of whom 12 are female. During the second semester there were 49 students including the 12 female students. All of the students are black and an African language is the mother tongue of all the students.

At time of writing the average M-score of this group was not available. Records since 1994 indicate that the average M-score of the POSC students is approximately 7 points lower that of the students on the 4YSP and 2-3 points lower than that of the other 5YSP students (Du Plessis, 2002).

Of the 52 students, 28 had had no previous exposure to computers. Nineteen students indicated that they had had previous experience with computers that was limited to introductory usage skills, some word processing and spread-sheet use.[102] Five students indicated that they had computers at home of which two have Internet access. Again none of the students had used a computer for mathematics before.

The SOMT-2 was done by 50 students during March 2002 and 47 students completed the SOMT-3 in August 2002 during the second semester. All 52 students completed the ILS during the first semester.

The identifying attributes of the POSC participants in 2002 are summarised in Table 5-11 on the following page.

[102] Although the students with "limited" computer knowledge indicated that they had skills with regard to word processing and spreadsheet use, the researcher again found during course activities in the second semester of 2002 that none of these students were proficient users of any application program.

Table 5-11 Attributes of the POSC participants of 2002

		Number of students 2002
Male		40
Female		12
Total		52
Mother tongue:		
	African language	52
Language of high school instruction in mathematics:		
		English
Average M-score:		
		Not available
Computer experience prior POSC enrollment:		
	No experience	28
	Limited experience	19
	Experience	5
	Used for mathematics	0
Participation in the:		
	SOMT-2 March 2002	50
	SOMT-3 August 2002	47
	ILS	52

5.9.2 The research activities of 2002

The 2002 research activity addressed the first three research questions stated in Chapter 1 with a particular focus on the first two research questions.[103]

[103] See Chapter 1 section 1.4 and section 5.5.2 of this chapter for detail on the research questions.

5.9.2.1 Planning the research activities of 2002

Similarly as in the research conducted during 2000 and 2001, the scheduling of the action research activities and the course activities during 2002 had to be done in such a way that the administering of the questionnaires for the purposes of the research had to be incorporated into the course activities so that they would be appropriate for the course content and had to be given at a time when students could realise the need thereof and could benefit from the resulting information.

5.9.2.2 Implementing and monitoring the research activities of 2002

Following the same schedule as in 2000 and 2001, the SOMT as a pre-intervention instrument was administered just after the first test week of the School of Engineering in the middle of March 2002. The SOMT as a post-intervention instrument was administered at the beginning of the second semester in August 2002.

Feedback on the SOMT during March was given to the group as a whole and as follows. The fields of the SOMT were explained and each student received a feedback form[104] on which he/she had to draw his/her study orientation profile. Feedback on the SOMT during August was conducted slightly differently and in the following way.

During the second semester a major focus of the POSC is on communication skills and in particular on scientific writing skills. This focus on developing writing skills as well as some analytical skills was incorporated into the follow up on the SOMT in August. Each student received a handout containing his/her SOMT scores of March and August as well as a writing assignment.[105] Again the fields of the SOMT were discussed in class and the students had to draw their two profiles (in class) on the same grid. For homework each student then had to analyse his/her profiles and give possible explanations for improvement/deterioration in their individual study orientation. They also had to reflect on the extent of correctness that the profile(s) give of their study orientation. They were given a week to compile and type the analysis of their study orientation profiles. The assignments were assessed and graded with regard to language use.

[104] Examples of the 2002 feedback forms for March and August are included in Appendix G.
[105] An example of the assignment is included in Appendix G.

5.9.2.3 Assessing the research activities of 2002

For the purpose of the research reported in this study, the written reflection of the students on their own profiles not only encouraged them to really think about their study orientation but also served as a source of information aiding the researcher in the interpretation of the data pertaining to study orientation. Only two students did not submit this written assignment. The results of the SOMT profiles of the 2002 study and the mentioned feedback of the students are given in Chapter 6 and discussed in Chapter 7.

5.10 Summary

In Chapter 5 the research activities during 2000 and 2001 that form the main focus of the present study reported in this thesis are discussed. The research activities are described within the context of the Professional Orientation Support Course of the Five Year Study Programme in the School of Engineering. The action research phases pertaining to the planning, implementation and monitoring of the research are detailed.

The planning phase concerned identifying the research participants, detailing the specific research activities and listing the scheduled activities of the POSC.

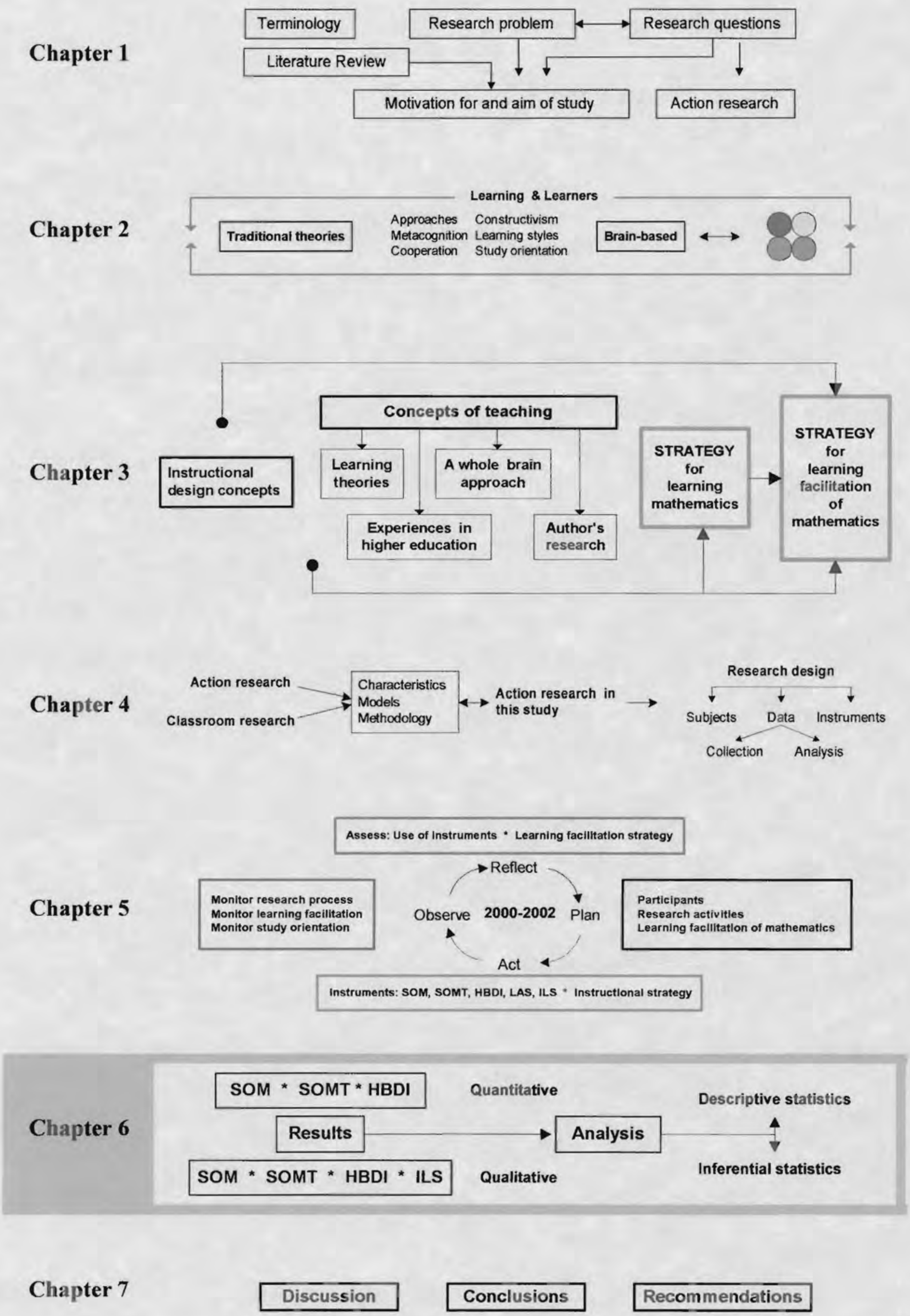
The implementation phase concerned that of the learning facilitation strategy and the research instruments. The implementation of the learning facilitation strategy for mathematics that is proposed in Chapter 3 is discussed in Chapter 5, highlighting the tasks of the facilitator, the instructional media used and how learning is facilitated. The implementation and monitoring of the research instruments are discussed including the Study Orientation Questionnaire in Mathematics and the Study Orientation Questionnaire in Mathematics Tertiary, the Herrmann Brain Dominance Instrument, the Learning Activity Survey and the Felder Solomon Index of Learning Styles.

The research study of 2002 that addressed further adaptations to the Study Orientation Questionnaire in Mathematics Tertiary is also discussed giving details on the planning, implementation and monitoring of the research activities.

In Table 5-12 a summary is given of the research interventions during 2000-2002, the research instruments implemented as well as the relevant statistical procedures used for processing the research results. In Chapter 4 details on the research instruments are given. In Chapter 5 the research interventions are detailed. The statistics of the results are presented and analysed in Chapter 6 and in Chapter 7 the results are further interpreted and discussed.

Table 5-12 Research interventions, research instruments and statistical procedures

	Pre-intervention	Intervention	Post-intervention
	Learning facilitation strategy		
Instruments	SOM SOMT-2	HBDI LAS ILS	SOMT-1 SOMT-3
Statistical procedures	Item analysis Cronbach alpha Regression analysis	Kruskal-Wallis test Pearson correlation	Item analysis Cronbach alpha Wilcoxon test Pearson correlation ANOVA


Chapter 1
Terminology
Research problem
Research questions
Literature Review
Motivation for and aim of study
Action research
Chapter 2
Learning & Learners
Traditional theories
Approaches
Metacognition
Cooperation
Constructivism
Learning styles
Study orientation
Brain-based
Chapter 3
Concepts of teaching
Instructional design concepts
Learning theories
A whole brain approach
Experiences in higher education
Author's research
STRATEGY for learning mathematics
STRATEGY for learning facilitation of mathematics
Chapter 4
Action research
Classroom research
Characteristics
Models
Methodology
Action research in this study
Research design
Subjects
Data
Instruments
Collection
Analysis
Chapter 5
Assess: Use of instruments * Learning facilitation strategy
Monitor research process
Monitor learning facilitation
Monitor study orientation
Reflect
Observe
2000-2002
Plan
Act
Participants
Research activities
Learning facilitation of mathematics
Instruments: SOM, SOMT, HBDI, LAS, ILS * Instructional strategy
Chapter 6
SOM * SOMT * HBDI
Quantitative
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Results
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SOM * SOMT * HBDI * ILS
Qualitative
Inferential statistics
Chapter 7
Discussion
Conclusions
Recommendations

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Results and analysis

6.1 Validity and reliability of the Study Orientation Questionnaire in Mathematics Tertiary

6.2 Results:
- Study Orientation Questionnaire in Mathematics
- Study Orientation Questionnaire in Mathematics Tertiary

6.3 Comparing means of pre- and post-intervention scores on the SOM/SOMT

6.4 Comparing groups regarding differences in means of pre- and post-intervention scores on the SOM/SOMT

6.5 Academic performance in mathematics

6.6 Results: Herrmann Brain Dominance Instrument

6.7 Results: Lumsdaine and Lumsdaine Learning Activity Survey

6.8 Results: Felder Soloman Index of Learning Styles

6.9 Participant observation: feedback

6.10 Summary

Chapter 6

Results and analysis

6. Introduction

In Chapter 4 the research design of the present study and the procedures for the processing and reporting of the research data were discussed. The results of the study are presented in this chapter and analysis of the data given. This will be conducted as follows:

Firstly the results of item analyses of the Study Orientation Questionnaire in Mathematics Tertiary (SOMT) are given.

Then the results pertaining to the Study Orientation Questionnaire in Mathematics (SOM) and the Study Orientation Questionnaire in Mathematics Tertiary (SOMT) are given. The analysis of these results is done referring to the arithmetic mean, standard deviation and coefficient of variation. The data is given for the 2000, 2001 and 2002 POSC groups respectively.

The results of regression analysis are then given considering the relationship between the different fields of the SOM as a pre-intervention instrument and performance in the standard first semester calculus course for the 2000 and 2001 POSC groups. Results of regression analysis are also given regarding the relationship between the different fields of the SOMT as a pre-intervention instrument and performance in the standard first semester calculus course for the 2002 POSC group.

Correlations between mathematics performance and the different fields of the SOMT as post-intervention instrument are given for the 2000, 2001 and 2002 POSC groups respectively.

The difference between the scores in the fields of the Study Orientation Questionnaire in Mathematics at course beginning and at course end is compared for each of the 2000, 2001 and 2002 POSC groups separately. Then one-way analysis of variance is done to compare the differences in the arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics as pre- and post-intervention instruments between the mentioned three POSC groups.

The means and standard deviations regarding the marks obtained in a first semester calculus course are given for the 2000, 2001 and 2002 POSC groups, the other students on the I and the engineering students on the regular 4YSP.

Then the results of the Herrmann Brain Dominance Instrument (HBDI) concerning students' thinking style preferences are given. These results include those of the 2000 POSC students and the first year civil engineering students of 2000 as well as that of a group of first year science students who did the HBDI during 1999.

The possible relationship between the results of the HBDI and the Lumsdaine and Lumsdaine learning activity survey (LAS) is considered concerning the 2000 POSC students and the first year civil engineering students of 2000.

Results regarding the Felder Soloman Index of Learning Styles (ILS) are qualitatively analysed for the 2001 and 2002 POSC groups.

A summary is given of aspects, identified by the POSC students themselves, that influence study orientation toward mathematics either positively or negatively.

Regarding the meaningfulness of results, McMillan and Schumacher (2001) remark that results should be *educationally significant, not just statistically significant* and that statistical significance does not necessarily imply educational significance. They also point out that meaningfulness is related to the specifics of a situation and that results are meaningful if they make a difference in the real world (McMillan & Schumacher, 2001:367). In the interpretation of the statistics regarding the research reported in this thesis, the mentioned views of McMillan and Schumacher are acknowledged.

For the purposes of the statistical conclusions in the current study, the Neyman-Pearson view on the results of an experiment is acknowledged. According to Howell (1997:94), in the Neyman-Pearson position one either rejects or *accepts* the null-hypothesis. *When we say that we "accept" a null-hypothesis ... we do not mean that we take it to be proven as true. We simple mean that we act as if it is true, at least until we have more adequate data.*

Phrases such as "retain the null hypothesis" and "fail to reject the null hypothesis" ... make clear the tentative nature of a nonrejection. (Howell, 1997:94).

Regarding the significance level of statistical results, Howell (1997:97) remarks that the opinion exists that more attention should be paid to the probability value itself and that in this alternative view one would think of $p = .051$ as "*nearly significant*" and of $p = .003$ as "*very significant*". In the assessment of the statistical results presented in the current study the significance level (rejection level) is taken as 5% throughout.

In the present study a distinction is made between a research hypothesis and statistical hypothesis. The convention is followed that in the case of a research hypothesis the expected outcome is stated and in the case of a statistical hypothesis a null hypothesis (H_0) and an alternative hypothesis (H_A) are stated.

6.1 Validity and reliability of the Study Orientation Questionnaire in Mathematics Tertiary (SOMT)

6.1.1 Validity of the SOMT: Item analysis

In order to determine the merit of the items in the SOMT for use with first year tertiary students on a support programme, three item analyses were performed on the 92 items of the SOMT. The ITEMAN™ Version 3.5 (ITEMAN ™, 1993) was used. In this study an item field correlation value of $r_{IF} \geq 0.30$ is regarded as a good value and a value of $0.20 \leq r_{IF} < 0.30$ is regarded a acceptable (Huysamen, 1996; Owen, 1995).

When analysing item test correlations, it should be borne in mind that a high item test correlation does not necessarily ensures content validity whereas a low item test correlation does not imply failure of the test. In this regard Cronbach (1971:457) remarks that

> *Low item correlations do not necessarily imply failure of the test content to fit the definition. Indeed, if the heterogeneous, consistently high intercorrelations imply inadequate sampling ... when the test constructor routinely discards the items whose intercorrelations with the total score for the pool are low, he risks making the tests less representative of the defined universe.*

As the SOMT is primarily based on the SOM the content validity of the SOMT is assumed *a priori*. Maree (2000) and Claassen (2001) who were involved in compiling the original SOM agree that the validity of the SOMT can be accepted for use with first year tertiary students. However, the three item analyses were carried out to ensure that the changes which had been made to the wording of some of the questions[106] properly convey the meaning of the questions as intended.

In Table 6-1 the final item analysis for the SOMT-1[107] is given for the 2000 and 2001 POSC groups combined. In Table 6-2 the item analysis for the SOMT-2 for the 2002 POSC group is given and in Table 6-3 the item analysis for the SOMT-3 for the 2002 POSC group is given.

Table 6-1 Final item analysis of the SOMT for the POSC 2000 and 2001 groups combined (N=61)

		Scale (% endorsing)							
Field	Item	0	1	2	3	4	Mean	Variance explained	Item field correlation
1	1	0	5	15	38	43	4.180	0.738	0.64
Study attitude	6	0	0	5	33	62	4.574	0.343	0.59
	16	0	5	7	43	46	4.295	0.634	0.47
	21	0	2	8	15	75	4.639	0.493	0.49
	28	0	5	5	33	57	4.426	0.638	0.60
	33	0	0	3	26	73	4.672	0.286	0.42
	38	0	10	15	38	38	4.033	0.917	0.38
	43	8	25	15	36	16	3.279	1.512	0.70
	48	3	11	5	36	44	4.066	1.242	0.56
	55	13	16	20	30	21	3.295	1.749	0.46
	60	13	16	23	31	16	3.213	1.610	0.44
	65	0	15	11	25	49	4.082	1.190	0.34
	70	0	10	23	31	36	3.934	0.979	0.57

[106] See Chapter 4, Section 4.6.5 for details on the adaptation of the SOM to the SOMT.
[107] The different versions of the SOMT are discussed in Chapter 4.

		Scale (% endorsing)							
Field	Item	0	1	2	3	4	Mean	Variance explained	Item field correlation
2	2	3	2	16	46	33	4.033	0.851	0.45
Mathematic confidence	7	3	11	16	33	36	3.869	1.261	0.47
	12	3	8	7	31	51	4.180	1.164	0.46
	17	2	7	10	38	44	4.164	0.924	0.35
	22	2	2	7	8	82	4.672	0.647	0.48
	29	10	8	8	30	44	3.902	1.728	0.69
	34	13	18	16	28	25	3.328	1.860	0.55
	39	5	10	21	25	39	3.836	1.416	0.62
	56	2	0	3	3	92	4.836	0.399	0.32
	61	5	31	21	39	3	3.049	1.030	0.53
	66	0	5	3	16	75	4.623	0.596	0.35
	71	28	23	8	18	23	2.852	2.421	0.55
3	3	2	10	25	28	36	3.869	1.130	0.50
Study habits	8	2	30	20	31	18	3.344	1.275	0.59
	13	3	7	10	31	49	4.164	1.121	0.58
	18	0	18	10	36	36	3.902	1.171	0.47
	23	10	28	21	33	8	3.016	1.328	0.63
	27	0	3	7	34	56	4.426	0.572	0.63
	30	0	8	8	30	54	4.295	0.864	0.65
	35	0	10	13	28	49	4.164	0.990	0.62
	40	0	13	13	38	36	3.967	1.015	0.64
Study habits	45	5	20	21	38	16	3.410	1.258	0.43
	50	23	30	16	18	13	2.689	1.821	0.54
	54	0	16	15	36	33	3.852	1.109	0.65
	57	3	11	10	28	48	4.049	1.325	0.58
	62	1	3	18	48	23	3.787	0.987	0.63
	67	8	11	23	30	28	3.574	1.523	0.27
	72	2	13	25	30	31	3.754	1.169	0.63
	74	2	8	15	39	46	4.098	1.072	0.69
4	4	7	38	18	26	11	2.984	1.360	0.65
Problem solving behaviour	9	7	23	25	28	18	3.279	1.414	0.69
	14	0	8	21	59	11	3.783	0.587	0.59
	19	2	10	23	34	31	3.836	1.055	0.69
	24	8	26	18	33	15	3.197	1.469	0.25
	26	0	10	11	46	33	4.016	0.836	0.56
	31	5	18	21	51	5	3.328	0.974	0.58
	36	15	34	26	21	3	2.639	1.149	0.65
	41	7	13	16	39	25	3.623	1.382	0.64

		Scale (% endorsing)							
Field	**Item**	**0**	**1**	**2**	**3**	**4**	**Mean**	**Variance explained**	**Item field correlation**
Problem solving behaviour	46	2	10	23	34	31	3.836	1.055	0.71
	51	3	16	21	30	30	3.656	1.340	0.52
	53	0	3	3	23	70	4.607	0.501	0.47
	58	21	28	16	21	13	2.770	1.816	0.56
	63	15	30	15	26	15	2.967	1.737	0.70
	68	30	33	16	15	7	2.361	1.509	0.58
	75	0	15	15	31	39	3.951	1.129	0.71
5	10	8	15	7	33	38	3.770	1.718	0.55
Study environment	15	11	15	25	26	23	3.344	1.668	0.58
	20	2	3	7	18	70	4.525	0.774	0.41
	25	23	34	10	20	13	2.656	1.865	0.57
	37	3	2	2	7	87	4.721	0.726	0.29
	42	2	3	3	30	62	4.475	0.708	0.43
	47	0	0	3	41	56	4.525	0.315	0.35
	52	3	15	11	33	38	3.869	1.360	0.68
	59	2	7	5	44	43	4.197	0.847	0.22
	64	3	7	8	28	54	4.230	1.128	0.48
	69	3	2	15	34	46	4.180	0.935	0.44
6	77	5	8	20	56	11	3.607	0.927	0.44
Information processing	79	3	8	23	43	23	3.738	1.013	0.36
	80	5	18	15	54	8	3.426	1.064	0.37
	81	3	11	16	46	23	3.738	1.079	0.45
	82	2	7	16	46	30	3.951	0.866	0.66
	83	3	31	18	28	20	2.295	1.421	0.41
	84	0	5	10	41	44	4.246	0.677	0.52
	85	3	15	33	26	23	3.508	1.201	0.47
	86	0	5	10	48	38	4.180	0.640	0.47
	87	0	7	15	46	33	4.049	0.735	0.68
	88	0	7	18	51	25	3.934	0.684	0.57
	89	0	2	3	36	59	4.525	0.413	0.56
	90	8	16	25	34	16	3.344	1.373	0.43
	91	0	3	2	31	64	4.557	0.476	0.36
	92	11	20	26	38	5	3.049	1.227	0.55

The item analysis presented in Table 6-1 was analysed and questions 11, 32, 44 and 49 had field correlation values $r_{IF} < 0.20$. These questions were carefully considered in order to ascertain possible reasons for the low correlation values. Question 11 was left unchanged. The wording of questions 32, 44 and 49 were adapted. These changes are detailed in Chapter 4 Table 4-14. These adjustments were implemented in the SOMT-2. The item analysis of the SOMT-2 is given in Table 6-2.

Table 6-2 Item analysis of the SOMT-2 for the 2002 POSC group (N=50)

		Scale (% endorsing)							
Field	**Item**	**0**	**1**	**2**	**3**	**4**	**Mean**	**Variance explained**	**Item field correlation**
1	1	0	8	16	34	42	4.100	0.890	0.56
Study attitude	6	2	2	6	36	54	4.380	0.716	0.35
	11	4	4	6	18	68	4.420	1.084	0.20
	16	4	4	10	20	62	4.320	1.138	0.47
	21	2	0	2	18	78	4.700	0.490	0.39
	28	2	0	0	24	74	4.680	0.458	0.16
	33	0	2	2	28	68	4.620	0.396	0.28
	38	6	12	20	26	36	3.740	1.512	0.39
	43	12	12	16	34	26	3.500	1.730	0.62
	48	6	10	6	18	60	4.160	1.574	0.55
	55	6	16	10	44	24	3.640	1.390	0.37
	60	2	6	6	50	36	4.012	0.826	0.35
	65	2	10	10	40	38	4.020	1.060	0.46
	70	0	0	10	30	60	4.500	0.450	0.19
2	2	2	14	12	58	14	3.680	0.898	0.46
Mathematic confidence	7	2	14	32	20	32	3.660	1.264	0.30
	12	2	12	0	34	52	40220	1.132	0.37
	17	2	10	12	28	48	4.100	1.170	0.50
	22	2	4	4	16	74	4.560	0.806	0.48
	29	8	22	10	24	36	3.580	1.884	0.42
	34	18	16	26	28	12	3.000	1.640	0.66
	39	12	10	12	34	32	3.640	1.790	0.54
	44	0	0	4	12	84	4.800	0.240	0.34
	49	0	0	4	20	76	4.720	0.282	0.18
	56	4	6	2	14	74	4.480	1.130	0.32
	61	4	20	38	38	0	3.100	0.730	0.44
	66	0	2	10	20	68	4.540	0.568	0.43
	71	22	24	10	14	30	3.060	2.456	0.44

Field	Item	Scale (% endorsing) 0	1	2	3	4	Mean	Variance explained	Item field correlation
3	3	2	8	12	40	38	4.040	0.998	0.44
Study habits	8	12	12	24	28	24	3.400	1.680	0.64
	13	0	2	2	20	76	4.700	0.370	0.44
	18	0	8	12	44	36	4.080	0.794	0.47
	23	8	10	20	38	24	3.600	1.400	0.60
	27	0	0	8	20	72	4.640	0.390	0.25
	30	0	2	6	26	66	4.560	0.486	0.39
	35	0	4	4	42	50	4.380	0.556	0.29
	40	2	10	14	20	54	4.140	1.240	0.51
Study habits	45	4	16	10	34	36	3.820	1.428	0.58
	50	24	24	14	24	14	2.800	1.960	0.51
	54	2	2	22	38	36	4.040	0.838	0.58
	57	2	0	12	30	56	4.380	0.716	0.63
	62	4	6	18	42	30	3.880	1.066	0.53
	67	8	18	12	28	34	3.620	1.756	0.67
	72	10	8	20	48	14	3.480	1.290	0.58
	74	0	4	10	42	44	4.260	0.632	0.61
4	4	10	26	22	30	12	3.080	1.434	0.70
Problem solving behaviour	9	6	24	26	30	14	3.220	1.292	0.63
	14	2	6	18	58	16	3.800	0.720	0.48
	19	8	4	8	46	34	3.940	1.296	0.65
	24	10	26	12	028	24	3.300	1.810	0.29
	26	0	4	10	26	60	4.420	0.684	0.53
	31	4	22	22	42	10	3.320	1.098	0.42
	36	22	32	20	20	6	2.560	1.446	0.64
	41	4	2	24	28	42	4.020	1.100	0.32
	46	2	6	12	36	44	4.140	0.960	0.50
	51	8	12	16	32	32	3.680	1.578	0.45
	53	0	4	2	18	76	4.660	0.504	0.09
	58	6	34	18	18	24	3.200	1.680	0.45
	63	8	26	18	32	16	3.220	1.492	0.67
	68	24	30	14	22	10	2.640	1.750	0.57
	73	2	8	16	38	36	3.980	1.020	0.22
	75	2	2	12	54	30	4.080	0.674	0.46
	76	6	6	18	34	36	3.880	1.306	0.19

Field	Item	Scale (% endorsing)					Mean	Variance explained	Item field correlation
		0	1	2	3	4			
5	5	2	4	2	30	62	4.460	0.768	0.38
Study environment	10	6	16	6	32	40	3.840	1.614	0.66
	15	18	16	16	30	20	3.180	1.948	0.53
	20	2	0	6	26	66	4.540	0.608	0.65
	25	28	28	14	20	10	2.560	1.806	0.45
	32	2	2	4	12	80	4.660	0.664	0.42
	37	2	6	10	16	66	4.380	1.036	0.50
	42	0	4	8	24	64	4.480	0.650	0.59
	47	0	4	8	28	60	4.440	0.646	0.28
	52	6	8	8	38	40	3.980	1.340	0.65
	59	0	12	6	42	40	4.100	0.930	0.29
	64	4	4	6	32	54	4.280	1.042	0.50
	69	4	8	8	38	42	4.060	10176	0.37
6	77	4	8	10	56	22	3.840	0.974	0.51
Information processing	78	4	2	24	52	18	3.780	0.812	0.38
	79	2	2	10	42	44	4.240	0.742	0.50
	80	2	16	14	46	22	3.700	1.090	0.54
	81	2	18	18	42	20	3.600	1.120	0.43
	82	2	2	14	52	30	4.060	0.696	0.66
	83	8	16	24	36	16	3.360	1.350	0.44
	84	4	2	6	38	50	4.280	0.922	0.63
	85	6	10	28	26	30	3.640	1.390	0.43
	86	0	4	10	52	34	4.160	0.574	0.69
	87	2	4	16	52	26	3.960	0.758	0.56
	88	0	2	14	58	26	4.080	0.474	0.64
	89	0	2	4	32	62	4.540	0.448	0.64
	90	6	8	18	40	28	3.760	1.262	0.47
	91	0	0	8	24	68	4.600	0.400	0.50
	92	20	18	32	24	6	2.780	1.412	0.70

Again the results of the item analysis presented in Table 6-2 were analysed. No questions were removed, but changes were made to the wording of questions 11 and 49. These changes are detailed in Chapter 4 Table 4-12. These adjustments were implemented in the SOMT-3.

The item analysis of the SOMT-3 is given in Table 6-3.

Table 6-3 Item analysis of the SOMT-3 for the 2002 POSC group (N=48)

		Scale (% endorsing)							
Field	**Item**	**0**	**1**	**2**	**3**	**4**	**Mean**	**Variance explained**	**Item field correlation**
1	1	0	0	9	43	49	4.404	0.411	0.75
Study attitude	6	2	2	4	19	72	4.574	0.713	0.27
	11	2	0	2	28	68	4.596	0.539	0.25
	16	0	9	6	32	53	4.298	0.847	0.49
	21	2	0	6	17	74	4.617	0.619	0.36
	28	2	0	6	28	64	4.511	0.633	0.30
	33	0	0	9	19	72	4.638	0.401	0.65
	38	0	4	21	40	34	4.043	0.722	0.34
	43	4	2	23	49	21	3.809	0.878	0.47
	48	0	11	4	34	51	4.255	0.914	0.71
	55	4	6	23	49	17	3.681	0.941	0.30
	60	4	15	21	30	30	3.660	1.373	0.70
	65	2	9	4	36	49	4.213	1.019	0.48
	70	0	2	9	36	53	4.404	0.539	0.38
2	2	0	4	11	43	43	4.234	0.674	0.47
Mathematic confidence	7	0	11	17	38	34	3.957	0.934	0.22
	12	4	2	6	36	51	4.277	0.966	0.19
	17	2	9	2	40	47	4.213	0.976	0.55
	22	2	4	4	6	83	4.638	0.827	0.47
	29	9	6	9	26	51	4.043	10615	0.49
	34	6	13	17	45	19	3.574	1.266	0.61
	39	4	9	13	47	28	3.851	1.105	0.50
	44	2	0	0	17	81	4.745	0.445	0.47
	49	0	4	9	28	60	4.426	0.670	0.49
	56	0	4	0	19	77	4.681	0.473	0.29
	61	6	19	26	45	4	3.213	1.019	0.29
	66	2	0	6	30	62	4.489	0.633	0.44
	71	19	19	6	19	36	3.340	2.480	0.58
3	3	0	2	4	34	60	4.511	0.463	0.48
Study habits	8	0	9	23	40	28	3.872	0.835	0.48
	13	2	0	9	30	60	4.447	0.673	0.51
	18	0	6	15	34	45	4.170	0.822	0.41
	23	6	11	19	40	23	3.638	1.295	0.65
	27	0	0	2	26	72	4.702	0.252	0.40
	30	0	2	4	32	62	4.532	0.462	0.47
	35	2	2	15	34	47	4.213	0.848	0.66
	40	2	4	9	34	51	4.277	0.881	0.71

Field	Item	Scale (% endorsing)					Mean	Variance explained	Item field correlation
		0	1	2	3	4			
Study habits	45	2	9	9	40	40	4.085	1.014	0.43
	50	13	9	21	43	15	3.383	1.470	0.50
	54	2	9	21	40	28	3.830	0.992	0.52
	57	4	2	9	28	57	4.319	1.026	0.39
	62	0	9	15	23	53	4.213	0.976	0.47
	67	4	17	17	28	34	3.702	1.486	0.51
	72	2	4	17	34	43	4.106	0.946	0.62
	74	0	4	15	30	51	4.277	0.753	0.60
4	4	6	32	30	23	9	2.957	1.147	0.76
Problem solving behaviour	9	4	26	28	36	6	3.149	1.020	0.57
	14	2	11	26	43	19	3.660	0.948	0.39
	19	2	6	9	53	30	4.021	0.829	0.48
	24	9	15	21	34	21	3.447	1.481	0.38
	26	0	2	6	40	51	4.404	0.496	0.43
	31	11	19	17	40	13	3.255	1.467	0.53
	36	11	32	23	28	6	2.872	1.260	0.69
	41	0	2	6	36	55	4.447	0.502	0.19
	46	0	0	17	45	38	4.213	0.508	0.47
	51	4	6	11	21	57	4.213	1.274	0.43
	53	0	2	9	11	79	4.660	0.522	0.22
	58	13	17	13	45	13	3.277	1.562	0.63
	63	6	19	17	34	23	3.489	1.484	0.72
	68	17	21	23	17	21	3.043	1.913	0.48
	73	4	2	15	47	32	4.000	0.936	0.34
	75	2	7	20	37	35	3.957	0.998	0.71
	76	2	0	15	43	40	4.191	0.708	0.25
5	5	2	9	4	32	53	4.255	1.041	0.38
Study environment	10	6	6	9	34	45	4.043	1.360	0.37
	15	6	6	9	34	45	4.043	1.360	0.76
	20	2	4	0	23	70	4.533	0.785	0.52
	25	9	30	28	13	21	3.085	1.610	0.68
	32	2	0	0	19	79	4.723	0.455	0.24
	37	2	2	4	28	64	4.489	0.718	0.34
	42	2	0	0	26	72	4.4660	0.480	0.45
	47	0	0	2	55	43	4.404	0.283	0.33
	52	2	6	19	30	43	4.043	1.062	0.69
	59	0	6	9	53	32	4.106	0.648	0.53
	64	6	9	2	19	64	4.255	1.509	0.68
	69	6	2	9	26	57	4.255	1.254	0.39

Field	Item	Scale (% endorsing) 0	1	2	3	4	Mean	Variance explained	Item field correlation
6	77	2	9	13	53	23	3.872	0.877	0.55
Information processing	78	2	4	21	40	32	3.957	0.892	0.53
	79	0	4	17	34	45	4.191	0.751	0.47
	80	6	4	9	60	21	3.851	1.020	0.19
	81	2	11	11	34	43	4.043	1.147	0.67
	82	4	4	9	38	45	4.149	1.063	0.72
	83	4	21	23	32	19	3.404	1.305	0.43
	84	0	4	0	38	57	4.489	0.505	0.53
	85	2	17	11	28	43	3.915	1.139	0.53
	86	2	4	4	40	49	4.289	0.805	0.42
	87	0	4	17	34	45	4.191	0.751	0.66
	88	2	4	13	49	32	4.043	0.807	0.54
	89	0	2	4	34	60	4.511	0.463	0.57
	90	6	9	11	43	32	3.851	1.318	0.35
	91	0	2	0	32	66	4.617	0.364	0.35
	92	13	9	19	49	11	3.362	1.380	0.61

The results of the item analysis presented in Table 6-3 indicate that the questions, which were adapted[108] from the previous version of the questionnaire, loaded well in the respective fields. Two questions (numbers 41 and 80) did not discriminate well although they loaded well in the respective fields of the previous item analyses (see Table 6-1 and Table 6-2).

Regarding question 41 in the field Problem solving behaviour, most of the students chose the option, 'almost always'. This choice could be expected if one considers that the interventions of the learning facilitation strategy followed in the POSC are successful. Regarding question 80 in the field Information processing, most of the students chose the option 'generally'. Again this choice is reasonable as one expects that the learners involved in the interventions of the POSC should realise that they have to prepare for their mathematics tests.

[108] The adaptations are listed in Table 4-11 to Table 4-15.

6.1.2 Reliability of the SOMT

The reliabilities of the different fields of the SOMT were determined with the Cronbach alpha coefficients. In Table 6-4 the Cronbach alpha coefficients for the fields of the three versions of the SOMT are given. The SOMT-1 was used as a post-intervention instrument (at the beginning of the POSC) with the 2000 and 2001 POSC groups. The SOMT-2 was used as a pre-intervention instrument (at the beginning of the POSC) with the 2002 POSC group and the SOMT-3 was used as a post-intervention instrument (after the POSC) with the 2002 POSC group.

Table 6-4 Cronbach alpha coefficients for the fields of the SOMT

	SOMT-1	SOMT-2	SOMT-3
Field	**N=61**	**N=50**	**N=47**
1 Study attitude (SA)	0.576 (≈0.6)	0.576 (≈0.6)	0.711 (≈0.7)
2 Mathematics confidence (MC)	0.654 (≈0.7)	0.654 (≈0.7)	0.664 (≈0.7)
3 Study habits (SH)	0.828 (≈0.8)	0.828 (≈0.8)	0.825 (≈0.8)
4 Problem solving behaviour (PSB)	0.783 (≈0.8)	0.783 (≈0.8)	0.813 (≈0.8)
5 Study environment (SE)	0.721 (≈0.7)	0.721 (≈0.7)	0.747 (≈0.7)
6 Information processing (IP)	0.827 (≈0.8)	0.827 (≈0.8)	0.802 (≈0.8)

According to the data in Table 6-4 the Cronbach alpha coefficients range between 0.6 and 0.8, for the fields of the SOMT-1 and the SOMT-2 and between 0.7 and 0.8 and for the fields of the SOMT-3. The value of the coefficients can be regarded as acceptable for the purpose for which the questionnaire was used. Although McMillan and Schumacher (2001) remark that one should be wary of reliabilities below 0.7 they point out that several factors should be considered when interpreting reliability coefficients. According to them, reliability is higher if a group is more heterogeneous regarding the trait that is measured; if the number of items in a instrument is high; if the range of scores is substantially large and if items discriminate between high and low achievement (McMillan & Schumacher, 2001:247-248).

Using McMillan and Schumacher's guideline for the minimum value of reliabilities, it is clear from Table 6-4 that in the final version of the SOMT (SOMT-3), as adapted and used in this research, all the fields comply with McMillan and Schumacher's (2001) minimum Cronbach alpha coefficient value of 0.7.

In Table 6-5 the main research hypotheses together with the sections in this chapter in which they are treated are listed.

Table 6-5 Section references where the main research hypotheses are treated

	Main research hypothesis	Chapter section
1	A relationship exists between the fields of the Study Orientation Questionnaire in Mathematics and performance in the standard first semester course in calculus.	6.2
2	Significant differences exist between the arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics at the beginning of the POSC and after the POSC.	6.4
3	No significant differences exist between the means of the fields of the Study Orientation Questionnaire in Mathematics as pre- and post-intervention instruments between the different groups.	6.5
4	The average mark achieved by the POSC group in a standard first semester calculus course is higher than the average mark of students not enrolled for the POSC.	6.3
5	The thinking style preferences of first year engineering students enrolled for a support course represent preferences distributed across all four quadrants of the Herrmann whole brain model.	6.6

In Table 6-6 on the following pages an overview is given of the research questions, the relevant research hypotheses, the details of the individual sub-hypotheses and the numbers by which the statistical hypotheses are treated in this chapter as well as the statistical information pertaining to the investigation of each of the hypotheses.

Table 6-6 Research questions and relevant research hypotheses

Research question	Main hypothesis	Sub-hypothesis	Number	Independent variables	Dependent variables	Statistical procedure
Research question 1: What is the study orientation towards mathematics of the students enrolled for the POSC? **Research question 2:** Does the learning facilitation strategy followed in the POSC have an effect on the students' study orientation in mathematics? In particular, is there an improvement in the students' study orientation towards mathematics?	**Main hypothesis 1:** A relationship exists between the fields of the Study Orientation Questionnaire in Mathematics and performance in the standard first semester course in calculus.	The scores in the different fields of the SOM can be regarded as predictors of students' marks in mathematics	H1-1	Scores in the different fields of the SOM	Mark in the standard first semester course in calculus for the 2000 POSC group 2001 POSC group	Regression analysis
		The scores in the different fields of the SOMT can be regarded as predictors of students' marks in mathematics	H1-2	Scores in the different fields of the SOMT	Mark in the standard first semester course in calculus for the 2002 POSC group	Regression analysis
		Significant correlations exist between the different fields of the SOMT and the performance in the standard first semester course in calculus.	H1-3	Scores in the different fields of the SOMT	Mark in the standard first semester course in calculus for the 2000 POSC group 2001 POSC group 2002 POSC group	Pearson correlation

Table 6-6 continues on the next page.

Table 6-6 Research questions and relevant research hypotheses (continued)

Research question	Main hypothesis	Sub-hypothesis	Number	Group	Variable	Statistical procedure
Research question 1: What is the study orientation towards mathematics of the students enrolled for the POSC?	**Main hypothesis 2:** Significant differences exist between the arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics at the beginning of the POSC and after the POSC.	None	H2	2000 POSC 2001 POSC 2002 POSC	Arithmetic means for the different fields of the SOM/SOMT	Wilcoxon test
Research question 2: Does the learning facilitation strategy followed in the POSC have an effect on the students' study orientation in mathematics? In particular, is there an improvement in the students' study orientation towards mathematics?	**Main hypothesis 3:** No significant differences (post- minus pre-intervention) exist in the means of the three POSC groups for the fields of the Study Orientation Questionnaire in Mathematics.	None	H3	2000 POSC 2001 POSC 2002 POSC	Differences between the arithmetic means of the different fields of the SOM/SOMT	ANOVA

Table 6-6 continues on the next page.

Table 6-6 Research questions and relevant research hypotheses (continued)

Research question	Main hypothesis	Sub-hypothesis	Number	Group	Variable	Statistical procedure
Research Question 3: Does the learning facilitation strategy for mathematics followed in the POSC have an effect on students' academic performance in the standard first semester calculus course?	**Main hypothesis 4:** The average mark achieved by the POSC group in a standard first semester calculus course is higher than the average mark of students not enrolled for the POSC.	None		2000 POSC 2000 Other 5YSP 2000 4YSP 2001 POSC 2001 4YSP 2001 Other 5YSP 2002 POSC 2002 4YSP 2002 Other 5YSP	Performance in the first semester course in calculus	Mean, standard deviation

Table 6-6 continues on the next page.

Table 6-6 Research questions and relevant research hypotheses (continued)

Research question	Main hypothesis	Sub-hypothesis	Number	Group	Variables	Statistical procedure
Research question 4: What are the thinking style preferences of first year engineering students enrolled for the POSC?	**Main hypothesis 5:** The thinking style preferences of first year engineering students enrolled for a support course represent preferences distributed across all four quadrants of the Herrmann whole brain model.	Differences exist in the arithmetic means of the scores for the quadrants of the HBDI between the POSC group, the civil engineering group and science students on a support course.	H4	2000 POSC 2000 First year civil engineering students 1999 First year science students	Different quadrants of the HBDI	Kruskal-Wallis test
		Significant correlations exist between the quadrants of the HBDI and the corresponding sections of the LAS		2000 POSC 2000 First year civil engineering students	Different quadrants of the HBDI Different sections of the LAS	Pearson correlation

6.2 Results: SOM and the SOMT

6.2.1 Descriptive statistics: Mean and standard deviation

Table 6-7 gives the arithmetic mean ($\bar{x}$), standard deviation (s) and coefficient of variation ($cv = \frac{s}{\bar{x}} \times 100\,\%$) regarding the SOM as a pre-intervention instrument and the SOMT-1 as a post-intervention instrument for the 2000 POSC group. Table 6-8 gives the same data for the 2001 POSC group. In Table 6-9 the same data regarding the SOMT-2 as a pre-intervention instrument and the SOMT-3 as a post-intervention instrument for the 2002 POSC group is given. The data was statistically processed using the SAS program, Version 8 (SAS, 1990).

Regarding the processing of the scores on the different fields of the questionnaires, the following should be noted. The arithmetic means are given as the means of percentile ranks.[109] In addition to the standard deviation, the coefficient of variation was used as a relative measure to investigate the precision of the arithmetic mean in order to determine the density of the values around the mean. A relatively large value for the coefficient of variation indicates less precision denoting that the scores are less dense around the arithmetic mean.

[109] See Chapter 4 section 4.6.4 for information on the percentile ranking and the scoring of the SOM/SOMT.

Table 6-7 The arithmetic mean, standard deviation and coefficient of variation regarding the SOM/SOMT for the 2000 POSC group

	2000 POSC					
	SOM (Pre-intervention) (N=30)			SOMT-1 (Post-intervention) (N=26)		
Fields of the SOM	Arithmetic mean $\bar{x}$	Standard deviation s	Coefficient of variation $cv\%$	Arithmetic mean $\bar{x}$	Standard deviation s	Coefficient of variation $cv\%$
1 Study attitude	67.73	25.42	37.53	60.88	25.09	41.21
2 Mathematics confidence	44.96	26.63	59.23	59.11	28.23	47.76
3 Study habits	56.96	26.51	46.54	57.53	28.69	49.87
4 Problem solving behaviour	63.96	27.27	42.64	68.26	28.71	42.06
5 Study environment	46.13	21.29	46.15	51.80	26.17	50.52
6 Information processing	70.60	20.35	28.78	70.38	23.41	33.26

Table 6-8 The arithmetic mean, standard deviation and coefficient of variation regarding the SOM/SOMT for the 2001 POSC group

	2001 POSC					
	SOM (Pre-intervention) (N=38)			SOMT-1 (Post-intervention) (N=36)		
Fields of the SOM	Arithmetic mean $\bar{x}$	Standard deviation s	Coefficient of variation $cv\%$	Arithmetic mean $\bar{x}$	Standard deviation s	Coefficient of variation $cv\%$
1 Study attitude	68.00	23.70	34.85	73.66	23.50	31.90
2 Mathematics confidence	51.15	22.74	44.46	58.33	23.25	39.86
3 Study habits	59.15	27.94	47.24	64.33	28.23	43.88
4 Problem solving behaviour	65.84	29.70	45.11	71.30	28.12	39.44
5 Study environment	59.18	21.33	36.04	59.33	23.65	39.86
6 Information processing	69.73	24.49	35.12	67.83	19.77	29.15

Table 6-9 The arithmetic mean, standard deviation and coefficient of variation regarding the SOMT for the 2002 POSC group

	2002 POSC					
	SOMT-2 (Pre-intervention) (N=50)			SOMT-3 (Post-intervention) (N=46)		
Fields of the SOM	Arithmetic mean $\bar{x}$	Standard deviation s	Coefficient of variation $cv\%$	Arithmetic mean $\bar{x}$	Standard deviation s	Coefficient of variation $cv\%$
1 Study attitude	76.35	18.11	23.72	78.21	18.59	23.77
2 Mathematics confidence	50.92	25.42	49.92	61.16	23.09	37.75
3 Study habits	72.21	23.61	32.70	76.60	19.79	25.84
4 Problem solving behaviour	78.80	20.78	26.37	82.45	18.57	22.52
5 Study environment	54.86	25.89	47.19	62.43	27.10	43.41
6 Information processing	73.89	22.05	29.84	78.97	19.57	24.78

With regard to the questionnaire as a pre-intervention instrument, the coefficient of variation has the smallest value in field six (Information processing) for the 2000 POSC group and in field one (Study attitude) for the 2001 and 2002 POSC groups. It can be deduced that in these cases the values in the mentioned fields are reasonably dense around the arithmetic mean.

With regard to the questionnaire as a pre-intervention instrument, the coefficient of variation has the largest value in field two (Mathematics confidence) for the 2000 and 2002 POSC groups and in field three (Study habits) for the 2001 POSC group. In these cases, relative large values occur in the fields Mathematics confidence and Study habits for all three groups indicating that the values are less dense around the arithmetic mean and more spread out.

With regard to the questionnaire as a post-intervention instrument, the coefficient of variation has the smallest relative value in field six (Information processing) for the 2000 and the 2001 POSC groups and in field four (Problem solving behaviour) for the 2002 POSC group. It is noticeable that the coefficient of variation has the second smallest value in field one (Study attitude) for all three groups indicating that for all three the groups the values in the field Study attitude are reasonably dense around the arithmetic mean.

With regard to the questionnaire as a post-intervention instrument, the coefficient of variation has the largest relative value in field three (Study habits) for the 2001 POSC group and in field five (Study environment) for the 2000 and 2002 POSC groups. It is noticeable that for the 2001 POSC group the value of the coefficient of variation is also relative large in the field Study environment. It thus follows that the values are statistically not dense with regard to the arithmetic mean and spread out for all the groups.

6.2.1 Inferential statistics

6.2.1.1 Predictive validity: Regression analysis

Concerning the use of the SOM (used as pre-intervention instrument[110]) as a predictor for performance in mathematics, the following statistical hypothesis is considered:

Hypothesis H1-1:

$H_0$1-1: The scores in the different fields of the SOM cannot be regarded as predictors of students' marks in mathematics.

H_A1-1: The scores in the different fields of the SOM can be regarded as significant predictors of students' marks in mathematics.

In Table 6-10 the results of step-wise regression analysis with the six fields of the SOM as independent variables and the performance in mathematics as dependent variable are given for the 2000 and 2001 POSC groups.

[110] Used with the 2000 and 2001 POSC groups.

Table 6-10 Step-wise regression model of the SOM and mathematics performance for the POSC 2000 and POSC 2001 groups

Fields of the SOM	Parameter estimate	Partial coefficient of determination R^2	Model/Cumulative coefficient of determination R^2	*P*
POSC 2000 group (N=30):				
Information processing (IP)	0.2528	0.3918	0.3918	0.0002*
Problem-solving behaviour (PSB)	0.1428	0.0772	0.4689	0.0579
Regression equation:	$y_1 = 34.44 + 0.25$ IP $+ 0.14$ PSB			
POSC 2001 group (N=38):				
Mathematics confidence (MC)	0.2397	0.2515	0.2515	0.0013*
Regression equation:	$y_2 = 45.65 + 0.25$ MC			

* Significant at the 5% level

The data in Table 6-10 indicate that the fields Information processing (IP) and Mathematics confidence (MC) of the SOM are significant predictors (at a 5% level) for performance in mathematics. The field Problem solving behaviour (PSB) has a marginal contribution as predictor for performance in mathematics.

Regarding sub-hypothesis H1-1, it follows from Table 6-10 that three of the fields of the SOM, although not simultaneously, can be regarded as significant predictors of performance in mathematics and in these cases hypothesis $H_0 1$-1 can be rejected in favour of hypothesis $H_A 1$-1.

Concerning the use of the SOMT (used as pre-intervention instrument) as a predictor for performance in a standard first semester course in calculus, the following statistical hypothesis is considered:

Hypothesis H1-2:

$H_0$1-2: The scores in the different fields of the SOMT can not be regarded as predictors of students' marks in mathematics.

H_A1-2: The scores in the different fields of the SOMT can be regarded as significant predictors of students' marks in mathematics.

In Table 6-11 the results of step-wise regression analysis with the different fields of the SOMT-2 as independent variables and the performance in mathematics as the dependent variable are given for the 2002 POSC group.

Table 6-11 Step-wise regression model of the SOMT-2 and mathematics performance for the 2002 POSC group (N=50)

Fields of the SOMT	Parameter estimate	Partial coefficient of determination R^2	Model/Cumulative coefficient of determination R^2	*P*
Study environment (SE)	0.2256	0.1203	0.1203	0.0146*
Information Processing (IP)	-0.1540	0.0605	0.1809	0.0717
Regression equation:	$y_5 = 63.14 + 0.23\text{ SE} - 0.15\text{ IP}$			

* Significant at the 5% level

The data in Table 6-11 indicates that the field Study Environment (SE) is a significant predictor (on a 5% level) for performance in mathematics. In this case hypothesis $H_0$1-2 can be rejected in favour of hypothesis H_A1-2.

The field Information processing (IP) has a marginal but negative contribution as predictor for performance in mathematics. From the available data it is not clear how this negative value should be interpreted. For the 2002 POSC group the correlation[111] between Information Processing and the final mark in the first semester calculus course is poor and not statistically significant. Feedback from the 2002 POSC group on possible reasons[112] for

[111] See Table 6-15 on page 262.
[112] See Table 6-28 on page 279 and Table 6-29 on page 280.

not statistically significant. Feedback from the 2002 POSC group on possible reasons[112] for deterioration/improvement regarding Information processing on study orientation only indicate that these students did not consider this aspect as having a notable influence on their study orientation.

The regression equations that can be used to predict the performance for mathematics in a standard first semester course in calculus are summarised in Table 6-12.

Table 6-12 Regression equations regarding the SOM and SOMT

Instrument	Group	Regression equation: Predictor for mathematics performance
SOM	2000 POSC	$y_1 = 34.44 + 0.25\ \text{IP} + 0.14\ \text{PSB}$
	2001 POSC	$y_2 = 45.65 + 0.25\ \text{MC}$
SOMT-2	2002 POSC	$y_3 = 63.14 + 0.23\ \text{SE} - 0.15\ \text{IP}$

6.2.1.2 Simultaneous validity: Pearson correlation

Pearson correlations between the different fields of the SOMT (used as a post-intervention instrument) and performance in a standard first semester course in calculus are considered. The following arbitrary criterion for the correlation coefficient is accepted for the purposes of this study, namely:

The correlation is good if $|r| > 0.75$; it is acceptable if $-0.75 \le r < -0.25$ or $0.25 < r \le 0.75$ and it is poor if $-0.25 \le r \le 0.25$.

In Table 6-13, Table 6-14 and Table 6-15 the Pearson correlations between the fields of the SOMT (used as a post-intervention instrument) as independent variables and performance in the standard first semester course in calculus as dependent variable are given for the 2000, 2001 and 2002 POSC groups respectively.

The following research hypothesis regarding the correlation between the different fields of the SOMT and performance in mathematics is investigated, namely that:

[112] See Table 6-28 on page 279 and Table 6-29 on page 280.

Significant correlations occur between the different fields of the SOMT and performance in the standard first semester course in calculus.

From the results in Table 6-14 it follows that for the 2001 POSC group the correlations between mathematics performance and Study attitude (field one), mathematics performance and Problem solving behaviour (field four) and mathematics performance and Study environment (field five) are acceptable. Of these the correlations between mathematics performance and Study attitude (field one) and between mathematics performance and Study environment (field five) are statistically significant at a 5% level.

According to the results in Table 6-15 the correlations between mathematics performance and all the fields of the SOMT are poor for the 2002 POSC group.

Post hoc analysis was carried out to further investigate the results in Table 6-15. This was done by comparing the arithmetic means and standard deviations of the marks in the standard first semester course in calculus. In Table 6-16, Table 6-17 and Table 6-18 the arithmetic means and standard deviations are given with regard to the semester mark, exam mark and final mark of the first semester course in calculus. The data reflects the performance of the POSC students, the other 5YSP students and the 4YSP students in 2000, 2001 and 2002. The data is given for all the freshmen engineering students who wrote the final exam in the standard first semester calculus course during 2000-2002.

Using the arbitrary criterion for the correlation coefficient accepted for this study[113], it follows from Table 6-13 that the correlations between performance in mathematics and all the respective fields of the SOMT-1 are acceptable for the 2000 POSC group. All the correlations except between mathematics performance and Study environment (field five) are statistically significant at the 5% level.

[113] The correlation is good if $|r| > 0.75$; it is acceptable if $-0.75 \le r < -0.25$ or $0.25 < r \le 0.75$ and it is poor if $-0.25 \le r \le 0.25$.

Table 6-13 Pearson correlations between the fields of the SOMT-1 (post-intervention) and mathematics performance for the 2000 POSC group (N=26)

Fields of the SOMT	Mathematics performance Pearson correlation coefficient	*P*
1 Study attitude (SA)	0.524	0.0060*
2 Mathematics confidence (MC)	0.460	0.0180*
3 Study habits (SH)	0.431	0.0279*
4 Problem solving behaviour (PSB)	0.651	0.0003*
5 Study environment (SE)	0.373	0.0601
6 Information processing (IP)	0.611	0.0009*

* Significant at the 5% level

Table 6-14 Pearson correlations between the fields of the SOMT-1 (post-intervention) and mathematics performance for the 2001 POSC group (N=35)

Fields of the SOMT	Mathematics performance Pearson correlation coefficient	*P*
1 Study attitude (SA)	0.481	0.0034*
2 Mathematics confidence (MC)	0.198	0.2531
3 Study habits (SH)	0.190	0.2724
4 Problem solving behaviour (PSB)	0.296	0.0832
5 Study environment (SE)	0.443	0.0077*
6 Information processing (IP)	0.231	0.1799

* Significant at the 5% level

Table 6-15 Pearson correlations between the fields of the SOMT-3 (post-intervention) and mathematics performance for the 2002 POSC group (N=46)

Fields of the SOMT	Mathematics performance Pearson correlation coefficient	*P*
1 Study attitude (SA)	0.072	0.6307
2 Mathematics confidence (MC)	0.022	0.8814
3 Study habits (SH)	0.240	0.1068
4 Problem solving behaviour (PSB)	0.218	0.0143*
5 Study environment (SE)	0.190	0.2040
6 Information processing (IP)	0.163	0.2777

* Significant at the 5% level

Table 6-16 Arithmetic means and standard deviations for marks in the standard first semester course in calculus 2000 for the POSC, other 5YSP and 4YSP groups

Group	N	Semester mark		Exam mark		Final mark	
		Arithmic mean $\bar{x}$	Standard deviation s	Arithmic mean $\bar{x}$	Standard deviation s	Arithmic mean $\bar{x}$	Standard deviation s
POSC	33	61.00	10.84	57.09	17.59	59.52	13.90
Other 5YSP	62	54.50	10.74	45.79	19.17	50.55	14.07
4YSP	406	66.24	13.85	60.70	19.48	63.77	15.75

Table 6-17 Arithmetic means and standard deviations for marks in the standard first semester course in calculus 2001 for the POSC, other 5YSP and 4YSP groups

Group	N	Semester mark		Exam mark		Final mark	
		Arithmic mean $\bar{x}$	Standard deviation s	Arithmic mean $\bar{x}$	Standard deviation s	Arithmic mean $\bar{x}$	Standard deviation s
POSC	40	58.83	12.03	58.70	12.84	59.10	11.08
Other 5YSP	46	52.35	11.76	35.22	15.99	45.65	12.26
4YSP	431	62.27	14.54	51.02	20.75	57.89	15.99

Table 6-18 Arithmetic means and standard deviations for marks in the standard first semester course in calculus 2002 for the POSC, other 5YSP and 4YSP groups

Group	N	Semester mark		Exam mark		Final mark	
		Arithmic mean $\bar{x}$	Standard deviation s	Arithmic mean $\bar{x}$	Standard deviation s	Arithmic mean $\bar{x}$	Standard deviation s
POSC	51	56.37	14.00	74.63	16.52	63.76	14.30
Other 5YSP	41	51.49	9.92	56.85	13.71	53.76	9.84
4YSP	547	59.02	13.15	66.76	16.35	62.16	13.65

Inspection of the data in Table 6-16, Table 6-17 and Table 6-18 reveals the following tendency that may account for the lack of correlation found between mathematics performance and the fields of the SOMT for the 2002 POSC group. In 2000 and 2001 the average semester marks are higher than the exam marks for all the groups. The corresponding standard deviations are relatively similar for all three of the groups except in 2001 where the standard deviation of the 4YSP is higher than those of the other two groups. In contrast with this tendency, the average semester mark is less than the exam mark in 2002 for all three the groups. In the latter case, the difference between the exam mark and the semester mark is the greatest for the POSC group (18.26%) followed by the 4YSP group (7.74%) and the other 5YSP group (5.36%). The standard deviations for the POSC group as well as the 5YSP group regarding both the semester mark and the exam mark in 2002 are relatively similar and both differ from that of the other 5YSP group in 2002. These figures point to the fact that in 2002 the POSC group seemingly performed remarkably well in the standard mathematics course in comparison with the other first year engineering students.

6.3 Academic performance in mathematics

Concerning the possible effect of the support in the POSC on performance in mathematics, the following research hypothesis is considered:

> The average mark achieved by the POSC group in a standard first semester calculus course is higher than the average mark of students not enrolled for the POSC.

From the data in Table 6-16, Table 6-17 and Table 6-18 on page 263 it is clear that the average final mark[114] in the standard first semester course in calculus of the POSC students is higher that that of the other 5YSP students in 2000, 2001 and 2002. The average mark of the POSC students is also marginally higher than that of the 4YSP students in 2001 and in 2002.

[114] In 2000 the final mark for mathematics in the standard first semester calculus course was calculated as semester mark 50% + exam mark 50%. In 2001 and 2002 the final mark was calculated as semester mark 60% + exam mark 40%.

6.4 Comparing means (post minus pre) of pre- and post-intervention scores on the SOM/SOMT

The non-parametric Wilcoxon rank-sum Test (BMDP3D, 1993) was used to compare (for each field) the difference between the Study Orientation Questionnaire in Mathematics at course beginning and at course end. The following statistical hypothesis is investigated:

Hypothesis H2:

$H_0$2: No significant differences exist in the arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics at the beginning of the POSC and at the end of the POSC.

H_A2: Significant differences exist in the arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics at the beginning of the POSC and at the end of the POSC.

In Table 6-19 the means, standard deviations, Wilcoxon statistics and *p*-values for the individual fields regarding the differences between the Study Orientation Questionnaire in Mathematics at course beginning and at course end are given.

From the data in Table 6-19 it follows that for the 2000 POSC group there was significant improvement in Mathematics confidence and Problem solving behaviour. The 2001 POSC group improved in Study attitude, Mathematics confidence, Study habits and Problem solving behaviour. The 2002 POSC group showed significant improvement in Mathematics confidence, Study habits and Information processing and to a lesser degree also in Problem solving behaviour.

Regarding hypothesis H2, it follows from Table 6-19 that with regard to the field Mathematic confidence, there are significant differences in the arithmetic mean between the pre and post-questionnaires in study orientation towards mathematics for all the groups and in this case hypothesis $H_0$2 can be rejected in favour of hypothesis H_A2. For the 2001 POSC group, hypothesis $H_0$2 can be rejected in favour of hypothesis H_A2 with regard to the fields Study attitude, Study habits and Problem solving behaviour. For the 2002 POSC hypothesis $H_0 2$ can also be rejected in favour of hypothesis $H_A 2$ with regard to Study habits and Information processing. However, with regard to the field Study environment, hypothesis $H_0 2$ is retained for all the groups.

Table 6-19 Means, standard deviations, test statistics and *p*-values of the difference between the study orientation questionnaire at course end and at course beginning for the individual fields of the SOM/SOMT

	2000 POSC				2001 POSC				2002 POSC			
	N=26				N=35				N=46			
Fields of the SOM/SOMT	Mean	Standard deviation	Wilcoxon test statistic	*P*	Mean	Standard deviation	Wilcoxon test statistic	*P*	Mean	Standard deviation	Wilcoxon test statistic	*P*
1 Study attitude	-4.53	18.76	119.0	0.3756	7.11	15.52	149.0	0.0111*	2.85	18.49	411.0	0.4537
2 Mathematics confidence	14.00	27.29	44.0	0.0074*	6.65	19.95	171.0	0.0503*	8.73	28.25	286.5	0.0149*
3 Study habits	3.11	23.28	145.5	0.6471	8.88	17.80	134.0	0.0088*	5.83	19.60	356.0	0.0438*
4 Problem solving behaviour	6.96	17.84	87.5	0.0741	8.85	16.17	110.5	0.0070*	4.84	18.06	322.5	0.1065
5 Study environment	4.76	19.18	117.5	0.2255	2.77	19.53	244.5	0.3638	6.00	26.39	409.0	0.1505
6 Information processing	1.23	18.58	137.5	0.5008	-1.31	21.88	250.0	0.4164	5.96	20.43	288.5	0.0415*

* Significant at the 5% level

6.5 Comparing groups regarding differences in means of pre- and post-intervention scores on the SOM/SOMT

One way analysis of variance (ANOVA) was used to investigate the differences (post minus pre) in the arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics used as pre- and post-intervention instruments between the 2000, the 2001 and the 2002 POSC groups. Where significant differences existed, the multiple Least Square Means *post hoc* procedure was applied to determine the specific group differences. The following statistical hypothesis is investigated:

Hypothesis H3:

$H_0 3$: No significant differences (post minus pre) exist in the means of the 2000, 2001 and 2002 POSC groups for the fields of the Study Orientation Questionnaire in Mathematics.

$H_A 3$: Significant differences (post minus pre) exist in the means of the 2000, 2001 and 2002 POSC groups for the fields of the Study Orientation Questionnaire in Mathematics.

In Table 6-20 the results are given of ANOVA comparing the differences in arithmetic means of the fields of the Study Orientation Questionnaire in Mathematics as pre- and post-intervention instruments for the 2000, 2001 and 2002 POSC groups.

Regarding hypothesis H3, it follows from Table 6-20 that statistically significant differences (post minus pre) exist in the means of the 2000, 2001 and 2002 POSC groups for the field Study attitude. In this case hypothesis $H_0 3$ can be rejected in favour of hypothesis $H_A 3$.

However, with regard to all the other fields, there are no significant differences (post minus pre) in the means of the 2000, 2001 and 2002 POSC groups. In these cases hypothesis $H_0 3$ is retained.

Table 6-20 Results of ANOVA comparing the difference between the arithmetic means of the fields of the Study Orientation Questionnaire as pre- and post-intervention instruments for the 2000, 2001 and 2002 POSC groups

		POSC groups per year N=107				
Field	**Post minus Pre**	**2000**	**2001**	**2002**	**F**	***P***
1 Study attitude	Pre	67.73	68.00	76.35		
	Post	60.88	73.66	78.21		
	Post-Pre	-6.85[a]	+5.66[b]	+1.86[b]	3.27	0.0418*
2 Mathematics confidence	Pre	44.96	51.15	50.92		
	Post	59.11	58.33	61.19		
	Post-Pre	+14.5	+7.18	+10.27	0.64	0.5313
3 Study habits	Pre	56.96	59.15	72.21		
	Post	57.53	64.33	76.60		
	Post-Pre	+0.57	+5.18	+4.39	0.63	0.5337
4 Problem solving behaviour	Pre	63.96	65.84	78.80		
	Post	68.26	71.30	82.45		
	Post-Pre	+4.3	+5.46	+3.65	0.53	0.5894
5 Study environment	Pre	46.13	59.18	54.86		
	Post	51.80	59.33	62.43		
	Post-Pre	+5.67	+0.15	+7.57	0.20	0.8176
6 Information processing	Pre	70.60	69.73	73.89		
	Post	70.38	67.83	78.97		
	Post-Pre	-0.22	-1.9	+5.08	1.36	0.2735

* Significant at the 5% level
[a,b] Means with different superscripts within rows differ significantly at $p < .05$

The *post hoc* results indicate that the means in the field Study attitude differ statistically significantly between the 2000 and 2001 POSC groups and between the 2000 and 2002 POSC groups. No statistically significant difference between the means for the 2001 and 2002 POSC groups occurred.

A possible reason for the differences between the 2000 POSC groups and the other two groups in Study attitude may be attributed to the fact that the 2000 POSC group did the post-intervention questionnaire at a later stage (in the second semester of the second year) that the other two groups. The 2001 and 2002 POSC groups did the post-intervention questionnaire in the second semester of their first year. For all three groups the proposed learning facilitation strategy in the mathematics component of the POSC was followed in the first semester of the first year. Other factors (experienced in the second study year) may thus particularly have influenced the 2000 POSC group's Study orientation.

6.6 Results: Herrmann Brain Dominance Instrument (HBDI)

In this section the average Herrmann Brain Dominance (HBD) profiles as well as the distribution of thinking style preferences are discussed. The subjects include the 2000 POSC students, the 2000 group of first year civil engineering students and the 1999 group of science students. Data pertaining to the HBDI was processed through the HBDI Processing System Version 5.2 (Herrmann International, 1999b).[115] The results were statistically analysed using the Kruskal-Wallis test (BMDP3D, 1993) to determine the distribution of the thinking style preferences of first year engineering students on a support course. The latter analysis is addressed in two ways, namely a comparison between two groups of freshmen engineering students and a comparison between two groups of students both on support courses (the one in the Faculty of Engineering and the other in the Faculty of Natural Sciences). In the first case the results pertaining to the POSC students are compared to those of a group of first year civil engineering students and in the second case they are compared to those of a group of science students on a support course.

6.2.1 Distribution of thinking style preferences

6.6.1.1 Average profiles

In Table 6-21 the average scores per quadrant according to the HBDI for the POSC, civil engineering and science students are given. In Figure 6-1 the average HBD profiles (generated by the HBDI Processing System) of the POSC, civil engineering and science students are given. All the profiles in Figure 6-1 tend towards a profile displaying almost equal preferences in all four quadrants of the Herrmann whole brain model. Inspection of Table 6-21 reveals the following regarding the average values per quadrant. The two groups of engineering students have a higher average value in quadrants A and B than the science group. In quadrants B and C the average score for the science groups is higher than that of the two engineering groups.

[115] See Chapter 4 section 4.6.6 for information on the scoring of the HBDI.

Table 6-21 Average scores per quadrant according to the HBDI for the POSC, civil engineering and science students

	A	B	C	D
2000 POSC 2000 students	82	70	65	74
Civil engineering students	84	76	55	76
Science students	70	84	71	63

Figure 6-1 Average profiles for the 2000 POSC, civil engineering and science students according to the HBDI

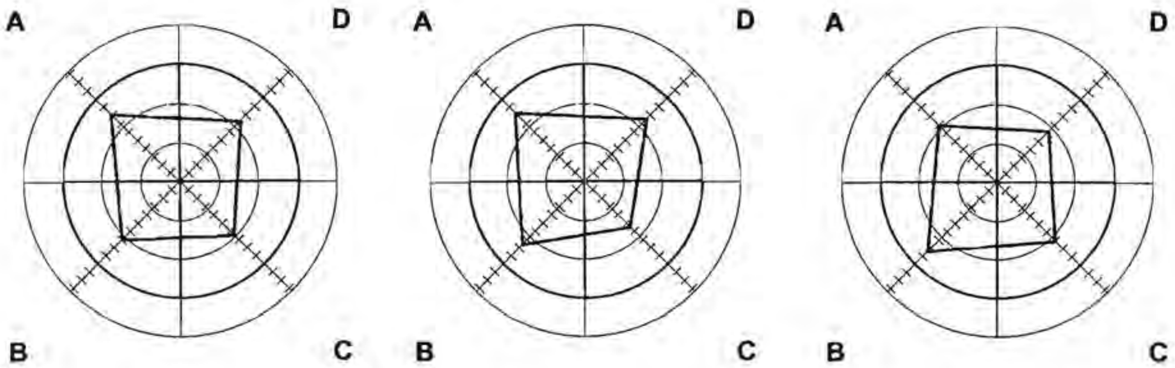

Figure 6-1 A
2000 POSC students

Figure 6-1 B
Civil engineering students

Figure 6-1 C
Science students

6.6.1.2 Dominance in the distribution of profiles

The differences in preferences for the four quadrants of the Herrmann whole brain model are also noticeable in the number of students with thinking preferences per quadrants. In Table 6-22 the number of POSC, civil engineering and science students per quadrant is given indicating their thinking preferences for the specific quadrant. Two students in the POSC group have HBD profiles representing thinking preferences almost equally distributed across all for quadrants and scores of the same magnitude for all the quadrant.

Table 6-22 Number of POSC, civil engineering and science students with highest score for thinking preferences per quadrant

	A	B	C	D	ABCD
2000 POSC students	15	5	5	6	2
Civil engineering students	18	3	6	3	0
Science students	9	18	7	4	0

In Figure 6-2 the dominance in distribution of the individual HBD profiles of the three groups of students is given. The distribution of profiles confirm the analysis in section 6.6.1.1 regarding the linear hemisphere that the thinking style preference of first year engineering students are seemingly more towards the upper left quadrant whereas the thinking preferences of this group of first year science students are more towards the lower left quadrant of the Herrmann whole brain model. Furthermore, the individual profiles of the two groups of engineering students seem to cluster in the upper left and right quadrants (A and D) of the Herrmann whole brain model whereas the profiles of the science students seem to cluster in the lower left and right quadrants (B and C) of the Herrmann whole brain model.

Figure 6-2 Distribution of HBD profiles for the 2000 POSC, civil engineering and science students

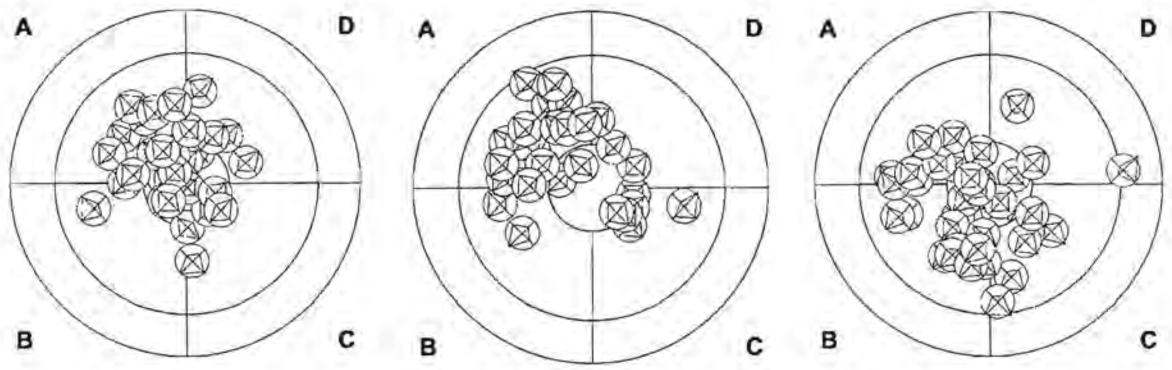

Figure 6-2 A
2000 POSC students

Figure 6-2 B
Civil engineering students

Figure 6-2 C
Science students

6.6.2 Comparing groups within quadrants of the HBDI

In this section the thinking style preferences of the POSC, civil engineering and science students are statistically analysed in order to determine the thinking style preferences of first year engineering students on a support course. The following statistical hypothesis regarding the scores for the different quadrants of the HBDI is investigated:

Hypothesis H4:

$H_0$4: No differences exist in the arithmetic means of the scores for the different quadrants of the HBDI between the POSC group, the civil engineering group and science students on a support course.

H_A4: Significant differences exist in the arithmetic means of the scores for the different quadrants of the HBDI between the POSC group, the civil engineering group and science students on a support course.

The non-parametric Kruskal-Wallis test (BMDP3D, 1993) was used to compare the arithmetic mean scores of the 2000 POSC, civil engineering and science groups for each of the four quadrants of the Herrmann whole brain model as measured by the HBDI. Table 6-23 on the following page gives the arithmetic means, standard deviations and *p*-values regarding the quadrants of the HBDI for the three groups.

From Table 6-23 it follows that there is no significant difference between the means of the scores for all the quadrants of the HBDI between the POSC group and the civil engineering group. Therefore, hypothesis $H_0$4 is retained and it is accepted that no differences exist in the arithmetic means of the scores for all four quadrants of the HBDI between the POSC group and the civil engineering group.

There is also no significant difference between the means of the scores for the B quadrant of the HBDI between all three the groups and in this case hypothesis $H_0$4 is retained and it is deduced that no differences exist in the arithmetic means of the scores for the B quadrant of the HBDI between all three groups.

From Table 6-23 it further follows that there is a significant difference between the means of the scores for the A-quadrant of the HBDI between the POSC group and the science group and between the civil engineering group and the science group respectively. Therefore hypothesis $H_0 4$ is be rejected in favour of the alternative hypothesis namely that there is a difference in the means of the scores for the A-quadrant of the HBDI between the POSC students and the science students and between the civil engineering group and the science group.

There is also a significant difference between the means of the scores for the C- and D-quadrants of the HBDI between the civil engineering group and the science group. In these cases hypothesis $H_0 4$ is rejected in favour of the alternative hypothesis namely that there is a difference in the means of the scores for the C and D quadrants of the HBDI between the civil engineering group and the science group. However, there is no significant difference between the means of the scores for the C and D quadrants of the HBDI between the POSC group and the science group and for these two groups the hypothesis $H_0 4$ is retained.

In all the cases where hypothesis $H_0 4$ is retained it may suggest that the sample data is be insufficient to indicate whether the means of the scores for the different quadrants of the HBDI differ or do not differ between the three groups of students.

Table 6-23 Means of the POSC, civil engineering and science groups for each of the quadrants of the HBDI

	POSC group (N=33)		Civil engineering group (N=30)		Science group (N=38)		
HBDI	**Arithmetic mean $\bar{x}$**	**Standard deviation s**	**Arithmetic mean $\bar{x}$**	**Standard deviation s**	**Arithmetic mean $\bar{x}$**	**Standard deviation s**	***P***
A-quadrant	82.06^{a}	16.89	83.66^{a}	20.70	69.78^{b}	18.70	0.0044*
B-quadrant	70.45^{ab}	13.59	76.03^{ab}	15.25	83.86^{b}	16.68	0.0006*
C-quadrant	64.75^{ab}	17.44	55.03^{a}	22.03	71.15^{b}	21.42	0.0045*
D-quadrant	73.06^{ab}	17.41	76.46^{a}	17.59	63.34^{b}	19.99	0.0085*

* Significant at the 5% level

^{a,b} Means with different superscripts within rows differ significantly at $p < .05$

6.7 Results: Lumsdaine and Lumsdaine Learning Activity Survey (LAS)

The main aim with the implementation of the LAS in 2000 was to determine if this questionnaire can be used in stead of the HBDI to make students aware of their own thinking style preferences.

The following research hypothesis regarding the quadrants of the HBDI and the corresponding sections of the LAS is investigated:

Significant correlations exist between the scores in the quadrants of the HBDI and the scores in the corresponding sections of the LAS for the 2000 POSC group and the 2000 civil engineering group.

Pearson correlation was used to determine whether there are significant correlations between the quadrants of the HBDI and the corresponding sections of the LAS questionnaire. These correlations and the corresponding values for *p* are given in Table 6-24.

Table 6-24 Pearson correlations and P-values between the quadrants of the HBDI and corresponding sections of the LAS

	LAS			
HBDI	**Section A**	**Section B**	**Section C**	**Section D**
A-quadrant	$r = 0.0825$ $p = 0.5307$			
B-quadrant		$r = 0.2149$ $p = 0.0991$		
C-quadrant			$r = 0.1588$ $p = 0.2254$	
D-quadrant				$r = 0.1956$ $p = 0.1341$

From Table 6-24 it follows that $0.0991 \le p \le 0.5037$ in all cases. Therefore, no statistically significant correlation exists between any of the quadrants of the HBDI and the corresponding section of the LAS. The use of the LAS instead of the HBDI is thus not recommended.

6.8 Results: Felder Soloman Index of Learning Styles (ILS)

The results concerning the choices per category of the ILS are given in Table 6-25 for the 2001 POSC group and in Table 6-26 for the 2002 POSC group.

Qualitative analysis of the choices in Table 6-25 indicates that the number of choices between 'reflective' and 'active' as well as between 'sequential' and 'global' is almost evenly spread among the 2001 POSC group. The total number of choices for 'verbal' is much lower than for 'visual' and the number of choices for 'intuitive' is also less than for 'sensing'.

It is noticeable that although the number of choices for 'visual' and for 'sensing' is high these choices reflect mild to moderate preferences. Furthermore, none of choices in any of the categories reflects high figures for strong preferences in the particular category.

Table 6-25 Number of choices per category of the ILS according to mild, moderate or strong preferences for the 2001 POSC group (N=35)

Mild	Moderate	Strong	Mild	Moderate	Strong
Reflective			Active		
10	5	2	12	4	2
Reflective total		17	18		Active total
Verbal			Visual		
2	5	0	11	12	5
Verbal total		7	28		Visual total
Sensing			Intuitive		
20	3	1	7	3	1
Sensing total		24	11		Intuitive total
Sequential			Global		
9	6	3	14	2	1
Sequential total		18	17		Global total

Qualitative analysis of the choices in Table 6-26 indicates that the number of choices between 'reflective' and 'active' as well as between 'sequential' and 'global' is almost evenly spread for the 2002 POSC group. The total number of choices for 'verbal' is much lower than for 'visual' and the number of choices for 'intuitive' is also less than for 'sensing'. Although the number of choices for 'visual' and for 'sensing' is high these choices reflect mild to moderate preferences. Furthermore, none of choices in any of the categories reflects high figures for strong preferences in the particular category.

Table 6-26 Number of choices per category of the ILS according to mild, moderate or strong preferences for the 2002 POSC group (N=51)

Mild	Moderate	Strong	Mild	Moderate	Strong
Reflective			**Active**		
19	7	3	13	9	0
Reflective total		**29**	**22**		**Active total**
Verbal			**Visual**		
3	0	0	20	19	9
Verbal total		**3**	**48**		**Visual total**
Sensing			**Intuitive**		
20	11	0	15	5	0
Sensing total		**31**	**20**		**Intuitive total**
Sequential			**Global**		
18	8	1	19	5	0
Sequential total		**27**	**24**		**Global total**

In Table 6-27 the distribution (as percentages) of choices for the categories of the ILS for the 2001 and 2002 POSC groups is given. It is noticeable that in the three categories verbal/visual, sensing/intuitive and sequential/global, the trend in preferences for the 2001 and 2002 groups is similar. Both groups have a much greater preference for visual than for verbal. About two thirds of each group prefer sensing to intuitive. Regarding the category sequential/global, the preferences are almost equally distributed for each of the categories sequential and global.

Table 6-27 Distribution of choices for the categories of the ILS for the 2001 and 2002 POSC groups

	Reflective	Active	Verbal	Visual	Sensing	Intuitive	Sequential	Global
2001 N=35	49%	51%	20%	80%	69%	31%	51%	49%
2002 N=51	57%	43%	6%	94%	61%	39%	53%	47%

6.9 Participant observation: participant feedback

For the purpose of the research as presented in this thesis the feedback from POSC participants during 2000-2001 is only qualitatively reported and discussed.

In Table 6-28 on page 279 possible reasons for a deterioration in study orientation in mathematics are given. The reasons are categorised according to feedback that students gave to explain their own weakening (if it occurred) in the different aspects of study orientation by comparing their study orientation (profile) at the beginning of the POSC to their study orientation (profile) after the POSC.

In Table 6-29 on page 280 possible reasons for improvement in study orientation in mathematics are given. The reasons are categorised according to feedback that students gave to explain their own improvement in the different aspects of study orientation by comparing their study orientation (profile) at the beginning of the POSC to their study orientation (profile) after the POSC. It should be kept in mind that study orientation in mathematics for the purposes of the research reported in this thesis reflects the students' study orientation toward the standard mathematics course and not towards the mathematics component of the POSC.

It should also be mentioned that the data in Table 6-28 and Table 6-29 are not ordered in any way and that the frequency of similar answers were not taken into account.

Students' own perceptions of the extent to which the study orientation profile, as measured by the SOMT, reflects study orientation towards mathematics were noted by the researcher during interviews and was also given through a writing assignment.[116] Most of the students agreed that the profile (regarding all six aspects of the questionnaire) was a fair indication of their orientation towards mathematics. Some students felt that it was a precise reflection of their orientation. Some students felt that certain aspects of the profile were a fair indication of their orientation and disagreed regarding some other aspects. With regard to those aspects that they did not consider a true reflection of their study orientation, they indicated that they perceived their orientation to be better than indicated by the profile. It was noticeable that with regard to those aspects of the SOMT profile where a favourable study orientation was not displayed, all students remarked that they intend working on that aspect to improve in it.

Table 6-28 Possible reasons for deterioration in study orientation

Aspect of study orientation	Factors that have a negative effect on study orientation
Study attitude (SA)	When the meaningfulness/usefulness of the work is not clear. Not being serious enough about studying. Negative peer influence. Feeling of hopelessness from not doing well (in other subjects).
Mathematics confidence (MC)	Bad grades. Not enough time on task. Trying hard but not achieving good grades. Too great a volume of work.
Study habits (SH)	Influence of lecturer – if he/she does not encourage students to work hard, they don't. Ignoring time planning.
Problem solving behaviour (PSB)	Lack of interest.
Study environment (SE)	New and foreign environment in a hostel. Too busy social life.
Information processing (IP)[117]	

[116] See Appendix G for a copy of the writing assignment.
[117] Students did not mention any aspect that has a negative influence on orientation with regard to this field.

Table 6-29 Possible reasons for improvement in study orientation

Aspect of study orientation	Factors that contribute to improved study orientation
Study attitude (SA)	Peer influence. Working in a study group. Information in the POSC. Personal motivation to work harder to improve grades. Achieving better grades. Better understanding of the work leads to enjoying maths and a positive attitude. Believing in oneself.
Mathematics confidence (MC)	Skills acquired through the POSC. Studying in groups. Time on task. Work and study everyday. Go to class prepared. Better understanding of the work. Believing in oneself. Achieving good grades. Making sense from what one is doing.
Study habits (SH)	Peer influence. Working in a study group. Skills acquired through the POSC. Follow up on mistakes and understand what was wrong. Good time management. Focus on the method and not only on getting to the correct answer.
Problem solving behaviour (PSB)	More practice. Peer interaction and lecturer influence give insight into different and useful strategies. Skills acquired through the POSC. Create a visual picture to understand something. Trying different approaches.
Study environment (SE)	Scheduling residence activities, social activities and study time.
Information processing (IP)	Skills acquired through the POSC.

6.10 Summary

The results of the 2000-2002 study presented in this chapter can be summarised as follows.

The results obtained from item analyses, the Cronbach alpha coefficients and feedback from the students indicate that the Study Orientation Questionnaire in Mathematics Tertiary (SOMT) can be used with first year engineering students on a support course to create an awareness of their own study orientation towards mathematics. Furthermore, results from regression analyses indicate that most of the fields of the SOMT, although not simultaneously, can be regarded as predictors of performance in mathematics. ANOVA and *post hoc* analysis indicate that there are no significant differences in the means (post minus pre) of the fields of the SOMT between the 2000, 2001 and 2002 POSC groups except in the field Study habits.

Concerning the thinking style preferences of the POSC students, the results pertaining to the Herrmann Brain Dominance Instrument (HBDI) indicate that the thinking style preferences of first year engineering students on a support course represent an array of preferences distributed across all four quadrants of the Herrmann whole brain model. Furthermore, it seems as if the thinking style preferences of the POSC students (being first year engineering students on a support course) do not differ from those of first year civil engineering students, but do differ in some quadrants from those of first year science students on a support course. Qualitative analysis of the data obtained from the Felder Soloman Index of Learning Styles (ILS) endorses the fact that a group of students represents an array of learning preferences.

In the Chapter 7 the results are further discussed and conclusions and recommendation presented.

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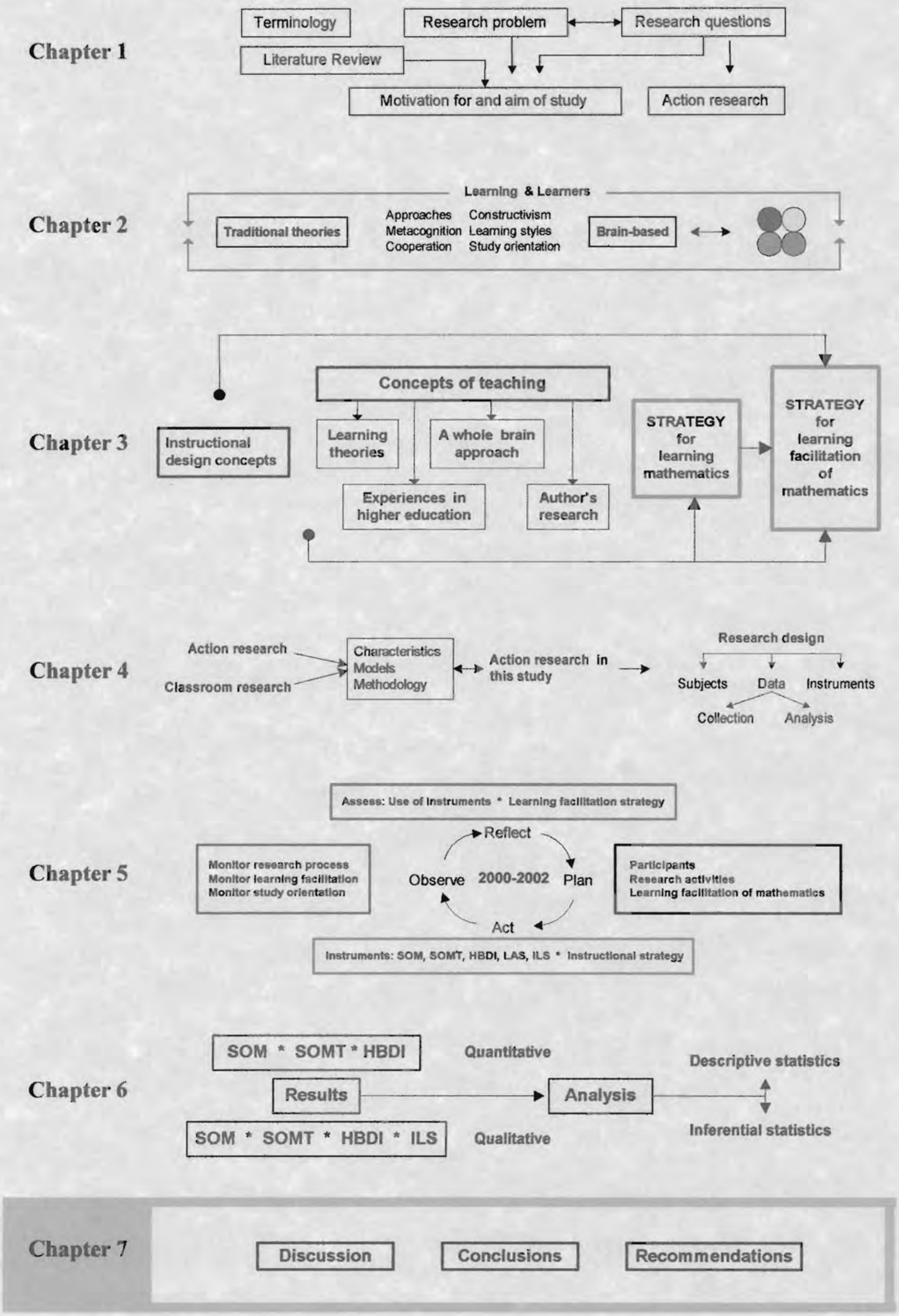

Discussion, conclusions and recommendations

- **7.1 Discussion**
  - 7.1 Study orientation in mathematics
  - 7.2 Performance in mathematics
  - 7.3 Thinking style preferences
  - 7.4 A strategy for learning facilitation of mathematics in a support course
- **7.2 Limitations of the study**
- **7.3 Conclusions**
- **7.3 Recommendations**

Chapter 7

Discussion, conclusions and recommendations

7. Introduction

The primary objectives of the research reported in this thesis were to propose a strategy for the learning facilitation of mathematics in a support course for first year engineering students, to define the aspects that constitute such a strategy and to determine the possible effects of the strategy on learners' study orientation towards mathematics and on their performance in mathematics.

In Chapter 2 aspects of learning relevant for the proposed learning facilitation strategy were identified. In Chapter 3 the learning facilitation strategy was defined. The research approach followed in this study was discussed in Chapter 4. In Chapter 5 the implementation of the strategy in the research studies during 2000-2002 was detailed. In Chapter 6 results pertaining to the effects of the strategy were presented and qualitatively and quantitatively analysed. In this chapter the focus is on determining whether the aims of the research has been met and the research questions answered.

In the following sections the research results, with reference to the effects of the implementation of the learning facilitation strategy on study orientation in mathematics and performance in mathematics, are discussed; insights gained during the study regarding the thinking style preferences of the students are then presented and the main aspects of the proposed learning facilitation strategy are highlighted. The chapter concludes by identifying possible limitations of the study, noting areas for further research and concludes with remarks on the use of the proposed learning facilitation strategy.

7.1 Discussion

In Table 7-1 the research questions and main research finding of the present study are summarised and aspects thereof are further highlighted in the discussion that follows.

Table 7-1 Research questions and main research findings

Research question	Research findings
1 What is the study orientation towards mathematics of the students enrolled for the POSC?	A specific trend regarding the POSC students' study orientation toward mathematics is noticeable that displays the following characteristics: • The POSC students seem to have a neutral to favourable study orientation towards mathematics. • Their mathematics confidence and study environment might influence their study orientation negatively. • The POSC students seem to have a fairly good study attitude toward mathematics.
2 Does the learning facilitation strategy followed in the POSC have an effect on the students' study orientation in mathematics? In particular, is there an improvement in the students' study orientation towards mathematics?	• The learning facilitation strategy followed in the POSC seemingly has a positive effect on the students' study orientation in mathematics and there is an improvement in the students' study orientation towards mathematics. • This improvement is noticeable for the 2000, 2001 and 2002 students. • Students' study attitude towards mathematics is seemingly vulnerable once they have left the environment of the POSC. In this regard it may be necessary to place stronger emphasis on the students' awareness and understanding of their own study orientation profile towards mathematics.
3 Does the learning facilitation strategy for mathematics followed in the POSC have an effect on students' academic performance in the standard first semester calculus course?	• The POSC students outperformed the other 5YSP students. • The grades of the POSC students compare favourably with that of the 4YSP students.
4 What are the thinking style preferences of first year engineering students enrolled for the POSC?	• The individual HBD profiles of the POSC students represent diverse thinking preferences in all four quadrants of the Herrmann model. • The average HBD profile of the POSC students displays a generic whole brain profile indicating the group represents thinking preferences distributed across all four quadrants of the Herrmann whole brain model. • Qualitative analysis of the ILS point to the following trends for both the 2001 and 2002 groups: A greater preference for visual than for verbal; A greater preference for sensing than intuitive; Almost equal preferences for sequential and global; Almost equal preferences for reflective and active but not the same distribution for the 2001 and 2002 groups.

7.1.1 Study orientation in mathematics

The study orientation profiles of the learners were interpreted in a diagnostic and evaluative manner. The facilitator gained insight into the study orientation of individual learners as well as into that of each of the POSC groups. The learners themselves became aware of their own study orientation. Comparing the group profiles at course beginning and at course end gave an indication of change in learners' study orientation.

In Figure 7-1, Figure 7-2 and Figure 7-3 on the following pages, the study orientation profiles in mathematics for the 2000, 2001 and 2002 POSC groups are given. These profiles were compiled for the different groups using the average score in each of the fields of the questionnaire. For the purpose of this discussion they will be referred to as "group profiles". In each case the profile indicated with a dotted line refers to the results of questionnaire done at the beginning of the POSC and the profile indicated with a solid line refers to the results of the questionnaire done after the POSC. Profile scores[118] of 40% and below indicate an unfavourable study orientation in that aspect; scores between 40% and 69% indicate a neutral study orientation and scores of 70% or above indicate a favourable study orientation. According to Maree *et al.* (1997:15) a neutral study orientation *can contribute to a positive or negative study orientation or aspect of it.*

It is noticeable that for all three the groups the scores in the fields Mathematics confidence and Study environment are the lowest both at course beginning and at course end. However, the group profiles at course end show a higher score in each of these fields. The results in Chapter 6 indicated that for all three the POSC groups the improvement in mathematics confidence was statistically significant.

Furthermore, none of the profiles is located in the unfavourable range[119] (40% and below) regarding study orientation in mathematics. For the 2000 group the profile (solid line) at the end of the POSC is still in the neutral range (40%-69%). This also applies to the 2001 group except for the fields Study attitude and Problem solving behaviour which are in the favourable range (70% and above). For the 2002 group the profile (solid line) at the end of the POSC is mainly in the favourable range (70% and above) and only the fields Mathematics confidence and Study environment are in the neutral range (40% to 69%).

[118] See Chapter 4 section 4.6.4 for detail on the interpretation of a study orientation profile.
[119] See Chapter 4 section 4.6.4 for detail on the terms "unfavourable", "neutral" and "favourable".

Regarding the sixth field, Information processing, the average scores in the end of course questionnaire for the 2000 and the 2001 groups are only marginally less than those in the beginning of course questionnaire (0.22 points less in the case of the 2000 group and 1.9 in the case of the 2001 group). In the same field the score for the 2002 group is 5.08 points higher in the end of course questionnaire. A possible explanation for the higher score in 2002 may be that during the research study in 2002 students were constantly encouraged and reminded to put into practice the aids and skills concerning learning and studying that they were introduced to in the POSC. These included constant reminders to the students to follow a healthy lifestyle (for example physical exercise and the intake of enough water), the use of mind maps, working in groups and reminding students about the advantages of whole brain usage. Overall, the profiles for all three the groups indicate an improvement in study orientation at the end of the POSC.

At the time of writing no published research on the use of the original SOM with first year tertiary students in mathematics was available. The version adapted for tertiary students, the SOMT, is now presented in the current study for the first time. Therefore, the results of this investigation regarding study orientation in tertiary mathematics, as measured by the SOMT, could not be corroborated with other research.

Figure 7-1 Group profiles representing the study orientation in mathematics of the 2000 POSC students

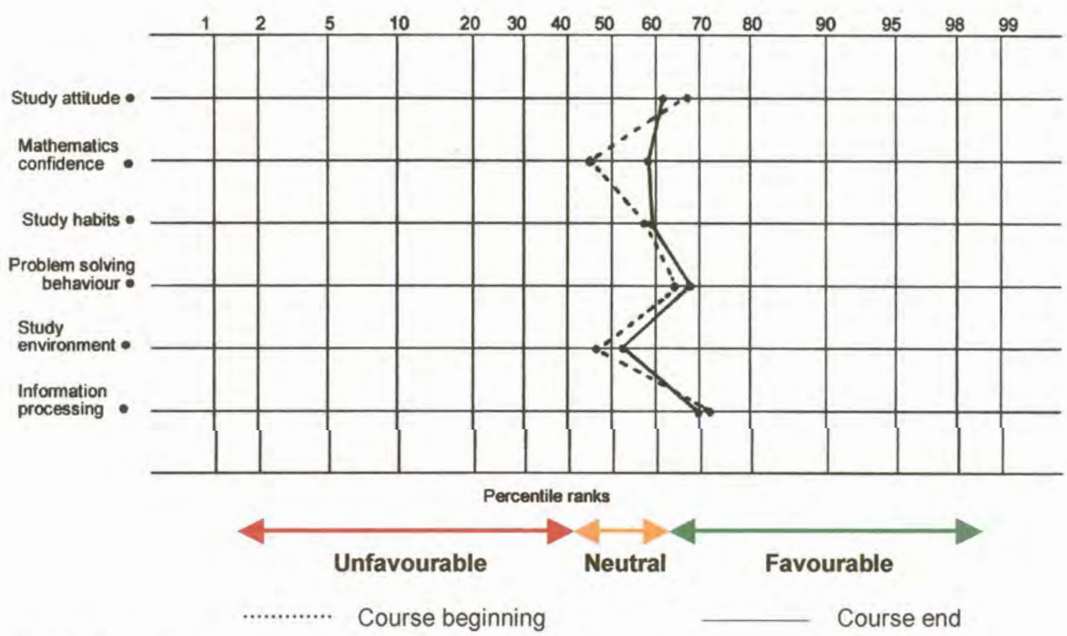

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Figure 7-2 Group profiles representing the study orientation in mathematics of the 2001 POSC students

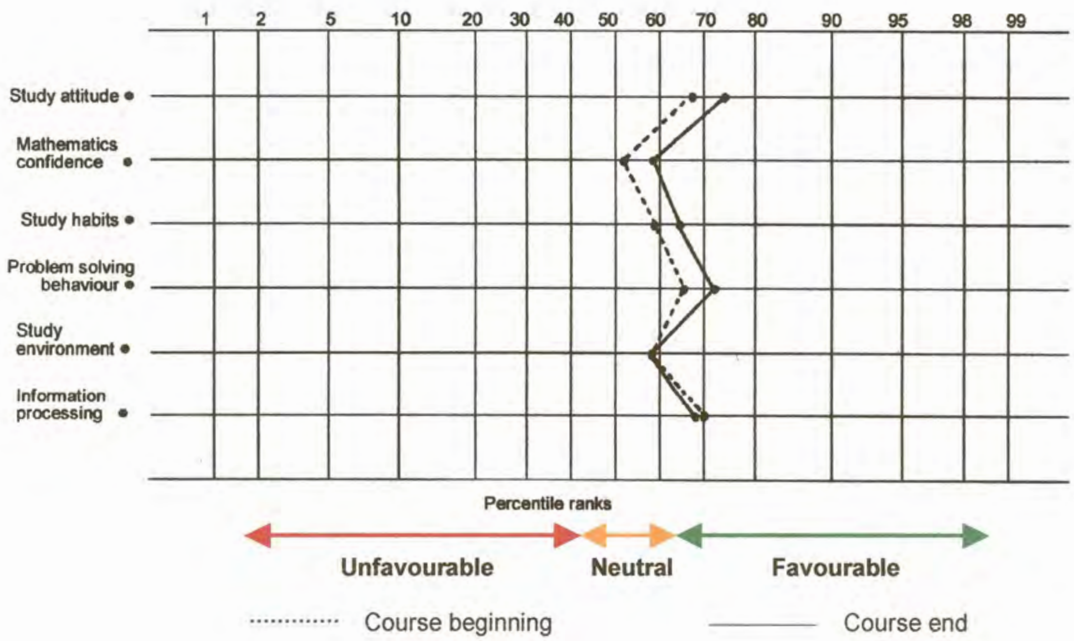

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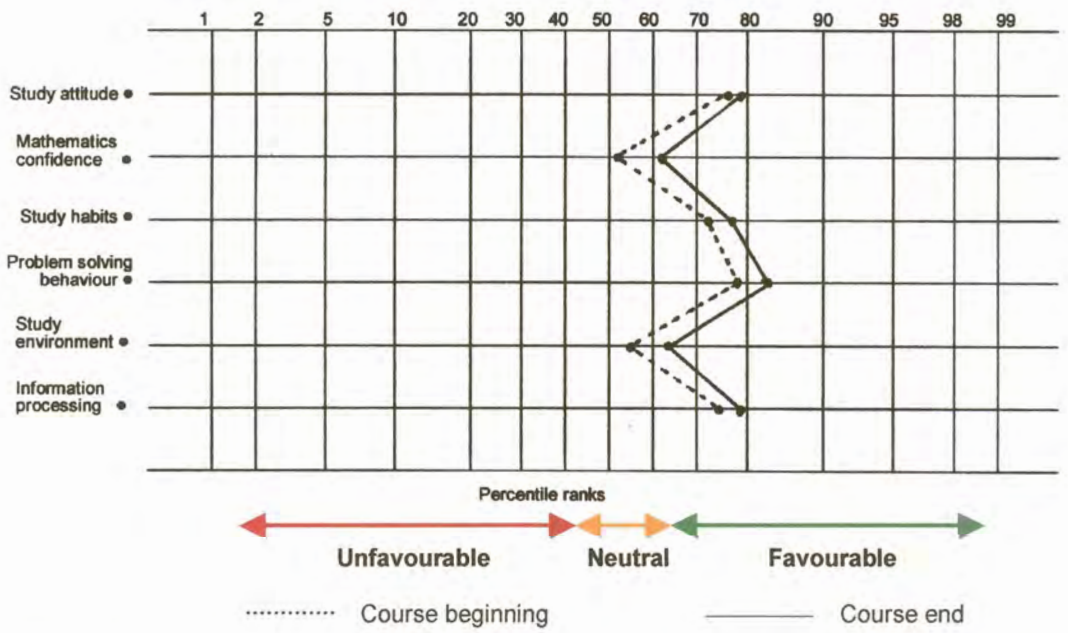
Figure 7-3 Group profiles representing the study orientation in mathematics of the 2002 POSC students



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7.1.2 Performance in mathematics

In Figure 7-4 the final marks in the standard first semester calculus course of first year engineering students during 2000, 2001 and 2002 are illustrated. These figures (as averages in percentages) give an indication of the performance in mathematics of students enrolled for the POSC compared to the performance of students on the regular 4YSP and to the performance of the other students on the 5YSP who are not enrolled for the POSC. In Figure 7-5 the average M-sores of the 2000 and 2001 groups are given.[120]

The data in Figure 7-4 indicates that the performance in standard first semester calculus course of the POSC students (left columns) compares favourably with those of the students on the regular 4YSP (right columns) and that the POSC group outperformed the other students on the 5YSP (middle columns).

When comparing the performance of the three groups in Figure 7-4, it must be kept in mind that all first year engineering students attend the same classes in the calculus course; that all the students on the 5YSP receive tutoring in mathematics but that the POSC students have the lowest M-score[121] of the three groups considered. The only difference between the three groups regarding their first semester mathematics experiences is that the POSC students are involved in the mathematics activities of the POSC that are structured according to the learning facilitation strategy proposed in this thesis.

The researcher is aware of the fact that in order to ascertain the real value of the effect of the support in a developmental approach as described in this thesis, the POSC students will have to be followed up further. Comparing first semester academic results (in mathematics) can lead to misinterpretation because of other variables present. However, a preliminary follow-up on the mathematics performance of the POSC students of 2000 and 2001 indicate that the trend in performance of the three groups is also noticeable for their performance in the second semester mathematics courses of the first year. In Figure 7-6 the final marks (as averages in percentages) in the first year mathematics courses are displayed for the POSC students, the other 5YSP students and the 4YSP students in 2000 and 2001.

[120] The M-score of the 2002 POSC group was not available at time of writing.
[121] The M-score of the POSC groups is usually approximately 7 points lower than that of the students on the 4YSP and 2-3 points lower than that of the other students on the 5YSP (Du Plessis, 2002).

It appears that the POSC students' enhanced ability in mathematics is not restricted to mathematics support given in the POSC during the first semester and that the composite approach followed in the proposed learning facilitation strategy contributes to the development of the mathematics potential of the learners.

Figure 7-4 Performance of first year engineering students in the standard first semester calculus course during 2000-2002

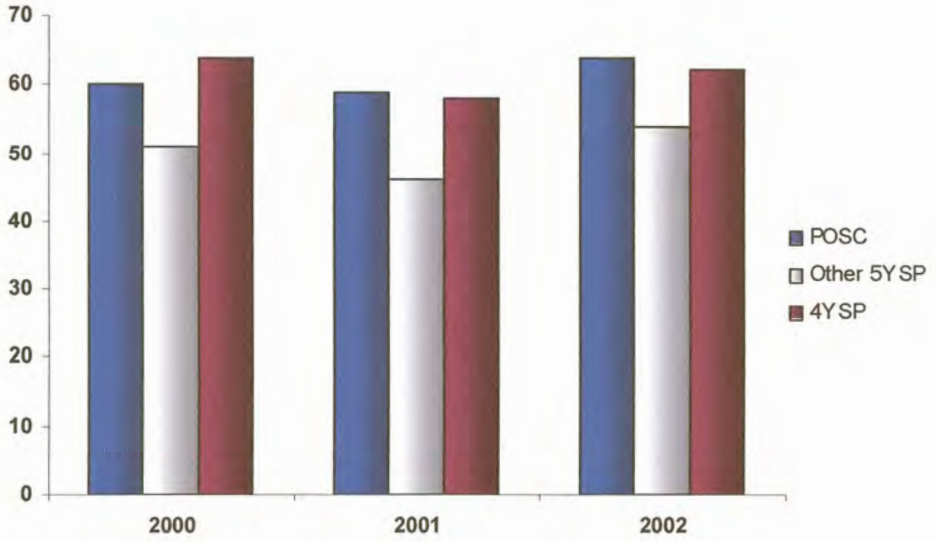

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Figure 7-5 Average M-scores of first year engineering students during 2000-2001

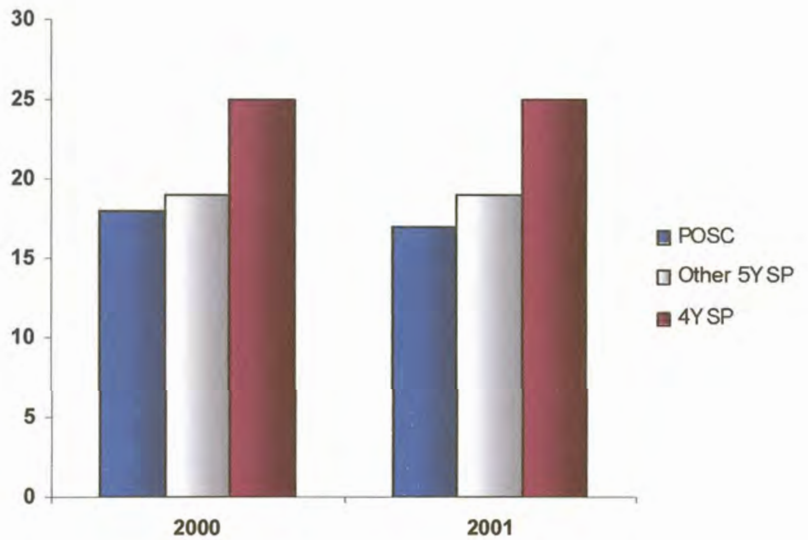

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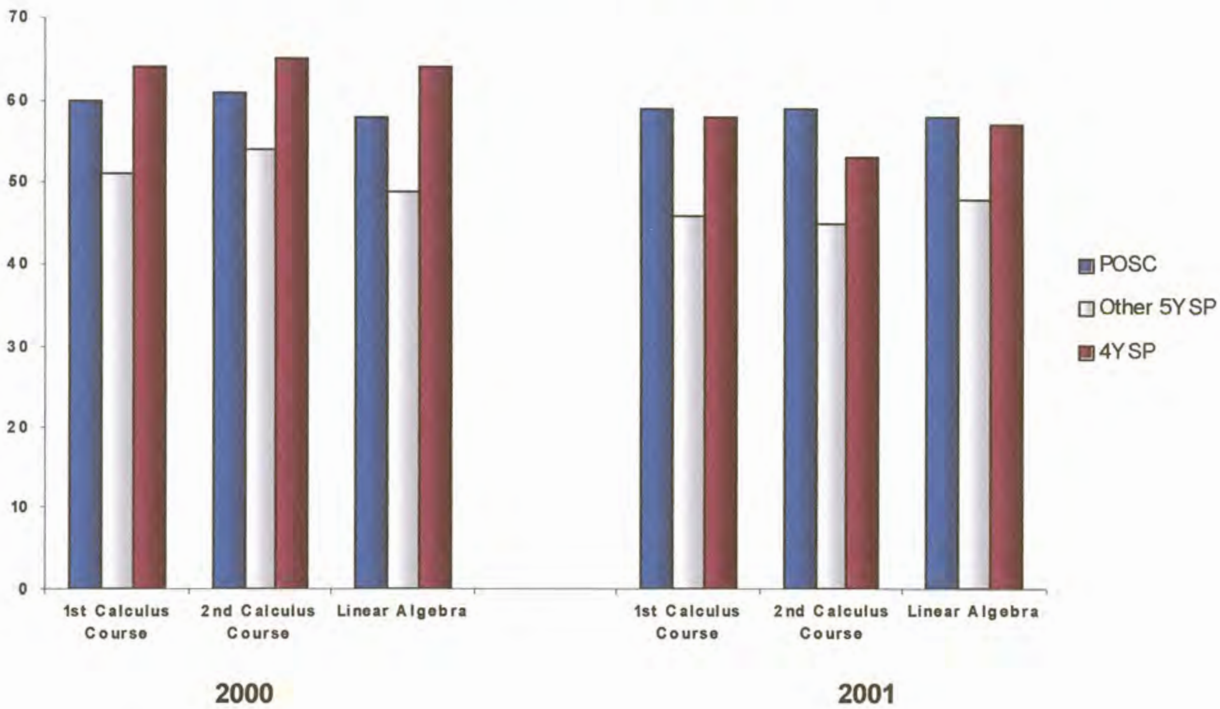
Figure 7-6 Performance of first year engineering students in the standard first year mathematics courses during 2000-2001



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7.1.3 Thinking style preferences of the POSC group

According to the results presented in Chapter 6 regarding the thinking style preferences of the POSC students the following can be deduced: No significant differences in thinking style preferences occur between the POSC students and the first year civil engineering students as measured by the HBDI. However, a significant difference in thinking style preferences regarding the A-quadrant of the Herrmann model occur between the two groups of engineering students on the one hand and the group of science students on the other. This finding corroborates previous research findings that engineers (engineering students) typically favour A-quadrant thinking (Herrmann, 1995 & 1996; Lumsdaine & Lumsdaine, 1995b; Lumsdaine *et al.*, 1999). For the purposes of this study the finding also highlights the fact that in spite of possible initial shortcomings in the educational background of the POSC students, they indeed display the same thinking style preferences (measured by the HBDI) as regular first year engineering students.

From inspection of the scores in the different quadrants[122] of the HBDI it is noticeable that for both the POSC and civil engineering students the score in the C-quadrant of the Herrmann model is the lowest. It can be speculated that this points to the fact that first year engineering students do not obviously or necessarily prefer activities associated with C-quadrant preferences as defined in the Herrmann model. According to Herrmann's model C-quadrant preferences are mostly feeling based and related to interactivity and communication (Herrmann, 1995, 1996, 1998). Herrmann (1995:83) remarks that a preference for the C-quadrant implies having *faith in groups and [being] open to the contribution of each person to a process or goal.* Although research has indicated that peer group learning works well, it seems as if first year engineering students need to be trained to work in groups and the classroom should be structured to foster interactivity.

Investigation of the individual profiles[123] of the POSC students indicates that the students have diverse thinking style preferences as measured by the HBDI. Furthermore, the preferences of the group, when combined, result in an average profile[124] that almost represents a generic whole brain profile. These findings are also in accordance with research that a group of individuals, on the one hand, represents diverse thinking preferences across all four quadrants of the Herrmann model and on the other, that the average profile of a group generally represents the generic whole brain profile displaying preference in all four the quadrants of the Herrmann model (Herrmann, 1995, 1996, 1998; Herrmann-Nedhi, 1999).

Investigation of the choices per category of the ILS[125] and a qualitative analysis thereof indicate, on the one hand, a diversity of learning style preferences as measured by the ILS, and on the other that the distribution of preferences is spread across all the categories of the ILS. At the time of writing and to the knowledge of the author no published research on the use of ILS with first year students on a support course was available and these qualitative findings could be neither compared nor corroborated with similar research.

The results above underscores, amongst other things, the aptness of using a composite strategy for learning facilitation that includes a whole brain approach whereby different thinking and learning styles are accommodated as well as promoted.

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[122] See Chapter 6, Table 6-21 for the scores in the HBDI.
[123] See Chapter 2 section 4.6.6, Figure 4-8 for examples of individual profiles.
[124] See Chapter 6 section 6.6, Figure 6-1 A.
[125] See Chapter 6 section 6.8, Table 6-25, Table 6-2 and Table 6-27.

7.1.4 A strategy for learning facilitation of mathematics in a support course

The diagram in Figure 7-7 illustrates the learning facilitation strategy proposed and defined in this study. The main aspects that contribute to this strategy are summarised as follows:

- The strategy is multifaceted and comprises learning facilitation; the learner and the learning environment.
- Facilitation includes subject content; creating an awareness of thinking and learning preferences and of study orientation and fostering appropriate learning and thinking skills. Facilitation is further aimed at structuring the learning environment for effective and optimal information processing.[126]
- Aspects related to the learner include existing mathematics knowledge; mathematics potential; sense modes for information processing; a (latent) whole brain approach to learning; thinking and learning style preferences; study orientation in mathematics and learner action in terms of acquiring a more favourable study orientation in mathematics and appropriate thinking and learning strategies.[127]
- The learning environment includes, amongst other things, the physical personal and tertiary environment and the contribution and the influences of lecturers and the peer group towards a learner's experienced learning environment.[128]

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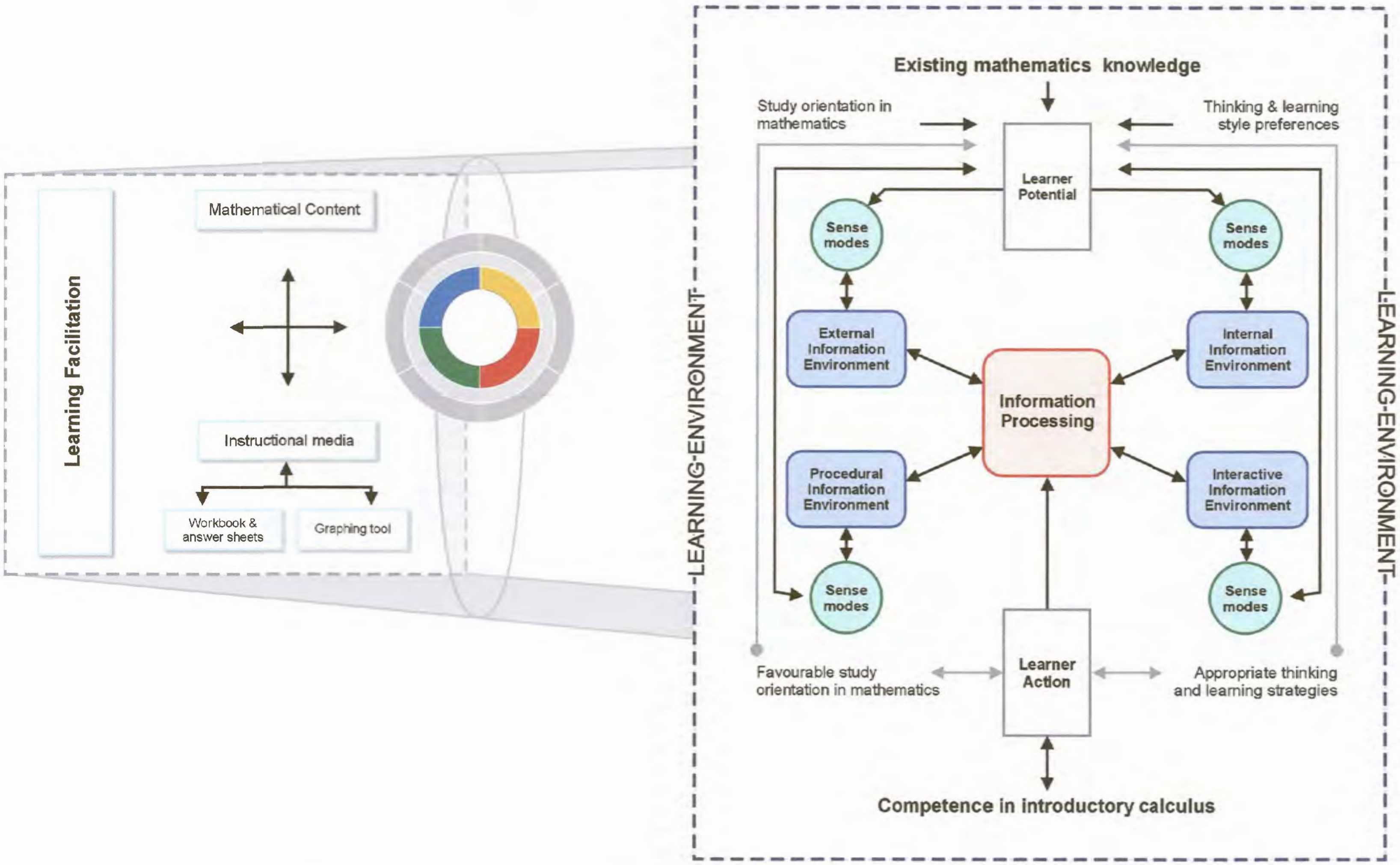
[126] These aspects were discussed in Chapter 3 and in Chapter 5.
[127] These aspects were discussed in Chapter 2 and in Chapter 5.
[128] These aspects were discussed in Chapter 2, Chapter 3 and in Chapter 5.

Figure 7-7 A multifaceted and composite approach to the learning facilitation of mathematics in a support course



Proposed and compiled by the author

7.2 Limitations of the study

In general, the researcher acknowledges the fact that the present study was carried out with a relatively small group of participants; that the interpretation of the results is done within the context of the research topic and that another researcher working from a different perspective may interpret the same data in his/her own way.

However, it should be borne in mind that restricting a study to a specific group in a particular setting is one of the core aspects of action research *in order to improve the rationality and justice of [the] own ... educational practice, as well a [the] understanding of [the] practice and the situations in which [this] practice [is] carried out* (Kemmis & McTaggart, 1988:5).

In particular, the following limitations are acknowledged. Regarding the Study Orientation Questionnaire in Mathematics Tertiary (SOMT) that was developed in the present study from the existing Study Orientation Questionnaire in Mathematics (SOM), it should be pointed out that no factor analysis was done because the number of respondents to the SOMT was insufficient for this purpose. For the same reason, the norm table was not edited.

Regarding the proposed learning facilitation strategy, no specific attention in the research focused on the development of the sense modes (auditory, visual and kinaesthetic). However, it can be asserted that these competencies are inherently also developed when learners are engaged in the mathematical activities using the graphing tool, analysing visual images and formulating mathematical concepts verbally in their communication with the facilitator (and their peers) and in writing mathematics.

7.3 Conclusions

The primary objective of the research reported in this study was to define and implement a strategy for the learning facilitation of mathematics in a support course for first year engineering students. This goal was met as the aspects that constitute the strategy were defined and the strategy was implemented during 2000-2002. To determine the possible effects of this strategy, four research questions were investigated. These concerned determining the thinking and learning style preferences of the POSC students; their study orientation in mathematics at the beginning and the end of the POSC and their performance in mathematics. The effects of the proposed learning facilitation strategy were qualitatively and quantitatively investigated and interpreted. From these results it can be deduced that the combined aspects (illustrated in Figure 7-7) that constitute the learning facilitation strategy proposed in this thesis seemingly have a beneficial effect on the learners involved.

7.4 Recommendations

Although the aim of the study was met, a few aspects emerged in the course of the study that pose opportunities for further research. These include the need to further investigate the following:

- The possible use of the proposed learning facilitation strategy (or aspects thereof) with first year students (other than engineering students) enrolled for a support course in mathematics.

- The possible use of the proposed learning facilitation strategy (or aspects thereof) with first year students registered for a regular study programme.

- The implementation of the SOMT with a variety of students from different tertiary institutions in order to carry out a factor analysis on the SOMT.

- The possible adaptation of the SOMT as an electronic version including online scoring and immediate feedback.

- The use of the online version of the Felder Solomon Index of Learning Styles (ILS) to create an awareness of thinking and learning preferences and to compare preferences for mathematics learning to that of learning in other subjects. It is recommended that on one occasion the ILS can be done with the specific instruction to students to interpret the questions of the ILS as they apply to mathematics activities. This can then be followed up in a few weeks time by letting students interpret the questions of the ILS with regard to another subject. The distribution of preferences for a particular group and the possible differences in distribution of preferences according to the ILS for different subjects could also be investigated.

In addition to the recommendations regarding further research, the following remarks concerning the use of the proposed learning facilitation strategy (illustrated in Figure 7-7) are made:

- When surveys or questionnaires (such as the HBDI, ILS or SOMT) are used, they should be incorporated into activities as part of the learning facilitation strategy.

- In South Africa the administering of the HBDI is costly and not easily done as part of course activities. Therefore, it is recommended that the ILS is used so that students become aware of their own learning style preferences. The availability of the ILS as an accessible, online or paper-based, self scored instrument with immediate feedback contributes to its efficacy.

Lastly, by presenting the conclusions and giving suggestions for further research and practice, the intention is not to restrict the implications of the study to these aspects. In essence the author is of the opinion that the value of this study is in highlighting the effectiveness of a composite and multifaceted approach in the learning facilitation of mathematics when the development of the mathematics potential of a learner is at stake.

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Appendix A

This appendix includes copies of the letters of consent for the study undertaken as well as for the use of students' data and comprises:

The consent of the Faculty Committee for Research Ethics and Integrity of the Faculty of Engineering, Built Environment and Information Technology.

The consent of the Faculty Committee for Research Ethics of the Faculty of Natural and Agricultural Sciences.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
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3 April 2002

Reference number: E/EBIT/01/2002

University of Pretoria
Pretoria 0002 Republic of South Africa Tel 012-420-4111
Fax 012-420-4555 http://www.up.ac.za

Faculty of Engineering,
Built Environment and
Information Technology

Ms TM Steyn
School of Engineering
University of Pretoria
Pretoria
2000

Dear Ms Steyn

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your application refers

1. I hereby wish to inform you that your research project titled *A learning facilitation strategy for mathematics in a support course for first year engineering students at the University of Pretoria* has been approved by the Committee.

2. This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Codes of Research Ethics of the University of Pretoria, if action is taken beyond the approved proposal.

3. According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of any member of the Faculty Committee who will deal with the matter.

4. The Committee must be notified on completion of the project.

The Committee wishes you every success with your research project.

I. du Plessis
Dr Ina du Plessis
Chair: Faculty Committee for Research Ethics and Integrity.

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YUNIBESITHI YA PRETORIA

University of Pretoria

Pretoria 0002 Republic of South Africa Tel (012) 420-4111
Fax (012) 362-5190 http:/www.up.ac.za

Faculty of Natural &
Agricultural Sciences
http://www.up.ac.za/academic/science/
Gold Fields Computer Centre
for Education
Phone (012) 420-2470 Fax (012) 362-5297

Prof J C van Staden
e-mail: jcvs@gold.up.ac.za

8 April 2002

Prof R M Crewe
Dean: Faculty of Natural and Agricultural Sciences
University of Pretoria
Pretoria.

Dear Prof Crewe,

Mrs TM Steyn: Aplication for inclusion of students' data in PhD thesis.

I am aware of mrs. Steyn's research. She started to collect data while being a staff member of the Gold Fields Computer Centre. She later moved to the Faculty of Engineering where she continued this research. I confirm that, while at the Gold Fields Computer Centre, the conditions under which the data was collected, were as stated in her application.

I am also familiar with the HBDI thinking styles assessment system. It is a non-contentious system providing valuable insights to individuals. If the results are used anonymously, as mrs Steyn intends to do, no harm, in my opinion, could be done to any individual or group.

I therefore find no grounds, ethical or otherwise, to deny mrs Steyn permission to use the data collected here, as part of her PhD.

Yours sincerely

Johan van Staden
Director: Discovery Centre @ Tuks

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June 12, 2002
Prof J van Staden
Discovery Centre@Tuks
UNIVERSITY OF PRETORIA

University of Pretoria

Ethics Committee
Faculty of Natural and Agricultural Sciences
E-mail: ethics@postino.up.ac.za

Dear Prof van Staden

Project: **Inclusion of student data in PhD thesis (EC020604-010)**

The project conforms to the requirements of the Ethics Committee.

Yours sincerely,

Prof NH Casey

Chairman: Ethics Committee
Faculty of Natural and Agricultural Sciences

Appendix B

This appendix includes an example of a worksheet and accompanying answer sheet from:

Greybe, W., Steyn, T. & Carr, A.1998. *Fundamentals of 2-D function graphing – a practical workbook for precalculus and introductory calculus.* Cape Town: Oxford University Press.

An adapted version of one of the exercises is also included.

Solving Inequalities and Piecewise Defined Functions

6

In this worksheet you will

- extend your knowledge of *Master Grapher for Windows*
- solve inequalities graphically
- explore a piecewise defined function

hints for solving **inequalities** with *Master Grapher for Windows*

Hints for solving inequalities with the *Grapher:*

- Plot the function and use one or more fixed lines to partially define the area of the graph window which contains the solutions.
- Use a vertical moving line and a right mouse button click to define the area of the graph window which contains the solutions.
- **Remember that explorations with a graphing tool are always done from left to right.**
- If you are in doubt as to the choice of the dimensions of the graph window, start with the default graph window: [-10, 10] x [-10, 10]
- Use **zoom** if applicable.

Solutions must be determined graphically and answers given to two decimal places.

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1 Use a suitable graph window and draw a complete graph of function f where $f(x) = -0.41x^2 + 3.9x + 2.8$

1.1 Write down the dimensions of the graph window that you use.

1.2 Solve for x: $-0.41x^2 + 3.9x + 2.8 > 0$
Give the dimensions of the graph window that you use.

1.3 Solve for x: $-0.41x^2 + 3.9x + 2.8 \leq -7.8$
Give the dimensions of the graph window that you use.

1.4 Solve for x: $-0.41x^2 + 3.9x + 2.8 > 5.2$
Give the dimensions of the graph window that you use.

2 Use applicable graphs to solve for x: $-\frac{3}{4} < \frac{3-x}{2} \leq 8$
Give the dimensions of the graph window that you use.

3.1 Use applicable graphs to solve for x: $|3.2x - 2.7| > 0.9$
Give the dimensions of the graph window that you use.

3.2 If $a \leq |3.2x - 2.7| \leq b$, determine the values of a and b given that $-0.34 \leq x \leq 2.5$
Give the dimensions of the graph window that you use.

4.1 Use the default graph window and draw a complete graph of f where $f(x) = \frac{2.2x + 3.4}{|x - 1.7|}$
Observe what the graph looks like.

4.2 Change the dimensions of the graph window to [-5, 10] x [-5, 20].
You can compare the graph in the two different graph windows as follows:
Click on **View**.
Click on **Previous Graph**.

The graph is displayed in the [-10, 10] x [-10, 10] graph window.

Click on **View** again.
Click on **Previous Graph**.

The graph is displayed in the [-5, 10] x [-5, 20] graph window.

4.3 Determine the intersection with the Y-axis.
Give the dimensions of the graph window that you use.

4.4 Solve for x: $\frac{2.2x+3.4}{|x-1.7|}=0$
Give the dimensions of the graph window that you use.

4.5 Solve for x: $\frac{2.2x+3.4}{|x-1.7|}>0$ and give the dimensions of the graph window that you use.

4.6 Redraw the graph of f in a graph window with dimensions [-5, 10] x [-5, 50]
What seems to happen with the function values $f(x)$ as x gets nearer and nearer to the value 1.7 ?

4.7 Is $x=1.7$ part of the solution to question **4.4** ?
Motivate your answer algebraically.

5.1 Use the default graph window and draw the graphs of f_1, f_2 and f_3 defined by
$f_1(x)=-|1.4x-3.6|+5$, $f_2(x)=x^2+3.5x-5.64$ and
$f_3(x)=1.86$ on the same set of axes.

5.2 Write down the domain and range of f_1
5.3 Write down the domain and range of f_2
5.4 Write down the domain and range of f_3
5.5 Draw fixed vertical lines at $x = -5$ and at $x = 1$
5.6 Use the graphs of f_1, f_2 and f_3 in question **5.1** and the lines drawn in question **5.5** as guidelines to draw a freehand sketch of the function g defined by:

$$g(x)=\begin{cases}1.86 & x\le -5\\ x^2+3.5x-5.64 & -5<x<1\\ 2 & x=1\\ -|1.4x-3.6|+5 & x>1\end{cases}$$

Hint: Use the graphs given on the answer sheet to compile g by tracing the appropriate section with colour.

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Your sketch must clearly indicate:

- the intersection with the axes
- the domain of g
- the range of g
- the zeros of g

5.7 Write down the domain and range of the function g

5.8 For which values of x is $g(x) > 0$?

5.9 Determine the values of x given that $-1 < g(x) < 1$

6 Two scuba divers explored a reef close to the shore. They swam out for 50m on the surface and then dived towards the reef at a trajectory described by the function $f(x) = 0.002x^2 - 0.574x + 23.746$ The divers then ascended to a depth of 15m below the surface to explore the reef at this depth for a further 50m still heading offshore. Finally they ascended to the surface at a trajectory described by the function $g(x) = 0.09x - 35.61$

Note

The distance from the shore is represented on the X-axis and the depth below the surface on the Y-axis.

6.1 Use a graph window with suitable dimensions to display the graphs representing the dive.

6.2 Draw a freehand sketch representing the dive.

6.3 Define a function p to describe this dive. Let x represent the distance from the shore and $p(x)$ the depth below the surface.

6.4 What was the maximum depth of this dive ?

6.5 How deep were the divers when they were 80m offshore ?

6.6 The most interesting part of the reef occurred at a depth of 15m. How far offshore was it ?

6.7 How far offshore did the divers start their final ascent ?

6.8 At what distance from the shore did they reach the surface again ?

6.9 Calculate the distance that the divers swam in the final ascent to the surface.

Name:____________________________ Student no: ______________ Date:__________

Note: The **dimensions of the graph window** required for the answers in this worksheet must **not** be that of the zoomed window but the window displaying a complete graph of the function.

Dimension of graph window	Solution(s)
1.1	
1.2	
1.3	
1.4	

2	

3.1	
3.2	

4.3	
4.4	
4.5	
4.6	
4.7	

Name: ____________________ Student no: ____________ Date: __________

5.2 Domain of f_1 = Range of f_1 =	**5.6**
5.3 Domain of f_2 = Range of f_2 =	
5.4 Domain of f_3 = Range of f_3 =	
5.7 Domain of g = Range of g =	

5.8

5.9

6.1 Dimensions of the graph window:

6.2

Name:__________ Student no: __________ Date:__________

6.3	
6.4	6.5
6.6	6.7
6.8	
6.9	

An adaptation of Question 6 of Worksheet 6[§]

Two scuba divers explored a reef close to the shore. They swam out for 50m on the surface and then dived towards the reef at a trajectory described by the function $f(x) = 0.002x^2 - 0.574x + 23.746$. The divers then ascended to a depth of 15m below the surface to explore the reef at this depth for a further 50m still heading offshore. Finally they ascended to the surface at a trajectory described by the function $g(x) = 0.09x - 35.61$

Note	The distance from the shore is represented on the X-axis and the depth below the surface on the Y-axis.

Use a graphing utility and a graph window with suitable dimensions to display the graphs representing the dive.

1 Draw a freehand sketch to represent the dive.

2 Define a function p to describe this dive. Let x represent the distance from the shore and $p(x)$ the depth below the surface.

2 What was the maximum depth of this dive?

4 How deep were the divers when they were 80m offshore?

5 The most interesting part of the reef occurred at a depth of 15m. How far offshore was it?

6 How far offshore did the divers start their final ascent?

7 At what distance from the shore did they reach the surface again?

8 Calculate the distance that the divers swam in the final ascent to the surface.

[§] In this adaptation the pictures were added to orientate those students who do not have a frame of reference regarding scuba diving. Although it is not part of the research reported in this thesis, it can be mentioned that this example was preceded in 2002 by course activities in skills training on accessing information through a traditional library (books) as well as an internet search. In addition students were shown a short video on a scuba dive.

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Answer sheet

1		
2		
3	4	5
6	7	
8		

Appendix C

This appendix includes examples of questions in the final version of the Study Orientation Questionnaire in Mathematics Tertiary (SOMT) as it was used in this study. The final version of the SOMT resulted from various editing, done in this research study, to the original Study Orientation Questionnaire in Mathematics (SOM) published in 1996:

Maree, J.G. 1996. *Study orientation: maths questionnaire.* Pretoria: Human Sciences Research Council.

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Name: .... **Date:** ....

This questionnaire is a survey regarding various aspects concerning your study orientation towards **mathematics at university**. Your answers will be treated confidentially.

Consider each of the questions below and then rate yourself according to one of the five possible options that are explained below. You are asked to rate yourself not as you think you should do or feel, or as you think others rate you, but as **you yourself** are in the **habit of doing or feeling**.

For every question, make an ✓ in the box to the left of the category that best describes your feeling about the statement **with reference to your university mathematics** to date.

Please note that there are no right or wrong answers.

Make sure that you do not omit any question.

Rarely means	0-15% of the time
Sometimes means	16-35% of the time
Frequently means	36-65% of the time
Generally means	66-85% of the time
Almost always means	86-100% of the time

1. I enjoy solving Maths problems.

☐ Rarely ☐ Sometimes ☐ Frequently ☐ Generally ☐ Almost always

2. While answering tests or exams in Maths, I panic

☐ Rarely ☐ Sometimes ☐ Frequently ☐ Generally ☐ Almost always

3. I catch up missed work in Maths.

☐ Rarely ☐ Sometimes ☐ Frequently ☐ Generally ☐ Almost always

4. I explain Maths to my fellow students.

☐ Rarely ☐ Sometimes ☐ Frequently ☐ Generally ☐ Almost always

5. My lecturer uses words that I do not know and that confuse me.

☐ Rarely ☐ Sometimes ☐ Frequently ☐ Generally ☐ Almost always

Appendix D

This appendix includes examples of questions in the Herrmann Brain Dominance Instrument (HBDI) (Herrmann, 1995:66-67; 1996:321-323) as well as an example of a full-sized profile from the database of the author of this thesis.

Herrmann, N. 1995. *The creative brain* (2nd ed.). Kingsport: Quebecor Printing Group.

Herrmann, N. 1996. *The whole brain business book*. New York: McGraw-Hill.

BIOGRAPHICAL INFORMATION

Please complete **every** question according to the directions given. Each response, including your answers to questions 2, 3 and 4, provide important data. When directions are not followed or data is incomplete we are unable to process your survey, and must return it to you.

1. Name ______________________ 2. Sex: M ☐ F ☐
3. Educational focus or major ______________________
4. Occupation or job title ______________________

Describe your work (please be as specific as possible) ______________________

____

HANDEDNESS

5. Which picture most closely resembles the way you hold a pencil?

A ☐  B ☐  C ☐  D ☐ 

6. What is the strength and direction of your handedness?

A ☐ Primary left B ☐ Primary left, some right C ☐ Both hands equal D ☐ Primary right, some left E ☐ Primary right

SCHOOL SUBJECTS

Think back to your performance in the elementary and/or secondary school subjects identified below. Rank order all three subjects on the basis of how well you did: **1** = best; **2** = second best; **3** = third best.

7. ______ Math 8. ______ Foreign language 9. _____ Native language or mother tongue

Please check that no number is duplicated: The numbers **1, 2,** and **3 <u>must be used once</u>** and **<u>only once</u>**. Correct if necessary.

WORK ELEMENTS

Rate each of the work elements below according to your strength in that activity, using the following scale: **5** = work I do best; **4** = work I do well; **3** = neutral; **2** = work I do less well; **1** = work I do least well. Enter the appropriate number next to each element. **Do not use any number more than <u>four</u> times.**

10. ______ Analytical
11. ______ Administrative
12. ______ Conceptualizing
13. ______ Expressing Ideas
14. ______ Integration
15. ______ Writing
16. ______ Technical Aspects
17. ______ Implementation
18. ______ Planning
19. ______ Interpersonal Aspects
20. ______ Problem Solving
21. ______ Innovating
22. ______ Teaching/Training
23. ______ Organization
24. ______ Creative Aspects
25. ______ Financial Aspects

Please tally: Number of 5's_____, 4's_____, 3's_____, 2's_____, 1's_____. If there are more than **<u>four</u>** for any category, please redistribute.

KEY DESCRIPTORS

Select **<u>eight</u> adjectives** which best describe the way you see yourself. Enter a **2** next to each of your **eight** selections. Then change one **2** to a **3** for the adjective which **best** describes you.

26. ______ Logical
27. ______ Creative
28. ______ Musical
29. ______ Sequential
30. ______ Synthesizer
31. ______ Verbal
32. ______ Conservative
33. ______ Analytical
34. ______ Detailed
35. ______ Emotional
36. ______ Spatial
37. ______ Critical
38. ______ Artistic
39. ______ Spiritual
40. ______ Rational
41. ______ Controlled
42. ______ Mathematical
43. ______ Symbolic
44. ______ Dominant
45. ______ Holistic
46. ______ Intuitive
47. ______ Quantitative
48. ______ Reader
49. ______ Simultaneous
50. ______ Factual

Please count: <u>seven</u> 2's and <u>one</u> 3? Correct if necessary.

HBDI™ Profile Overlay

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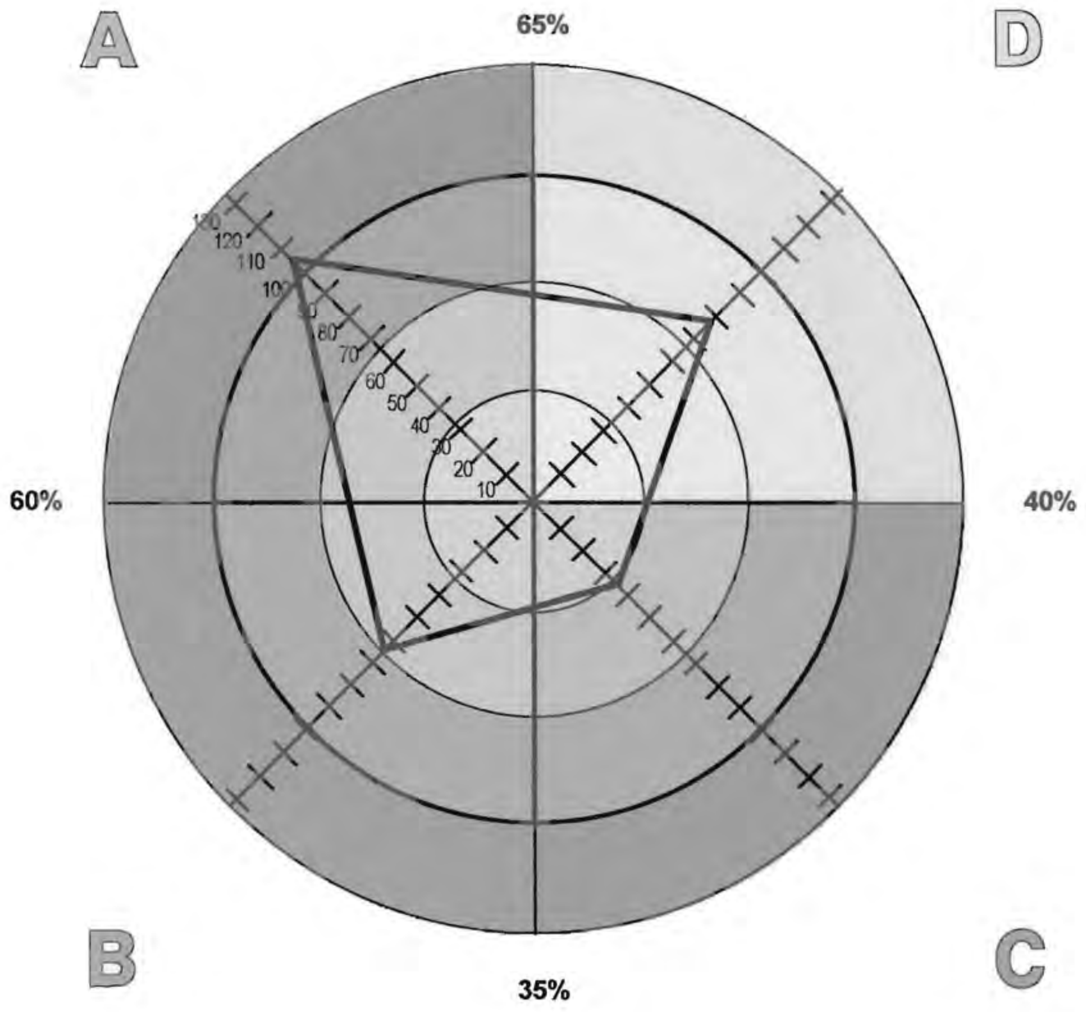
[redacted]

Quadrant:	A	B	C	D
Preference Code:	1	2	2	1
Adjective Pairs:	7	6	1	10
Profile Score:	105	65	35	77



Appendix E

This appendix includes a copy of the Lumsdaine and Lumsdaine Learning Activity Survey (LAS) that was used in this research study. This survey was adapted from Lumsdaine and Lumsdaine (1995:83, 86, 89,93).

Lumsdaine, E. & Lumsdaine, M. 1995. *Creative problem solving – thinking skills for a changing world*. Singapore: McGraw-Hill.

Name: ______________________ UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA Date: __________

Survey on learning activity preferences of First Year Engineering Students

About the survey:

Please note that it is not a test and it is not compulsory. It is merely a survey to get an indication of the activities that you find easy and like doing. So, why do you have to complete it and how will you be able to use the results? By completing the survey honestly, you will hopefully get an indication of your thinking style preferences and you will also become aware of those activities that you do not like. Developing skills to utilise activities, associated with your lesser preferences, may contribute to success in your academic career and in your communication with other people.

What to do:

In Sections 1 – 4 below, circle the dots of those items that are *easy* for you **and** that you *enjoy* doing.

Section 1

- Looking for data and information
- Organising information logically in a framework (but not down to the last detail)
- Listening to informational lectures.
- Reading textbooks.
- Studying example problems and solutions.
- Thinking through ideas in a rational and critical manner.
- Doing library searches.
- Doing research using principles associated with scientific methods.
- Making up a hypothesis (tentative assumption), then testing it to find if it is true.
- Judging ideas that are based on facts and logical reasoning.
- Reading (studying) technical information.
- Knowing how much things cost; studying financial information.
- Knowing how computers work; using them for information processing.
- Dealing with things, rather than with people.
- Dealing with reality and the present, rather than with future possibilities.

Section 2

- Following directions (guidelines) carefully instead if trying to do something your own way.
- Doing detailed homework problems neatly and conscientiously.
- Testing theories and procedures to find flaws and shortcomings.
- Doing lab work step by step.
- Writing a sequential report on the results of lab experiments.
- When using computers there must be detailed guidelines and tutoring.
- Finding practical uses for knowledge learned – theory is not enough.
- Planning projects; doing schedules and then executing them according to plan.
- Listening to detailed lectures.
- Taking detailed, comprehensive notes.
- Studying according to a fixed schedule in an orderly environment.
- Making up a detailed budget to manage your money.
- Practising new skills through frequent repetition.
- Taking a field trip (gaining on-site knowledge) to learn about organisations and procedures.
- Writing a "how-to" manual (keeping detailed instructional notes) about a project.

Section 3

- Listening to others and sharing ideas and intuitions.
- Motivating yourself by asking "why" and by looking for personal meaning.
- Learning through sensory input – moving, feeling, smelling, tasting, listening.
- Hands-on learning by touching, feeling and using a tool or object.
- Using group-study opportunities and group discussions.
- Keeping a journal to record feelings and spiritual values, not details.
- Doing dramatics: the physical acting out of emotions is important, not imagination.
- Taking people oriented field trips.
- Gaining knowledge of other cultures to find out about the people and how they live.
- Studying with classical background music, or making up rap songs as a memory aid.
- Reading (studying) people oriented case studies.
- Respecting others' rights and views; people are important, not things.
- Learning by teaching others.
- Preferring visual to audio information to make use of body language clues.
- Reading the preface of a book to get clues on the author's purpose.

Section 4

- Looking for the big picture and context, not the details, of a new topic.
- Taking the initiative in getting actively involved to make learning more interesting.
- Doing simulations and asking "what-if" questions.
- Making use of the visual aids in lectures. Preferring pictures to words when learning.
- Doing open-ended problems and finding several possible solutions.
- Appreciating the beauty in a problem and the elegance of the solution.
- Leading a brain storming session – wild ideas, not the team, are important.
- Experimenting and playing with ideas and possibilities.
- Like to have physical adventures and explore new places.
- Thinking about trends.
- Thinking about the future.
- Relying on intuition to find solutions, not on facts or logic.
- Synthesising (combining) ideas and information to come up with something new.
- Using future-oriented case discussions.
- Trying a different way (not the general procedure) of doing something.

Name: ______________________ UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA Date: __________

Learning activity preference distribution

To determine your preferred mode(s) of learning activities, do the following analysis:

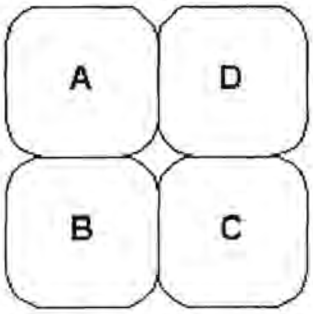
- Count the total number of circled dots in each of the sections above and write it down in the 2nd column of Table 1 below.
- Add up the total for all the responses (Section 1-4) and write it down.
- Calculate the average number of circled dots for the responses in each of Sections 1-4: divide total § by 4.

Table 1

	Number of circled dots	
Section 1		Quadrant A
Section 2		Quadrant B
Section 3		Quadrant C
Section 4		Quadrant D
Total:Sections 1-4	§	

Average number of circled dots (Divide total § by 4):

Figure 1



How to interpret Figure 1:

The quadrant with the highest score is likely the quadrant representing your strongest preferences for learning activities, especially if the score is much higher than your average.

Here are two examples to illustrate the above interpretation:

Example 1:
Number of circled dots: Section 1=12; Section 2 =3 Section 3=7 Section 4=8
Total Sections 1-4: 30
Average/quarter: 7.5 circled dots
From these results, it can be said that this student prefers learning activities in the A-quadrant, which is learning activities associated with those listed in Section 1.

Example 2:
Number of circled dots: Section 1=3; Section 2 =1 Section 3=3 Section 4=2
Total Sections 1-4: 9. Average/quarter: 2 circled dots.
No valid conclusion on preferred learning activities could be drawn due to insufficient data points.

Appendix F

This appendix includes:

Examples of questions in the printed version of the Felder Soloman Index of Learning Styles (ILS).

Examples of questions answered in the online version of the ILS as well as a printout of the results obtained from completing the online version.

A handout on *Learning Styles and Strategies* that is recommended reading for anyone who does the ILS.

All the above documents accessible from links at: *www.ncsu.edu/effective_teaching/*

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INDEX OF LEARNING STYLES*

Barbara A. Soloman
First-Year College
North Carolina State University
Raleigh, North Carolina 27695

Richard M. Felder
Department of Chemical Engineering
North Carolina State University
Raleigh, NC 27695-7905

DIRECTIONS

Circle "a" or "b" to indicate your answer to every question. Please choose only one answer for each question.

If both "a" and "b" seem to apply to you, choose the one that applies more frequently.

1. I understand something better after I
   (a) try it out.
   (b) think it through.
2. I would rather be considered
   (a) realistic.
   (b) innovative.
3. When I think about what I did yesterday, I am most likely to get
   (a) a picture.
   (b) words.
4. I tend to
   (a) understand details of a subject but may be fuzzy about its overall structure.
   (b) understand the overall structure but may be fuzzy about details.
5. When I am learning something new, it helps me to
   (a) talk about it.
   (b) think about it.
6. If I were a teacher, I would rather teach a course
   (a) that deals with facts and real life situations.
   (b) that deals with ideas and theories.
7. I prefer to get new information in
   (a) pictures, diagrams, graphs, or maps.
   (b) written directions or verbal information.
8. Once I understand
   (a) all the parts, I understand the whole thing.
   (b) the whole thing, I see how the parts fit.
9. In a study group working on difficult material, I am more likely to
   (a) jump in and contribute ideas.
   (b) sit back and listen.
10. I find it easier
    (a) to learn facts.
    (b) to learn concepts.
11. In a book with lots of pictures and charts, I am likely to
    (a) look over the pictures and charts carefully.
    (b) focus on the written text.
12. When I solve math problems
    (a) I usually work my way to the solutions one step at a time.

NC STATE UNIVERSITY

Index of Learning Styles Questionnaire

Barbara A. Soloman
First-Year College
North Carolina State University
Raleigh, North Carolina 27695

Richard M. Felder
Department of Chemical Engineering
North Carolina State University
Raleigh, NC 27695-7905

Directions

Please provide us with your full name. Your name will be printed on the information that is returned to you.

Full Name
Student

For each of the 44 questions below select either "a" or "b" to indicate your answer. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently. When you are finished selecting answers to each question please select the submit button at the end of the form.

1. I understand something better after I
   - ○ **(a)** try it out.
   - ● **(b)** think it through.

2. I would rather be considered
   - ○ **(a)** realistic.
   - ● **(b)** innovative.

3. When I think about what I did yesterday, I am most likely to get
   - ● **(a)** a picture.
   - ○ **(b)** words.

4. I tend to
   - ○ **(a)** understand details of a subject but may be fuzzy about its overall structure.
   - ● **(b)** understand the overall structure but may be fuzzy about details.

39. For entertainment, I would rather
    - (●) **(a)** watch television.
    - ( ) **(b)** read a book.

40. Some teachers start their lectures with an outline of what they will cover. Such outlines are
    - ( ) **(a)** somewhat helpful to me.
    - (●) **(b)** very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,
    - ( ) **(a)** appeals to me.
    - (●) **(b)** does not appeal to me.

42. When I am doing long calculations,
    - ( ) **(a)** I tend to repeat all my steps and check my work carefully.
    - (●) **(b)** I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been
    - (●) **(a)** easily and fairly accurately.
    - ( ) **(b)** with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to
    - ( ) **(a)** think of the steps in the solution process.
    - (●) **(b)** think of possible consequences or applications of the solution in a wide range of areas.

When you have completed filling out the above form please click on the Submit button below. Your results will be returned to you. If you are not satisified with your answers above please click on Reset to clear the form.

Submit | Reset

Last Updated: June 29, 1999 :bh
Dr. Richard Felder, felder@eos.ncsu.edu

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NC STATE UNIVERSITY

Learning Styles Results

```
Results for: Student

ACT                                          X              REF
     11   9   7   5   3   1   1   3   5   7   9   11
                          <--   -->

SEN                               X                          INT
     11   9   7   5   3   1   1   3   5   7   9   11
                          <--   -->

VIS  X                                                       VRB
     11   9   7   5   3   1   1   3   5   7   9   11
                          <--   -->

SEQ                                               X          GLO
     11   9   7   5   3   1   1   3   5   7   9   11
                          <--   -->
```

- If your score on a scale is 1-3, you are fairly well balanced on the two dimensions of that scale.
- If your score on a scale is 5-7, you have a moderate preference for one dimension of the scale and will learn more easily in a teaching environment which favors that dimension.
- If your score on a scale is 9-11, you have a very strong preference for one dimension of the scale. You may have real difficulty learning in an environment which does not support that preference.

We suggest you print this page, so that when you look at the explanations of the different scales you will have a record of your individual preferences.

For explanations of the scales and the implications of your preferences, click on Learning Style Descriptions.

For more information about learning styles or to take the test again, click on Learning Style Page.

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LEARNING STYLES AND STRATEGIES

Richard M. Felder
Hoechst Celanese Professor of Chemical Engineering
North Carolina State University

Barbara A. Soloman
Coordinator of Advising, First Year College
North Carolina State University

ACTIVE AND REFLECTIVE LEARNERS

- Active learners tend to retain and understand information best by doing something active with it--discussing or applying it or explaining it to others. Reflective learners prefer to think about it quietly first.
- "Let's try it out and see how it works" is an active learner's phrase; "Let's think it through first" is the reflective learner's response.
- Active learners tend to like group work more than reflective learners, who prefer working alone.
- Sitting through lectures without getting to do anything physical but take notes is hard for both learning types, but particularly hard for active learners.

Everybody is active sometimes and reflective sometimes. Your preference for one category or the other may be strong, moderate, or mild. A balance of the two is desirable. If you always act before reflecting you can jump into things prematurely and get into trouble, while if you spend too much time reflecting you may never get anything done.

How can active learners help themselves?

If you are an active learner in a class that allows little or no class time for discussion or problem-solving activities, you should try to compensate for these lacks when you study. Study in a group in which the members take turns explaining different topics to each other. Work with others to guess what you will be asked on the next test and figure out how you will answer. You will always retain information better if you find ways to do something with it.

How can reflective learners help themselves?

If you are a reflective learner in a class that allows little or not class time for thinking about new information, you should try to compensate for this lack when you study. Don't simply read or memorize the material; stop periodically to review what you have read and to think of possible questions or applications. You might find it helpful to write short summaries of readings or class notes in your own words. Doing so may take extra time but will enable you to retain the material more effectively.

SENSING AND INTUITIVE LEARNERS

- Sensing learners tend to like learning facts, intuitive learners often prefer discovering possibilities and relationships.
- Sensors often like solving problems by well-established methods and dislike complications and surprises; intuitors like innovation and dislike repetition. Sensors are more likely than intuitors to resent being tested on material that has not been explicitly covered in class.
- Sensors tend to be patient with details and good at memorizing facts and doing hands-on (laboratory) work; intuitors may be better at grasping new concepts and are often more comfortable than sensors with abstractions and mathematical formulations.

- Sensors tend to be more practical and careful than intuitors; intuitors tend to work faster and to be more innovative than sensors.
- Sensors don't like courses that have no apparent connection to the real world; intuitors don't like "plug-and-chug" courses that involve a lot of memorization and routine calculations.

Everybody is sensing sometimes and intuitive sometimes. Your preference for one or the other may be strong, moderate, or mild. To be effective as a learner and problem solver, you need to be able to function both ways. If you overemphasize intuition, you may miss important details or make careless mistakes in calculations or hands-on work; if you overemphasize sensing, you may rely too much on memorization and familiar methods and not concentrate enough on understanding and innovative thinking.

How can sensing learners help themselves?

Sensors remember and understand information best if they can see how it connects to the real world. If you are in a class where most of the material is abstract and theoretical, you may have difficulty. Ask your instructor for specific examples of concepts and procedures, and find out how the concepts apply in practice. If the teacher does not provide enough specifics, try to find some in your course text or other references or by brainstorming with friends or classmates.

How can intuitive learners help themselves?

Many college lecture classes are aimed at intuitors. However, if you are an intuitor and you happen to be in a class that deals primarily with memorization and rote substitution in formulas, you may have trouble with boredom. Ask your instructor for interpretations or theories that link the facts, or try to find the connections yourself. You may also be prone to careless mistakes on test because you are impatient with details and don't like repetition (as in checking your completed solutions). Take time to read the entire question before you start answering and be sure to check your results

VISUAL AND VERBAL LEARNERS

Visual learners remember best what they see--pictures, diagrams, flow charts, time lines, films, and demonstrations. Verbal learners get more out of words--written and spoken explanations. Everyone learns more when information is presented both visually and verbally.

In most college classes very little visual information is presented: students mainly listen to lectures and read material written on chalkboards and in textbooks and handouts. Unfortunately, most people are visual learners, which means that most students do not get nearly as much as they would if more visual presentation were used in class. Good learners are capable of processing information presented either visually or verbally.

How can visual learners help themselves?

If you are a visual learner, try to find diagrams, sketches, schematics, photographs, flow charts, or any other visual representation of course material that is predominantly verbal. Ask your instructor, consult reference books, and see if any videotapes or CD-ROM displays of the course material are available. Prepare a concept map by listing key points, enclosing them in boxes or circles, and drawing lines with arrows between concepts to show connections. Color-code your notes with a highlighter so that everything relating to one topic is the same color.

How can verbal learners help themselves?

Write summaries or outlines of course material in your own words. Working in groups can be particularly effective: you gain understanding of material by hearing classmates' explanations and you learn even more when you do the explaining.

SEQUENTIAL AND GLOBAL LEARNERS

- Sequential learners tend to gain understanding in linear steps, with each step following logically from the previous one. Global learners tend to learn in large jumps, absorbing material almost randomly without seeing connections, and then suddenly "getting it."
- Sequential learners tend to follow logical stepwise paths in finding solutions; global learners may be able to solve complex problems quickly or put things together in novel ways once they have grasped the big picture, but they may have difficulty explaining how they did it.

Many people who read this description may conclude incorrectly that they are global, since everyone has experienced bewilderment followed by a sudden flash of understanding. What makes you global or not is what happens before the light bulb goes on. Sequential learners may not fully understand the material but they can nevertheless do something with it (like solve the homework problems or pass the test) since the pieces they have absorbed are logically connected. Strongly global learners who lack good sequential thinking abilities, on the other hand, may have serious difficulties until they have the big picture. Even after they have it, they may be fuzzy about the details of the subject, while sequential learners may know a lot about specific aspects of a subject but may have trouble relating them to different aspects of the same subject or to different subjects.

How can sequential learners help themselves?

Most college courses are taught in a sequential manner. However, if you are a sequential learner and you have an instructor who jumps around from topic to topic or skips steps, you may have difficulty following and remembering. Ask the instructor to fill in the skipped steps, or fill them in yourself by consulting references. When you are studying, take the time to outline the lecture material for yourself in logical order. In the long run doing so will save you time. You might also try to strengthen your global thinking skills by relating each new topic you study to things you already know. The more you can do so, the deeper your understanding of the topic is likely to be.

How can global learners help themselves?

If you are a global learner, it can be helpful for you to realize that you need the big picture of a subject before you can master details. If your instructor plunges directly into new topics without bothering to explain how they relate to what you already know, it can cause problems for you. Fortunately, there are steps you can take that may help you get the big picture more rapidly. Before you begin to study the first section of a chapter in a text, skim through the entire chapter to get an overview. Doing so may be time-consuming initially but it may save you from going over and over individual parts later. Instead of spending a short time on every subject every night, you might find it more productive to immerse yourself in individual subjects for large blocks. Try to relate the subject to things you already know, either by asking the instructor to help you see connections or by consulting references. Above all, don't lose faith in yourself; you will eventually understand the new material, and once you do your understanding of how it connects to other topics and disciplines may enable you to apply it in ways that most sequential thinkers would never dream of.

- Click on tell me more for more information about the learning styles model and implications of learning styles for instructors and students.

- Click here to return to Richard Felder's home page.

Appendix G

This appendix includes examples showing the format of the feedback sheets that were used during the research reported in this thesis.

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Individual student's photo

My preferences as in May 2001

1. Felder Soloman Index of learning style

Use the inventory that you received back and indicate preferences as *mild*; *moderate* or *strong*.

For processing information:	Reflective	Active
For perceiving information:	Sensing (logical, factual)	Intuitive
For the way in which information is presented:	Verbal	Visual
For progressing to understand information:	Sequential	Global

2. Survey for First Year Engineering students of preferred learning/thinking activities:

Enter percentage of your preferences as compiled on the survey form in each of the quadrants.

Logical Factual Critical Deductive Analyse Technical Sequential	Experiential Conceptual Intuititive Inductive Synthesise Imaginative Global
Structured Organised, planned Detail Evaluative Individual	Experiential Emotional Feeling Cooperative

Student: ....

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Your Profile of the SOM as in March 2001

	1	2	5	10	20	30	40	50	60	70	80	90	95	98	99
Study attitude •															
Math confidence •															
Study habits •															
Problem solving behaviour •															
Study environment •															
Information processing •															

Percentile ranks

Average (Study attitude + Math confidence + Study habits + Problem solving behaviour + study milieu):

Your Profile of the SOTM as in September 2001

	1	2	5	10	20	30	40	50	60	70	80	90	95	98	99
Study attitude •															
Math confidence •															
Study habits •															
Problem solving behaviour •															
Study environment •															
Information processing •															

Percentile ranks

Average (Study attitude + Math confidence + Study habits + Problem solving behaviour + Study environment):

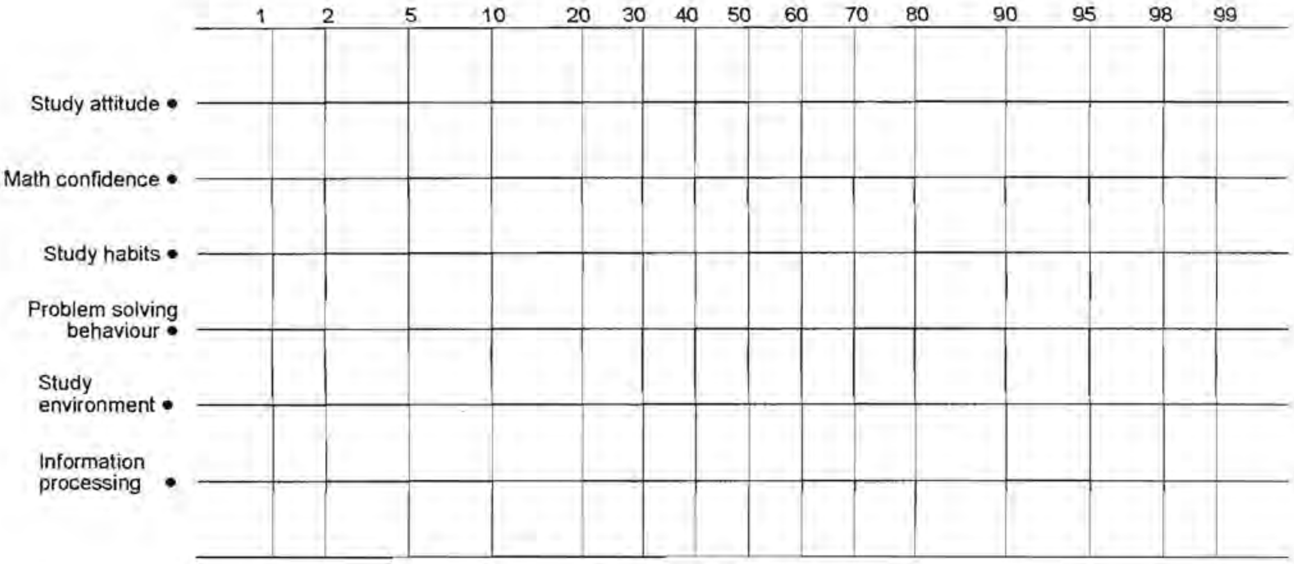
Feedback on the Study UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA ematics Tertiary.

March 2002					
SA	MC	SH	PSB	SE	IP

August 2002					
SA	MC	SH	PSB	SE	IP

Use the data above to draw your study orientation profiles on the grid below. Use two different colours representing each profile as in March and August 2002.

My study orientation in mathematics as in 2002



For each of the fields:
A score of 0-39% indicates an unfavourable study orientation
A score of 40-69% indicates a neutral study orientation
A score of 70-100% indicates a favourable study orientation

Explanation of the fields of the study orientation questionnaire:

Study attitude (SA) deals with feelings (subjective but also objective experiences) and attitudes towards mathematics that are manifested consistently and which affect your motivation, expectation and interest with regard to mathematics.

Mathematics confidence (MC) concerns an overall feeling of 'comfort' toward mathematics. An 'uncomfortable' feeling, on the contrary, can be associated with anxiety which manifests itself in insignificant behaviour (like excessive sweating, scrapping of correct answers and an inability to formulate mathematics concepts).

Study habits (SH) refers to the displaying of acquired, consistent and effective study methods.

Problem solving behaviour (PSB) in mathematics includes the strategies that you use in mathematics.

Study environment (SE) includes factors relating to the social, physical and perceived environment.

Information processing (IP) reflects on general and specific learning, summarising and reading strategies, critical thinking and understanding strategies such as optimal use of sketches, tables and diagrams.

Assignment: Analysis of my study orientation in mathematics as in 2002

For this assignment you have to do an analysis of your profile concerning your study orientation in mathematics. Do the analysis according to the guidelines given below and as they apply to your profiles. Off course, like always, you must adhere to the guidelines for writing assignments in JPO 120

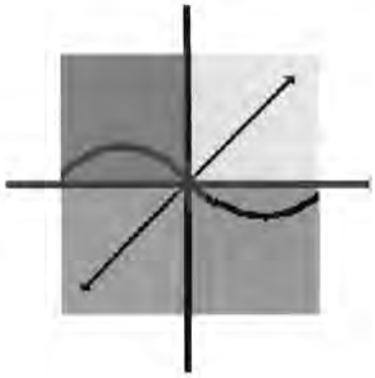
Submission: This analysis and your profiles must be stapled together and be submitted no later than

Friday 23 August 9:00.

1. The fields in which I have improved from March to August 2002 are:
2. The fields in which I have not improved from March to August 2002 are:
3. The fields in which my study orientation remained more or less the same from March to August 2002 are:
4. Possible reasons for my improvement in ....are the following:
5. Possible reasons why I did not improve in ....are the following:
6. Concerning the field(s) in which my study orientation remained more or less the same, I think ....
7. Overall, the study orientation profiles give a good/fair/ etc. indication of my study orientation in mathematics. Motivate your statement.

Appendix H

Colour code of the whole brain model



According to Herrmann (1999), the creator of the whole brain metaphor, the colour designations for each quadrant has the following meaning:

- The upper left A-quadrant typifies **cerebral** processing and therefore the colour chosen to represent this quadrant is **cerulean** blue.
- The lower left B-quadrant indicates strong structure and is colour coded by **green** because green suggests **groundedness**.
- The lower right C-quadrant, because of its **emotional**, feeling and interpersonal orientation, is colour coded by **red** because of the **emotional passion** implied by this colour.
- The upper left D-quadrant signifies **imaginative** qualities and is represented by **yellow** which indicates **vibrancy**.

The author of this thesis used the original idea of the four quadrant whole brain metaphor of Ned Herrmann to compile the figure above. This figure depicts a whole brain approach to the exploration of 2-D functions and their graphs.

Herrmann, N. 1999. Information given to TM Steyn during personal communication.

Treat people as if they were what they ought to be and you help them become what they are capable of being.

Johann W von Goethe