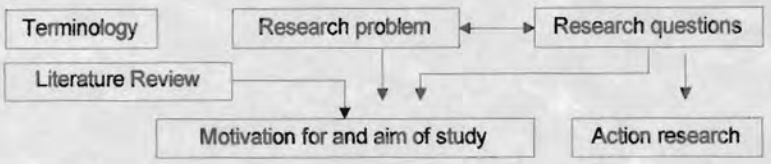
Chapter 1



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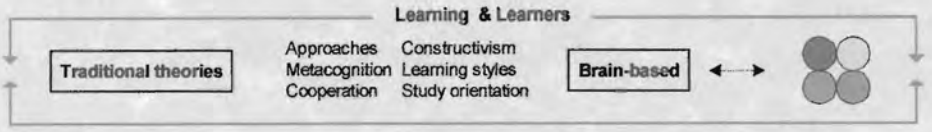

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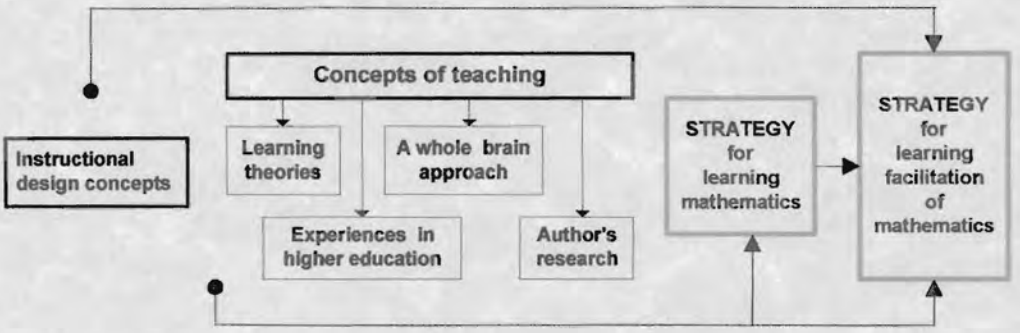

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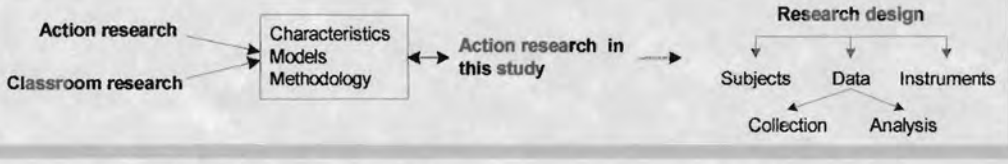

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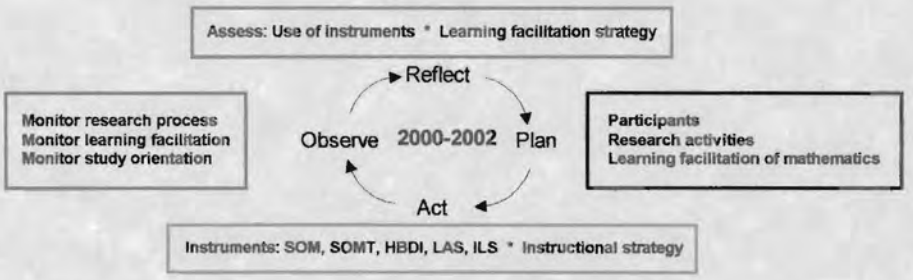

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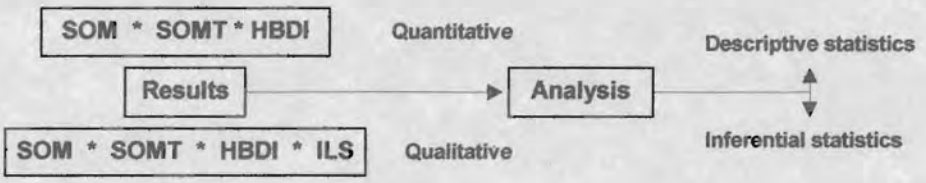

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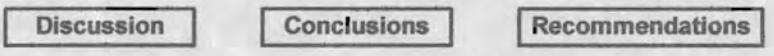

Research design

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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)

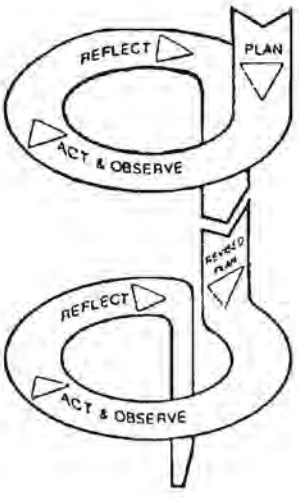


Figure 4-1 A

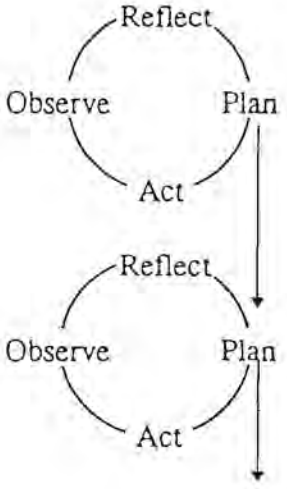


Figure 4-1 B

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)

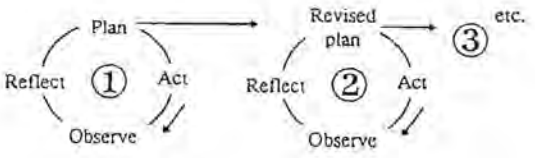


Figure 4-2 A

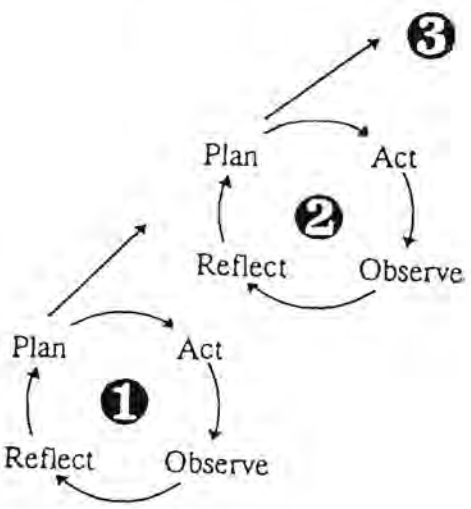


Figure 4-2 B

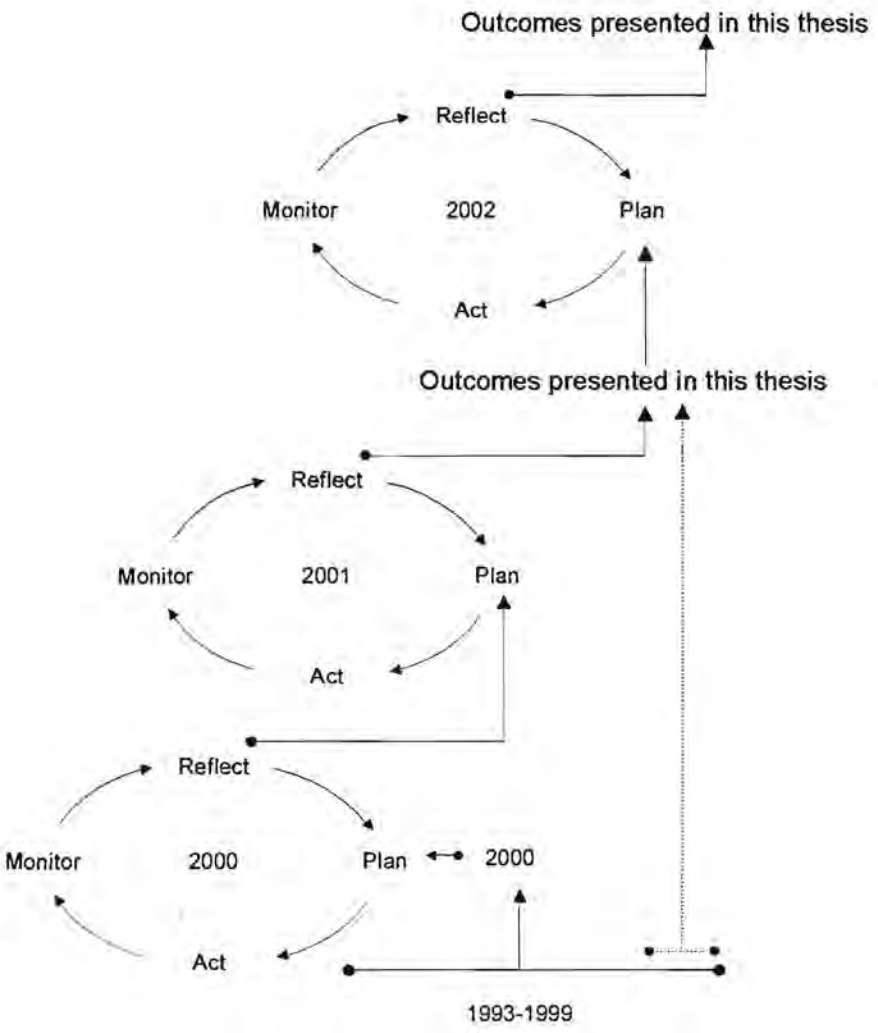
Zuber-Skerritt (1992b:13, 1997 III-3:13)

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

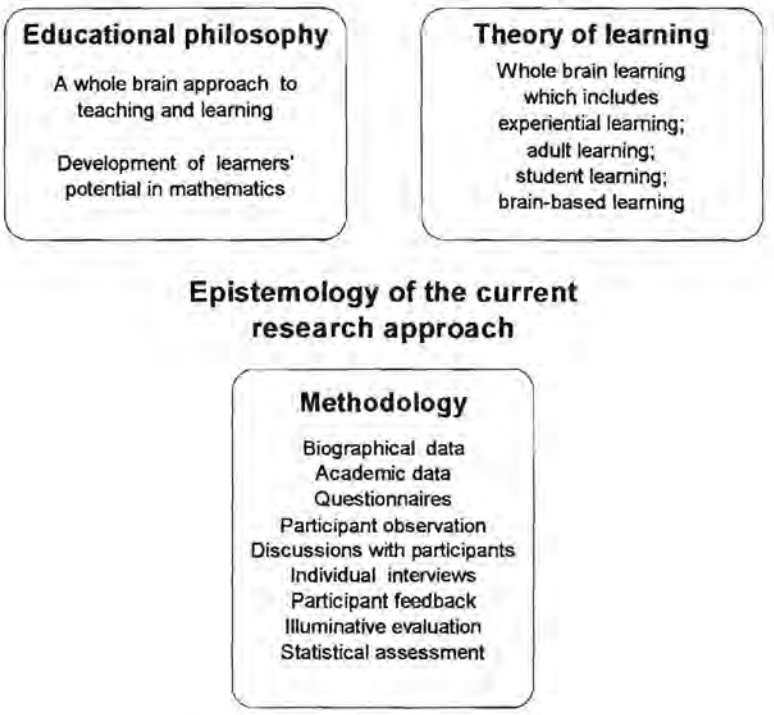
Plan	Analysis of the problem Identify the vision, the general idea. Formulate general idea that something might be improved. State questions to be addressed. Select the research procedures, methodology and instruments. Choose evaluation procedures: qualitative and quantitative. Prioritise and define 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.

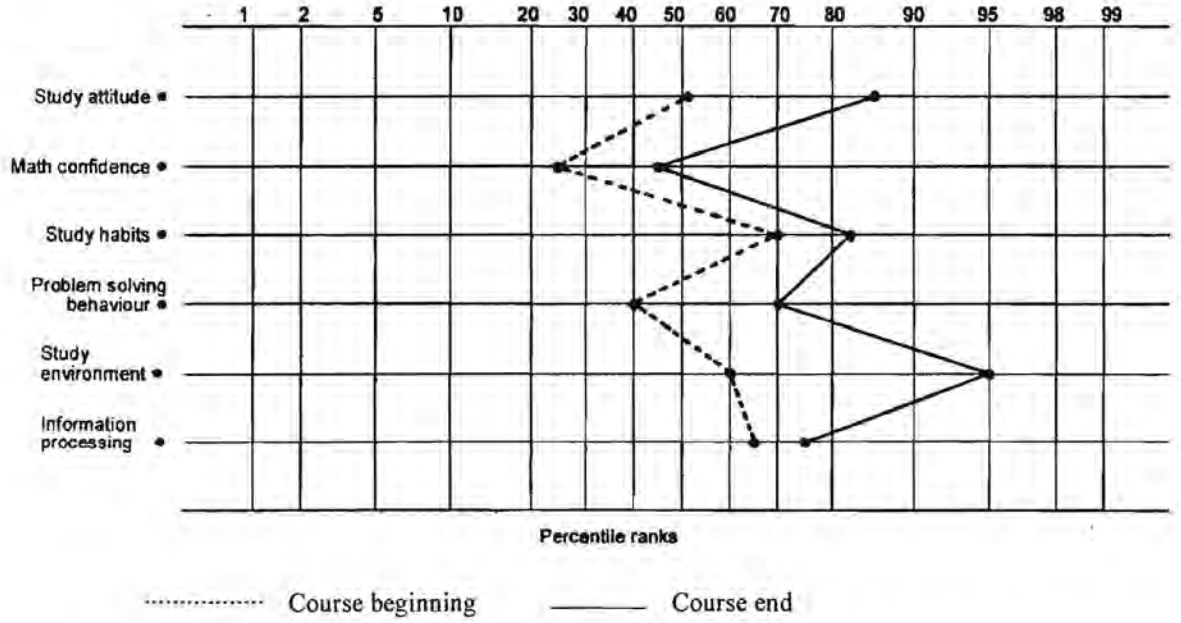
Table 4-10 Edits in the original SOM for use with tertiary students

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



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

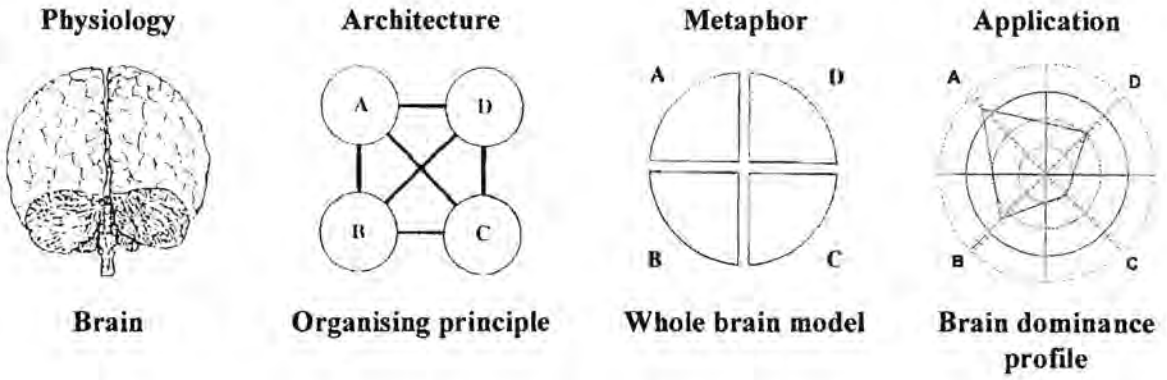
	Adaptation details in	Used for	Used as a pre/post intervention instrument	Date implemented
Original SOM adapted	Table 4-10	2000 POSC group 2001 POSC group	Pre-intervention Pre-intervention	March 2000 March 2001
SOMT-1	Table 4-11, Table 4-12 and Table 4-13	2000 POSC group 2001 POSC group	Post-intervention 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.

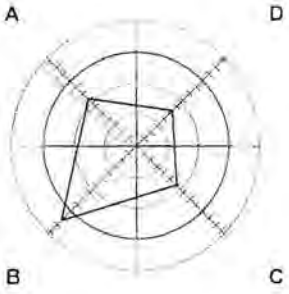
The HBDI comprises 120 items. The items include biographical data as well as questions on topics of handedness and secondary (high) school performance in mathematics and language. In a section on adjective pair data, forced choices have to be made between two different terms. The adjective pair data 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

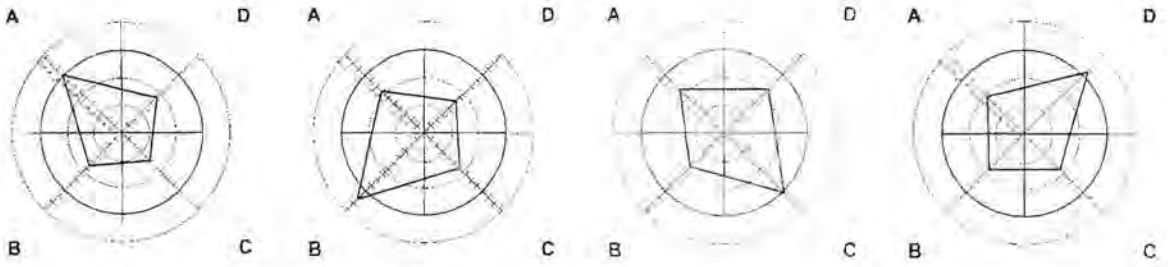


Figure 4-8 A

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.

[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.