THE FAMILY MATHS PROGRAMME: 
FACILITATORS’ ABILITY TO IMPLEMENT 
INQUIRY-BASED TEACHING AND LEARNING 
WITH LEARNERS AND PARENTS 

by 

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Despite the fact that the facilitation of inquiry learning is a core methodology in the General Education and Training (GET) band of the South African National Curriculum Statement, rote learning and memorization of algorithms remains common practice in many mathematics classrooms. The inquiry-based Family Maths professional development programme, offered by the Nelson Mandela Metropolitan University, attempts not only to support the transformative education practices targeted by the South African National Department of Education, but also to extend them beyond the school walls to the community at large. This study investigates the extent to which the Family Maths professional development programme develops facilitators’ ability to implement inquiry-based learning. It also seeks to explore which aspects of the programme are effective in developing an inquiry-based approach. The research undertaken is an empirical study of 39 facilitators and uses both qualitative and quantitative methods. The facilitators’ inquiry beliefs and ability to implement inquiry learning was measured by means of questionnaires, observation schedules and interviews. As the ‘teacher as facilitator of inquiry-based teaching and learning’ is a requirement of all South African teachers, the findings of this research should make a meaningful contribution to the field of mathematics teacher education in the South African context.
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CHAPTER ONE

INTRODUCTION AND OVERVIEW

1. INTRODUCTION

South Africa has experienced a crisis situation in its educational policies for many decades and this has continued since the new dispensation of 1994 (de Lange, 1981; Taylor & Vinjevold, 1999, Asmal, 2000). Traditionally the South African education system was driven by the ideology of Fundamental Pedagogics, which had wide ranging detrimental effects on teachers’ thinking and practice and was characterised by major inequalities, high failure rates, emphasis on rote learning and unimaginative teaching methods (ANC, 1994; Chisholm, 1993; Enslin, 1990; Hartshorne, 1992; Hofmeyr, 1993; NEPI, 1992). Over the past decade the government has been striving to root out heavily entrenched traditional approaches and replace them with a new vision for education in which all learners are empowered for responsible citizenship in the 21st century (Department of Education, 2002). The Revised South African National Curriculum Statement (hereafter referred to as RNCS) forms part of a process of education transformation focusing on the introduction of Outcomes Based Education (OBE) which is underpinned by an inquiry-based philosophy of teaching and learning (Moll, 1994).

The Family Math programme, which was conceptualised and designed at the Lawrence Hall of Science in Berkeley, California as a subset of the EQUALS programme is designed to allow meaningful links to be made between school and home learning by using cooperative learning strategies (Thompson & Mayfield-Ingram 1998). The South African Family Maths programme focuses on inquiry-based
learning which supports current thinking on how mathematics learning should take
place and provides contexts for the exploration and implementation of the Revised
National Curriculum Statement (Department of Education, 2002).

2. FAMILY MATH PROGRAMME

As noted above, the Family Math programme was developed as a subset of the
EQUALS programme to redress inequalities perceived in the schooling system in the
United States of America, particularly inequalities in terms of race and gender
(Thompson & Mayfield-Ingram 1998). The strategy aims at dispelling negativity
toward mathematics and encourages learners, parents and other family members to
translate new experiences and concepts into workable solutions through discussion
and the use of hands-on, minds-on, process oriented, inquiry-based activities. This
inquiry-based approach assists in the understanding of important mathematical
concepts and processes. Family Math sessions give learners and parents opportunities
to engage in inquiry-based experiences and to develop higher order thinking skills as
they ask questions, conduct problem solving activities, interpret and discover
solutions while constructing mathematical understanding of content.

The Family Math approach requires teachers to act as facilitators in inquiry-
centered learning situations. Because participants initiate much of the action, teachers
must surrender some degree of control over activities. They are required to encourage
and guide participants by rephrasing questions, providing clues, if requested, or ask
probing questions that may guide them in the right direction. This is an intrinsic part
of the process of effective facilitation.

Inquiry learning is facilitated learning which focuses and supports problem
solving during interaction with students. It recognises and responds to student
diversity and encourages all students to participate fully in the learning process (NSES, 1996). While it is recognised that the characteristics of inquiry apply to all learning areas, this teaching and learning approach is the main focus of the Family Math programme implementation strategy.

3. FAMILY MATHS IN THE SOUTH AFRICAN CONTEXT

The Family Maths (as opposed to ‘Math’ in the USA) programme is based on American philosophy and has operated in South Africa since 1996 by a number of organisations such as the Cooperative Organization for the Upgrading of Numeracy Training (COUNT), the Department of Science, Mathematics and Technology Education (SMATE) at the Nelson Mandela Metropolitan University (NMMU) and the University of the Free State. The largest programme that has been run consistently and continuously over the past five years has been the one offered by SMATE, impacting on an average of two thousand teachers, learners and parents per annum. This research study focuses on the Family Maths programme offered by SMATE at the NMMU.

The Family Maths Programme offered by SMATE provides support for the transformative education practices targeted by the South African National Department of Education (Department of Education, 2002) that extend beyond the school walls to the community at large by offering a creative education practice that reaches teachers, parents, learners and community members. Against a backdrop of national concern about the negativity towards mathematics (Asmal, 2000), the project attempts to:

- Eliminate much of the pressure, anxiety and fear of failure experienced by both parents and their children
- Secure parental and community involvement in learners’ education
• Dispel incorrect perceptions that school mathematics is unrelated to a child’s everyday experience
• Develop language necessary for meaningful communication in mathematics
• Develop problem solving skills
• Develop confidence and enjoyment of mathematics

Family Maths facilitator professional development workshops allow educators to practice inquiry teaching methods which aim at allowing learners the opportunity to solve mathematical problems in a non-threatening atmosphere in which they feel comfortable with risk taking. The training course is implemented over a two year cycle during which facilitators attend quarterly workshops and work collaboratively to present at least one workshop per quarter with parents, children and teachers. These workshops are structured to afford opportunities for participants to engage in fun-filled mathematics activities in a relaxed, non-threatening atmosphere. By using inquiry-based teaching and learning skills, these activities are designed to promote problem solving skills, cognitive development, meaningful discussion opportunities and the use of hands-on materials.

4. STATEMENT OF THE PROBLEM

The reason for this study is that, despite the fact that the facilitation of inquiry learning is a core methodology in the General Education and Training (GET) band of the RNCS (Department of Education, 2002), rote learning and memorization of algorithms remains common practice in many mathematics classrooms (Taylor & Vinjevold, 1999). This may possibly be attributed to the fact that many teachers were not exposed to inquiry learning approaches during their professional teacher training. Nonetheless, these very same teachers are presently charged with teaching by inquiry
as required by the RNCS (Department of Education, 2002). An investigation into the effect of the Family Maths approach, which is underpinned by inquiry learning theory, should make a contribution to the debate in terms of promoting inquiry-based mathematics approaches in the South African context.

5. **RESEARCH QUESTION**

This study investigates the extent to which the Family Maths training programme develops facilitators’ ability to implement inquiry-based learning. The primary research question is therefore:

*To what extent does the Family Maths facilitator training programme develop facilitators’ ability to implement inquiry-based learning?*

The subsidiary questions underpinning the primary question are:

- *Is there a difference in facilitators’ beliefs regarding inquiry learning as they proceed from novice to veteran category?*

- *Is there a difference between the ability to facilitate inquiry learning amongst facilitators who have been participating in the training programme for more than two years, those who have been participating for one to two years, and those who have been participants on the course for less than a year?*

- *How do facilitators’ approaches to facilitating Family Maths workshops change as they engage in the programme?*

- *What aspects of the programme are effective in developing an inquiry-based approach?*
6. RESEARCH DESIGN

The research undertaken is an empirical study which uses both qualitative and quantitative methods to examine participating teachers’ ability to facilitate inquiry learning as they conduct workshops with learners and their parents. The techniques used include questionnaires, observation and interviews.

Facilitators’ inquiry belief system was measured according to a questionnaire which was completed by facilitators from all three categories viz., novice, intermediate and veteran.

The facilitators’ ability to implement inquiry learning was measured by means of observations of facilitators conducting Family Maths workshops with learners and their parents. Discourse amongst learners, parents and teachers’ was observed as teachers attempted to use inquiry-based learning to encourage learners and parents to solve mathematical problems. Two observation schedules were used simultaneously during each workshop. Each observer used a modified workshop interaction coding system observation instrument (Brophy & Good, 1970) to determine the frequency of verbal feedback techniques used by facilitators. The techniques observed were: giving answers, repeating questions, giving clues and rephrasing questions. Observers also used a workshop observation instrument which measured the implementation strategies of the first three stages of inquiry-centred instruction, which was adapted from the United States National Science Education Standards (NSES) of 1996. The observation instruments were designed on the key attributes of inquiry learning as reflected by the literature on the subject.
After each facilitator had presented a workshop they were interviewed for the purposes of deeper probing into their understanding and implementation of their facilitation strategies for inquiry-based learning.

Primary data were generated via various methods which included questionnaires, observation of discussions between teachers, parents and learners and interviews with facilitators.

Goodell (2000) confirmed in her research that providing an opportunity for reflection is an important element in learning to teach for understanding. Lerman (2002) also suggests that it is in reflection that a teacher recognises the conflict between what one wishes to do and what is happening in reality. He further advocates that it is in reflection that brings about change. Facilitators were provided with opportunities to reflect on their practice, and the Family Maths facilitation process, during the research interviews.

7. SAMPLE AND SETTING

A sample of 39 facilitators, predominantly teacher educators and intermediate phase teachers, were selected from amongst the volunteer facilitators to participate in this study. Each of the 39 facilitators was observed once during their facilitation of a workshop, which provided a sufficient sample size for meaningful statistical analyses of the data that was generated (Gravetter, & Walnau, 2002). The selection of facilitators was based firstly on their willingness to participate in the study and also on their availability at the time of workshop observation by trainers of the Family Maths training programme. The 39 selected facilitators were drawn from a population of approximately one hundred teachers and Education Department officials who were participating in the Nelson Mandela Metropolitan University (NMMU) Family Maths
programme in the Eastern and Southern Cape at that time. Facilitators were observed in each of the geographical centres of East London, Port Elizabeth, George, Mossel Bay and Beaufort West. Participants were drawn from each of the following categories of facilitators viz. Novice (less than a year’s participation), Intermediate (one to two year’s participation) and Veteran (more than two years’ participation in the Family Maths programme).

8. ANALYSIS AND INTERPRETATION OF DATA

The quantitative statistical data generated from the facilitator inquiry learning belief system questionnaire and the workshop observation instrument were analysed and subjected to analysis of variance (ANOVA) techniques to provide descriptive and inferential statistics. Quantitative data generated from a second observation instrument, namely, the workshop interaction coding system instrument, were analysed within the framework of the workshop interaction coding system of Brophy and Good (1970).

Qualitative data were also gathered from responses to semi-structured interviews with facilitators. Data gathered from facilitator interview schedules were classified into broad categories and analysed within the framework of the literature reviewed.

9. ETHICAL ISSUES

All of the teachers and educators involved in this study were volunteer participants and the nature of the research project was explained to them. They were also told that it was anticipated that their participation in the study would directly benefit the Family Maths teacher training programme, that the researcher was engaged in a research project that would result in a Master of Education degree and
that the results of the research would be made available to them at the end of the study.

10. SIGNIFICANCE OF THE RESEARCH

In South Africa the Family Maths programme has taken on the challenge of building public awareness and support for greater interest and performance in mathematics. The programme is designed to encourage inquiry-based learning which, in turn, develops higher order thinking skills and facilitates the development of mathematical knowledge, skills and positive attitudes (Thompson & Mayfield-Ingram, 1998). As such, the development of higher order thinking skills, via inquiry learning, should become available to the participants to use in their teaching duties.

The teacher as facilitator of inquiry-based teaching and learning is a requirement of all South African teachers (Department of Education, 2002) and this applies not only to the teaching of mathematics, but to all learning areas. This research, therefore, should not only make a meaningful contribution to the field of mathematics teacher education, but to teacher education as a whole.

The NMMU Family Maths programme has reached thousands of parents, teachers and learners each year. It is therefore important that the teachers’ ability to facilitate inquiry learning effectively is monitored and researched so that the programme is able to reach its goal of promoting inquiry-based teaching and learning in mathematics education.

11. DELIMITATION OF THE RESEARCH

This study focuses on urban, peri-urban and rural schools in the Eastern and Southern Cape. The focus centres, including the rural communities within an eighty
kilometre radius of each centre, include East London, Port Elizabeth, George, Mossel Bay and the nodal area of Beaufort West.

The participants in this study included predominantly Intermediate Phase in-service teachers, school principals and Department of Education officials from the Eastern and Southern Cape.

12. OUTLINE OF THE STUDY

Chapter one of this study provides an overview of the Family Maths facilitator training programme within which the research is carried out. It introduces the research question and the subsidiary questions which underpin the primary question. The overview of the research methods used and a concise literature review set the scene for the study.

Chapter two provides a more comprehensive literature review of theoretical frameworks of inquiry-based teaching and learning, underpinned by constructivism. The way in which inquiry-based instruction impacts on education is investigated and reported.

Chapter three provides an outline of the research design and includes reasons for particular research approaches and methods used. The types of data required and the techniques and tools used for gathering data, including the use of a coding system, questionnaires and interviews, are discussed. A description of the methods used to analyse the data obtained is included.

Chapter four examines the results of the data analysis and findings of the research. The quantitative and qualitative data obtained from questionnaires, observations and interviews were statistically and descriptively analysed and comparisons made across the three categories of facilitators.
Chapter five is a discussion and interpretation of the results reported in chapter four. The results of each subsidiary question are addressed and the analyses of the quantitative and qualitative data are related to the theoretical underpinnings noted in prior chapters, and their relevance to the research question is described. The implications of the findings for the Family Maths teacher development programme, and for teaching and learning of mathematics, are also discussed and conclusions drawn.

Chapter six discusses the implications of the findings described in chapter five for the Family Maths facilitators’ training course. It also includes implications for further research.
CHAPTER TWO

LITERATURE REVIEW

1. INTRODUCTION

In this chapter I describe the historical and political context of education in South Africa as it applies to teaching practices, outline the broad concept of constructivism and inquiry-based teaching and learning and consider various definitions of this concept. I briefly examine how a traditional education system discourages the natural process of inquiry and highlight the importance and implications of inquiry for both teachers and learners. Current thinking on inquiry learning and constructivism is reviewed and a correlation drawn between the two approaches to teaching and learning. I also give a brief outline of the history, ethics and philosophy of the Family Maths programme, which is underpinned by the characteristics of inquiry learning and give a synopsis of the implementation of the Family Maths programme in South Africa. The relationship between inquiry learning and the Family Maths programme is explored and the relevance and impact inquiry learning has had on education throughout the world is highlighted.

The issues discussed above provides the theoretical framework and rationale for the research question of this study, viz., To what extent does the Family Maths teacher training programme develop facilitators’ ability to implement inquiry-based learning?
2. EDUCATION IN SOUTH AFRICA

South Africa’s first democratic government inherited a divided and unequal system of education (Department of Education, 2002). Curriculum change in the post-apartheid South Africa started immediately after the election in 1994 when the National Education and Training Forum began a process of curriculum revision in order to lay the foundations for a single national core curriculum. The Revised National Curriculum Statement (2002) emphasises the need for a shift from the traditional approach to outcomes-based education which is underpinned by constructivism and inquiry-based learning. South Africa is at present in the process of introducing an outcomes-based Education (OBE) approach at all levels, the implementation of which has unfortunately been severely hampered by factors such as large classes, physical condition of many schools, social environment of many pupils, teachers’ inadequate training in OBE and lack of teacher commitment (Webb & Glover, 2004).

2.1 Historical legacy

In 1948 the newly elected Nationalist government introduced a system of “Bantu Education” for Black South Africans (Samuel, 1990). Separate education systems were introduced, with Bantu education having a different and inferior curriculum – usually with no science or mathematics offerings (Hartshorne, 1992). In 1976 African pupils collectively rejected Bantu Education, causing a collapse of schooling in their communities (Cross & Chisholm, 1990). The education and Training Act of 1980 replaced the Bantu Education Acts and the de Lange Commission (1981) was appointed to investigate the education system of South Africa.
2.2 Educational policies

During the apartheid years, Fundamental Pedagogics was characterised by teacher-centeredness, pupil passivity and rote learning. A number of researchers (Chisholm, 1993; Hartshorne, 1992 and Hofmeyr, 1993) suggest that the ideology of Fundamental Pedagogics has had wide ranging detrimental effects on teachers’ thinking and practice. Reports by the ANC (1994) also acknowledged the negative influence this ideology had on education. Chisholm (1993) believes that the values of approaches of fundamental pedagogics hinder the development of critical and innovative teaching strategies. Hofmeyr (1993) asserts that the philosophy of Christian National Education and its offspring, Fundamental Pedagogics, entrenched authoritarian teaching methods and there is broad consensus that teaching and learning in the majority of South African schools currently still leaves much to be desired (Taylor & Vinjevold, 1999). This is borne out by the fact that Kader Asaml, then Minister of Education, commented in the preface of the RNCS document (2002) that it requires the commitment and participation of all who work in education to alleviate the inequality and poverty that still plague the educational experience of too many families and their children.

2.3 Traditional approaches

A traditional approach is characterised by teachers who disseminate knowledge, and student initiated questions and student-to-student interactions are atypical (Brooks & Brooks, 1993). Most teachers rely heavily on textbooks and the information teachers disseminate to students is directly aligned with the information offered by textbooks, providing students with only one view of complex issues and one set of truths which often devalues student thinking (Brooks & Brooks, 1993). “Schooling is premised on the notion that there exists a fixed world that the learner...
must come to know. The construction of new knowledge is not as highly valued as the ability to demonstrate mastery of conventionally accepted understandings” (Layman, 1996:7).

Llewellyn (2005) describes a traditional classroom setting in which students usually sit in straight rows of desks and learn through rote memorization. Students attentively listen to the teacher, who usually stands in the front of the room “imparting” information, while they passively take notes from the board. The lesson is structured around “teacher-talk” and student responses. A single textbook usually guides the teacher’s presentation. Llewellyn further believes that many teachers view learners as passive participants who need to know and master a fixed body of information. The traditional approach is interpreted as being authoritarian, an aspect which, in the South African context, has been attributed to the adoption of Fundamental Pedagogics by the Education Department during the Apartheid era (Chisholm, 1993; Hartshorne, 1992 and Hofmeyr, 1993). According to Taylor & Vinjevold (1999) there is broad consensus that teaching and learning in the majority of South African schools still focuses on teacher-centeredness, pupil passivity and rote learning, a practice which is problematic worldwide, but which is particularly true in South Africa because of the historical legacy of past political practice.

2.4 The crisis in mathematics and science education

It has become apparent, since the release of the de Lange Report in 1981, that the problems surrounding science and mathematics education contribute significantly to the current South African national crisis in education. Little has changed to date; learner achievement is still very poor in general and there are a large number of under-qualified primary and secondary school teachers who do not have the knowledge and skills to teach these subjects competently (Asmal, 2000; Taylor &
Vinjevold, 1999). The above factors are exacerbated by the fact that teaching and learning most often takes place in a second language and in under-resourced classrooms (Taylor & Vinjevold, 1999).

Research has shown that South African teachers appear unable to communicate attitudes of curiosity, respect for evidence, and critical reflection necessary for the development of higher-order cognitive skills (Enslin, 1990). It has also been noted that in the early years of schooling pupils’ listening, speaking, reading and writing skills were poorly developed in both their first language and in English. As further progress at school depends on these four skills, black children, who generally come from disadvantaged homes, are further handicapped by the practices prevalent in their classrooms (Taylor & Vinjevold, 1999).

Other research has shown that learners’ level of language competence in black schools is so poor that they are unable to read the learning material provided for them, and that the tasks and exercises they are given are often conceptually too difficult and beyond their competence (Taylor & Vinjevold, 1999). This leads to a heavy reliance on rote learning and makes the learners dependent on the teachers for everything they learn (Rodseth, 1995; Setati, 1998). In spite of this, South Africa is under tremendous pressure to meet international standards, particularly with regard to science and mathematics teaching and learning. The highly reputable Third International Mathematics and Science study (TIMSS) of 50 countries is the latest to reveal the dismal state of these two subjects at schools in South Africa. (Financial Mail, 2004:23).

The Human Science Research Council (HSRC) of South Africa published a number of reports on the teaching of physical science and mathematics in ‘white’ education in South Africa in the late 1970s and early 1980s. In 1981 the de Lange
commission highlighted the crisis in education in South Africa with regard to extremely poor teaching and learning of science and mathematics. However, according to Howie (2001), it was the results of the Third International Mathematics and Science Study in 1995 that shocked the nation. The results of the 2004 TIMS study revealed that South Africa had come last of the fifty countries who participated. A report in the Financial Mail (December 2004) reveals that there is no significant difference between South Africa’s performance in the latest study of 2004, and the learners performance in the 1999 study. South Africa’s positioning in international studies of teaching and learning science and mathematics, and the failure of the education system to deliver appropriately equipped mathematics and science school leavers, amounts to a national crisis in mathematics teaching and learning.

The Revised National Curriculum Statement was introduced in an attempt to bring about fundamental changes to the mathematics curriculum, how it is taught and how the learners learn (Department of Education, 2002). The review of C2005 in 2000 led by Professor Linda Chisholm was extremely controversial within the ANC, the key players being the Minister of Education, South African Democratic Teachers Union, Departments of Education and Cabinet (Chisholm, 2003). However, the relative independence of the Review Committee members from the ANC meant that the Report of the Review Committee was also independent from the view and approaches dominant within the bureaucracy and teacher unions. Ultimately Cabinet accepted the recommendation of the Review Committee. A middle ground around outcomes-based education was found and role players united around the need for a secular, liberal humanist, rights-based curriculum that recognised the diversity of South Africans. The RNCS was duly produced and became policy early in 2002.
2.5 **The national curriculum statement**

As noted above, with the new political dispensation in South Africa in 1994, a new national curriculum was developed which was legislated in 1995. The new government, largely represented by the formerly oppressed constituency, opted for a liberal, progressive model of education. The new South African curriculum has a clear political agenda aimed at transcending the curriculum of the past, which perpetuated race, class, gender and ethnic divisions and which emphasised separateness, rather than common citizenship and nationhood (Department of education, 1997). This new curriculum, C2005, was characterised by very complex logic and vague content, with Taylor & Vinjevold (1999) claiming that it appears to promote superficiality at the expense of systematic and grounded conceptual development. In the face of strong national criticism C2005 was simplified, refined and strengthened and the Revised National Curriculum Statement of 2002 (grades 0 to 9) was the result of that process. Considering the implications of the South African curriculum reform process described above, the endeavour to implement a curriculum which is relevant in content and context to South African education demanded a strategic, controversial reform process. Considering the crisis in mathematics and science education in South Africa, Gray’s statement which follows, warns of the dangers of a generic curriculum design. Curriculum reform in the developing world is of concern in that it is feared that some countries will simply follow First World developments whether or not they have the capabilities to support the change and with no regard to the relevance to their country (Gray, 1999).

**Rationale and philosophy**

South Africa. The Manifesto on Values, Education and Democracy (Department of Education, 2002) identifies strategies for familiarising young South Africans with the values of the Constitution. These strategies find expression in the RNCS which includes “ensuring equal access to education” (Department of Education, 2002:7) and “freeing the potential of girls as well as boys” (Department of Education 2002:8) as a priority. The Family Maths programme concurs with this priority in making mathematics accessible to learners of all race, gender and background – Kreinberg (1989) states that the Family Maths programme was first developed from a concern with gender equity and grew to encompass issues concerning race and class of all underrepresented students in mathematics.

The government is striving for transformative education practices that extend beyond the school walls to the community at large and the Family Maths programme offers a practical route to doing this by means of a creative and well researched strategy which gives meaning to OBE, underpinned by constructivism and inquiry learning. The South African national mathematics learning area outcomes listed below are promoted by the principles of the Family Maths programme.

1. **NUMBERS, OPERATIONS AND RELATIONSHIPS**

   The learner is able to recognise, describe and represent numbers and their relationships and can count, estimate, calculate and check with competence and confidence in solving problems.

2. **PATTERNS, FUNCTIONS AND ALGEBRA**

   The learner is able to recognise, describe and represent patterns and relationships, and solves problems using algebraic language and skills.
3. **SPACE AND SHAPE**

The learner is able to describe and represent characteristics and relationships between 2-D shapes and 3-D objects in a variety of orientations and positions.

4. **MEASUREMENT**

The learner is able to use appropriate measuring units, instruments and formulae in a variety of contexts.

5. **DATA HANDLING**

The learner is able to collect, summarise, display and critically analyse data in order to draw conclusions and make predictions and to interpret and determine chance variation.

According to Spady (1994), chief proponent of outcomes-based education, outcomes are what learners can actually do with what they know and have learned – they are the tangible application of what has been learned. Spady further explains that outcomes are actions and performances that embody and reflect learner competence in using content, information, ideas and tools successfully. The demonstrative verbs given in the mathematics learning area outcomes above include: recognise, describe, represent, count, estimate, calculate, check, solve, use, collect, summarise, display, analyse, draw conclusions, make predictions, interpret and determine. All of these would require that learners demonstrate their knowledge in measurable actions.

According to the overview of the RNCS (Department of Education, 2002:10-11), “both the process and the content of education are emphasised by spelling out the outcomes to be achieved at the end of the process”. Nancy Kreinberg, current director of EQUALS, from which the Family Maths programme originated (Stenmark 1986; Thompson, 1986; Cossey, 1986), supports the OBE philosophy that “outcomes
encourage a learner-centred and activity-based approach to education” (Department of Education, 2002:1). Problem solving strategies used in Family Maths activities include: looking for patterns, drawing pictures, using tables, diagrams, graphs, calculators and computers, working backwards, estimating and predicting (Kreinberg, 1989).

The RNCS policy document (Department of Education, 2002:4) states that “being mathematically literate enables persons to contribute to and participate with confidence in society”. The mathematics learning area statement of this document follows from the above statement that “access to Mathematics is, therefore, a human right in itself” (Department of Education, 2002:4). The outcomes and assessment standards leave “considerable room for creativity and innovation on the part of teachers in interpreting what and how to teach” (Department of Education, 2002: 12). As such, teaching and learning according to this particular philosophy of outcomes-based education concurs with philosophies which underpin constructivism and inquiry-based education.

**Critical and Developmental Outcomes**

The critical and developmental outcomes of the RNCS, which underpin the rationale and the philosophy of the curriculum statement, are derived from the Constitution and are contained in the South African Qualifications Act (1995). They describe the kind of citizen the education and training system should aim to develop so that learners will develop into responsible citizens of the 21st century (Department of Education, 2002). The Revised National Curriculum Statement attempts to embody and uphold a democratic vision of the society and the citizens that should emerge from our school system. The critical outcomes listed below envisage learners who will be able to:
Identify and solve problems and make decisions using critical and creative thinking

Work effectively with others as members of a team, group, organisation and community

Organise and manage themselves and their activities responsibly and effectively

Collect, analyse, organise and critically evaluate information

Communicate effectively using visual, symbolic and/ or language skills in various modes

Use Science and Technology effectively and critically showing responsibility towards the environment and the health of others

Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation

In turn, the developmental outcomes of the Revised National Curriculum Statement (Department of Education, 2002) envisage learners who are also able to:

Reflect on and explore a variety of strategies to learn more effectively

Participate as responsible citizens in the life of local, national, and global communities

Be culturally and aesthetically sensitive across a range of social contexts

Explore education and career opportunities

Develop entrepreneurial opportunities
The critical and developmental outcomes noted above support and concur with the philosophy of constructivism and inquiry-based education, as does the philosophy underpinning the Family Maths programme. The mathematics learning area, as described in the RNCS (Department of Education, 2002) includes interrelated knowledge and skills which concur with the skills which need mastery in constructivism and inquiry-based education approaches, and the skills fostered by the Family Maths programme. These skills include:

- representation and interpretation
- estimation and calculation
- reasoning and communication
- problem posing
- problem solving and investigation
- describing and analysing

**Learning Outcomes and Assessment Standards**

Learning outcomes of the RNCS are derived from the critical and developmental outcomes noted above. The learning outcomes and assessment standards express the minimum requirements and expectations of learners at each grade level. According to the RNCS (Department of Education, 2002), learning outcomes and assessment standards are cognitively dependent and supportive of each other. As noted previously, the outcomes and assessment standards emphasise participatory, learner-centred and activity-based education and leave considerable room for creativity and innovation on the part of teachers in interpreting what and how to teach. (Department of Education, 2002:12). Also, the RNCS emphasises “the importance of learning support materials and teacher development programmes to
interpret and give expression to the learning outcomes and assessment standards” (Department of Education, 2002:15). The learning outcomes emphasise the importance of using a range of teaching and learning strategies in a variety of contexts, which is also promoted by constructivism and inquiry-based education. These characteristics of outcomes-based education, as interpreted in the South African context, are underpinned by the principles of constructivism and inquiry-based learning and which are, therefore, in accord with the approaches used by the Family Maths programme.

2.6 Implications for teaching and learning

The RNCS overview policy document emphasises the need to transform teaching and learning in South Africa and shift from the traditional aims-and-objectives approach to outcomes-based education (Department of Education, 2002), the characteristics of which underpin inquiry-based teaching and learning. According to Drayton and Falk (2001) inquiry is not process versus content; rather, it is a way of learning content.

Current mathematics education reforms supporting a constructivist perspective suggest that the automation of skills and passive intellectual involvement should be replaced by active learning processes (Hiebert, 1992). According to Anthony (1996) ‘active’ learning denotes learning activities in which students are given considerable autonomy and control of the direction of the learning activities, such as investigational work, problem solving, small group work, collaborative learning and experiential learning. In contrast, ‘passive’ learning activities denotes learning activities in which students are passive receivers of information, include listening to the teacher’s exposition, being asked a series of closed questions, and practice and application of information already presented. The RNCS concurs with the active
learning process in that it states that ‘the mathematics learning area develops an ability to engage in the process of inquiry and investigation’ (Department of Education, 2002).

According to Llewellyn (2005) we can differentiate the characteristics of traditional and inquiry-based classrooms by examining three areas: what the classroom looks like, what the students do, and what the teacher does. Inquiry-based classrooms are described as learner friendly, where learners feel that their teacher and peers value their ideas, thoughts and opinions. The classroom provides opportunities for active involvement in the learning process. Styles of presentation, organisation, questioning skills, and even body language seem to differ from those observed in traditional settings.

According to the National Science Education Standards (1996), teachers should make it clear that each student must take responsibility for his or her work. Teachers also create opportunities for students’ own learning, individually and as members of groups. Teachers do so by supporting students’ ideas and questions and by encouraging them to pursue them. Teachers give individual students active roles in the design and implementation of investigations, in the work with their peers, and in student assessment of their own work (National Research Council, 1994:36).

The RNCS describes mathematics as a human activity that involves observing, representing and investigating patterns and quantitative relationships in physical and social phenomena and between mathematical objects themselves. Through this process new mathematical ideas and insights are generated. This definition of mathematics given by the South African government supports current thinking on how children learn best. The implementation of outcomes-based education, which is
underpinned by inquiry-based education and constructivism, is the required approach to developing learners who will meet the learning outcomes and assessment standards of the RNCS.

3. CONSTRUCTIVISM

According to Llewellyn (2005), constructivists do not view the mind as a ‘blank slate’ or an ‘empty vessel’, as in John Locke’s famous expression *tabula rasa*. In the constructivist approach the student is an active participant in the learning process.

Constructivism is a theory about how we come to know what we know (Llewellyn, 2005). It is founded on the premise that learners construct or make meaning about the world around them based on the context of their existing knowledge. In a constructivist point of view, according to Llewellyn (2005), the learner is constantly filtering incoming information based on his or her existing conceptions and preconceived notions to construct and reconstruct his or her own understanding. Thus the meaning of ‘knowing’ is an active, adaptive and evolutionary process. Although literature expounds many types of constructivism (Ernest, 1995), all seem to embrace the basic principle that ‘learning is not a passive receiving of ready-made knowledge but a process of construction in which the students themselves have to be the primary actors’ (von Glasersfeld, 1995). Rather than passively receiving and recording information, learners actively interpret and impose meaning through the lenses of their existing knowledge structures.

According to Webb and Glover, learners construct meanings of what they see and hear by generating links between what they already know and the new things they experience. They further explain that “the idea that we construct meaning suggests
that it is not so much what we get out of a situation, but what we bring to it, that
determines the sense we make of it” (Webb and Glover, 2004).

3.1 Philosophy underpinning constructivism

Constructivism embraces the basic principle that “learning is not a passive
receiving of ready made knowledge but a process of construction in which the
students themselves have to be the primary actors” (von Glasersfeld, 1995: 120)

A prerequisite for becoming an inquiry-based teacher is embracing a
philosophical mind set founded on the ideals and principles of constructivism
(Llewellyn, 2005). Llewellyn further describes constructivism as a philosophy about
how an individual learns, one in which the student is embedded in active engagement
and is constantly constructing and reconstructing knowledge through environmental
interactions. Constructivism is underpinned by the belief that children best gain
knowledge by inventing it, that they construct knowledge for themselves. According
to Piaget (1973), ‘to understand is to discover, or reconstruct by rediscovery, and such
conditions must be complied with if in the future individuals are to be formed who are
capable of production and creativity and not simply repetition.’ Based heavily on the
work of Piaget, constructivism guides teachers to interact with learners through
questioning and discussion, skilfully responding to the learners’ ideas, and allowing
children to discover relationships and predict future events. “A constructivist
framework challenges teachers to create environments in which they and their
students are encouraged to think and explore. This is a formidable challenge. But to
do otherwise is to perpetuate the ever present behavioural approach to teaching and
learning.” (Brooks & Brooks, 1993:30).

3.2 Constructivism and the South African National curriculum statement
Current mathematics education reforms supporting a constructivist perspective suggest that the automation of skills and passive intellectual involvement should be replaced by active learning processes (Hiebert, 1992). Glenda Anthony in her article entitled, *Active Learning in a constructivist Framework*, defines active learning as denoting learning activities in which students are given considerable autonomy and control of the direction of the learning activities. Learning activities commonly identified in this manner include investigational work, problem solving, small group work, collaborative learning and experiential learning. In contrast, she describes ‘passive learning’ as denoting learning activities in which the students are passive receivers of information, include listening to the teacher’s exposition, being asked a series of closed questions, and practice and application of information already presented. This means that mathematics is most effectively learned through students’ active participation in mathematical situations, rather than through passive acceptance and repetition of knowledge (Ministry of Education, 1992). The RNCS states that ‘Outcomes based education forms the foundation of the curriculum in South Africa. The outcomes encourage a learner-centred and activity based approach to education’. Inquiry based teaching and learning which is underpinned by constructivism is therefore greatly promoted by the South African national curriculum. Herrington (1990) further supports that the active nature of learning, encouraged by curriculum documents, is aligned with the active mental experiences which result in strong acts of construction if student are to learn the desired mathematical understandings.

### 3.3 Constructivism and inquiry learning

Inquiry-based learning is supported by constructivist principals and the findings of Piaget and Vygotsky (Engel, 1996). Piaget viewed learning as an internally driven process, an individual construction, which results from learners
engaging in the world, whereas Vygotsky argued that learners acquire knowledge in the course of social relationships (Moll, 2002; Western Cape Department of Education, 2000). The learner does not construct his/her own knowledge independently, but finds that learning occurs on a social level, within a cultural context. (Moll, 2002; Western Cape Department of Education, 2000).

According to Llewellyn (2005), teachers’ understanding of constructivist principles will enable a better vision of their role as inquiry-based teachers. He also states that constructivist and inquiry-based teachers should be constantly aware of shifting the onus of responsibility from the teacher to the student, enabling the student to become a more independent learner.

4. INQUIRY-BASED LEARNING

Layman (1996) describes inquiry-based learning as continually encouraging students to translate new experiences and concepts into workable solutions through experimentation. Through leaps of insight, trial and error, argumentation, and frustration, students apply the concepts of physics (or any other discipline) to expand what they know and are able to do.

4.1 What is inquiry-based learning?

According to Llewellyn (2005), author of Teaching High School Science Through Inquiry, a prerequisite for becoming an inquiry based teacher is embracing a philosophical mind-set founded on the ideals and principles of constructivism. Because the tenets of constructivism align closely with the practice of inquiry, it becomes essential that inquiry-based teachers have a firm foundation in the propositions of constructivism.
Llewellyn (2005:27) highlights that constructivist learning strategies are compatible with inquiry and learner-centred classrooms and holds that “a prerequisite for becoming an inquiry-based teacher is embracing a philosophical mind-set founded on the ideals and principles of constructivism. He further emphasises that constructivism is one theory or philosophy about how an individual learns, one in which the learner is embedded in active engagement and is constantly constructing and reconstructing knowledge through interaction. A brief definition of constructivism given by Treagust et al. (1996) is, ‘Constructivism focuses on the way in which learners construct viable and useful knowledge’. Smerdon et al. (1999) describe constructivism as being based on the premise that learners actively construct knowledge and reconcile new information. Layman (1996) argues that there is a sharp distinction between knowledge and thinking. He states that a great deal of knowledge can be acquired without much thought, but one is not able to do much thinking without knowledge.

Brooks and Brooks (1993) outline the main characteristics that underpin inquiry-centred instruction as a learning theory and as an approach to teaching and learning in mathematics. These characteristics were shared by teachers adopting this approach. Such teachers:

- Allow student responses to drive lessons, shift instructional strategies and alter content
- Engage learners in experiences that pose contradictions to their initial hypotheses and then encourage discussion
- Familiarise themselves with learners’ understandings of concepts before sharing their own understandings of those concepts
o Encourage learners to engage in dialogue, both with the teacher and with one another

o Encourage learner inquiry by posing thoughtful, open-ended questions and asking learners to question each other

(Layman, 1996)

4.2 A context for inquiry

According to Maree and Fraser (2004:6) “teaching and learning were, and still are, very much content-based in a significant number of schools in South Africa. The focus of content-based learning is on prescribed syllabi which learners must master.” Maree and Fraser further explain that traditional and content-dominated teaching and learning seldom relates to real-world demands and real-life experiences. In terms of the White Paper on Education and Training (1995), the need for major changes in education and training in South Africa was emphasised in order to normalise and transform teaching and learning. It also stressed the need for a shift from the traditional aims and objectives approach to outcomes-based education (Department of Education, 2002).

4.3 The importance for teachers

Llewellyn (2005) predicates his book entitled Teaching High School Science Through Inquiry on the question, “How can we expect our students to engage in inquiry-based activities if we, as teachers, do not have a sufficient understanding of inquiry ourselves?” He believes that teachers should be able to articulate, in detail, their understandings, attitudes and dispositions with regard to being an inquiry teacher. He further describes inquiry as a personal and professional journey that starts with developing a constructivist-based philosophy and reflecting, both individually
and with others, on their instructional beliefs and practices. Llewellyn encourages teachers to journey further into their understanding of inquiry in order to realise how inquiry-based classrooms promote critical thinking skills and empower students to become independent, life-long learners.

Layman (1996) advocates that inquiry-centred instruction be described in terms of a set of characteristics shared by teachers adopting this approach. Such teachers:

- encourage and accept student autonomy and initiative
- use raw data and primary sources, along with manipulative, interactive, and physical materials
- when framing tasks, use cognitive terminology such as classify, analyse, predict and create
- allow student responses to drive lessons, shift instructional strategies, and alter content
- familiarize themselves with students’ understandings of concepts before sharing their own understandings of those concepts
- encourage students to engage in dialogue, both with the teacher and with one another
- encourage student inquiry by posing thoughtful, open-ended questions and asking students to question each other
- seek elaboration of students’ initial responses
- engage students in experiences that pose contradictions to their initial hypotheses and then encourage discussion
allow time after posing questions

provide time for students to construct relationships and create metaphors

nurture students’ natural curiosity

(Brooks and Brooks 1993, 101-18)

According to McKenzie (2004) the success of an inquiry classroom comes from a shift in the teachers’ role from the ‘sage on the stage’ to the ‘guide on the side’. He emphasises the need for the classroom environment to shift from teacher-centered to learner-centered. Hewson (1996) suggests that teachers allow students to become active participants in class, but, to create a balance between the teacher’s views and discovery learning. According to Bruning et al. (1995), it is important that, in order to encourage learning, teachers reveal learners’ preconceptions and create cognitive conflict between learner’s current conceptions and the new concept to be learnt.

4.4 The importance for learners

Brooks and Brooks (1993) emphasize the importance of seeking to understand students’ points of view. They describe students’ points of view as windows into their reasoning and hold that valuing students’ points of view means not only recognizing them but also addressing them, making school experiences both contextual and meaningful.

Llewellyn (2005) holds that inquiry involves active explorations by students in which they use critical, logical and creative thinking skills to raise and engage in questions of personal interest. Inquiry-based activities are driven by students’
curiosity and students in inquiry-based classrooms are expected to take responsibility for their own learning.

5. FAMILY MATHS PROGRAMME

The Family Maths Programme aims to assist in the process of restoring a culture of learning in our schools by helping teachers reshape their instructional practice in mathematics (Kreinberg, 1989). Family Maths involves parents and children in problem solving, experimenting and discovering mathematical concepts in a relaxed non-threatening atmosphere where risk taking is encouraged. Inquiry-based teaching and learning, which is underpinned by the principles and practices of constructivism, assists teachers in the implementation of outcomes-based education as specified in the RNCS. According to the Eastern Cape Department of Education Teacher’s Resource Book, the government promotes the breaking down of negative stereotypes in mathematics classrooms and advocates that teachers should ‘make maths exciting for learners, create a stress-free environment where learners are free to make mistakes, but take responsibility to learn from them’. Family Maths, therefore, holds important lessons for both curriculum development and developing positive attitudes towards mathematics (Kreinberg, 1989).

5.1 History of the Family Maths programme

The term Family Maths refers to a specific programme established by the EQUALS project at the Lawrence Hall of Science, University of California, Berkeley during the late 1970s. The Lawrence Hall of Science is a public science centre and a centre for teacher education, research and curriculum development. The Family Maths programme has developed innovative mathematics curriculum materials to increase access and equity for all students and to help children everywhere realise success in
At the time that Family Maths began in the United States of America, participating teachers were asked to ‘challenge the education system that resulted in socially unjust outcomes in mathematics classrooms and to re-examine, reshape and diversify instructional practice and attitudes to eliminate gender, race and class bias that hinder children’s learning – and to engage parents as partners in overcoming these obstacles’ (Kreinberg, 1989). Similar challenges face teachers in our country, particularly given the introduction of the Revised National Curriculum Statement which seeks to embody the nation’s social values and its expectations of the roles, rights and responsibilities of citizens in a democratic South Africa (Department of Education, 2002:8).

5.2 Introduction of Family Maths to South Africa

Since its introduction to South Africa in 1996, Family Maths programmes have been successfully implemented in an increasing number of schools and communities throughout South Africa.

The Family Maths core programme, which we have adapted, South Africanised and localised to meet the needs of respective communities, supports current thinking on how mathematics teaching and learning should take place. It provides contexts for the exploration and implementation of the Revised National Curriculum Statement and makes meaningful links between school and home learning. Both the critical and developmental outcomes of the RNCS are greatly promoted by the principles of the Family Maths programme.
Family maths offers a practical route for transformative education practices that extend beyond the school walls to the community at large. Types of activities explored and the experiential aspect supports current philosophies of effective learning practice. Since its inception, the Family Maths programme has impacted significantly on the school environment where many teachers have adopted its hands-on, minds-on approaches for classrooms.
5.3 Philosophy of the Family Maths programme

The programme has proven to be a powerful catalyst in engaging parents and families in their children’s education and in providing teachers with ways of inculcating positive motivation in their learners, thereby improving school performance.

The programme complements current educational policies and supports outcomes-based education by focusing on problem solving skills, cooperative learning, active involvement of participants and discovering mathematical concepts using multiple teaching and learning strategies, with a focus on inquiry learning. The emphasis is on cooperative problem solving and the development of communication skills in mathematics. According to research most learning takes place during communication so the development of this skill is emphasised. Parents, teachers and learners develop skills in logic, estimation, problem solving, communication, and understanding of mathematics concepts in an informal, relaxed, non-threatening atmosphere. Learners are also motivated to broaden their career options by building a strong background in mathematics.

Learners are encouraged to take risks in identifying solutions – a high priority on longer term problem solving and process discovery, as opposed to drill and practice techniques. Many of the activities make use of manipulatives, which include inexpensive, readily available objects, such as sticks and beans.

Parents, family members, friends, teachers and educators all enjoy “doing” maths in a relaxed, non-threatening atmosphere conducive to developing problem solving skills and building on an understanding of mathematics with hands-on materials. Such an inquiry-based approach directly reflects John Dewey’s 1916 position that learners learn
by doing, an idea supported by more recent research in science education (Brederman, 1983; Champagne & Horning, 1986; Olson & Loucks-Horsley, 2000 & Rutherford & Ahlgren, 1990). Knowledge of mathematical concepts, like science concepts, is best learned once students possess the skills necessary to discover the concepts on their own (Davis, Maher, & Noddings, 1990).

The Family Maths philosophy and principles promote a positive attitude towards mathematics and contribute to the restoration of a learning culture in our communities, which, during the many years of an imposed apartheid education system, have been severely eroded.

5.4 The Family Maths programme underpinned by Inquiry learning

Inquiry learning is facilitated learning which focuses and supports inquiries during interaction with students. It orchestrates discourse among students, recognises and responds to student diversity and encourages all students to participate fully in the learning process (NSES, 1996) The characteristics of inquiry-based teaching and learning apply to all learning areas of the RNCS and the Family Maths programme has this approach as a focus of the implementation strategy.

A five stage instructional model illustrates how inquiry is implemented in the Family Maths programme. This model has been adapted from the outline described in “Science for Life and Living” (NSES 1996, 187)

STEP 1: Engage the learner

Activities are introduced that engage learners and parents with a problem or phenomenon. Such activities capture participants’ interest and enable them to make connections with what they know and can do.

STEP 2: Explore the concept
Next, learners and parents participate in hands-on experiences through which they explore the concept further. They receive little explanation or terminology at this point because they are expected to define the problem or phenomenon in their own words. At this stage in the learning process, learners and parents are meant to acquire a common set of experiences so that they can help one another make sense of the concept. Participants spend considerable time talking about their experiences, both to articulate their own understanding and to understand one another’s point of view.

**STEP 3: Explain the concept and define the terms**

Only after participants have explored the concept independently are relevant mathematical explanations and terms introduced. Participants then use the terms to describe what they have experienced and begin to examine how the explanation fits with what they already know.

**Steps 4 and 5 are implemented with learners in the classroom situation, after the workshop experience, and do not necessarily form part of the Family Maths programme in which the research is being conducted.**

**STEP 4: Elaborate on the concept**

Learners are given opportunities to apply the concept in the classroom situation and they are introduced to related ideas that they explore and explain using the information and experiences they have accumulated so far. Interaction between learners is essential during the elaboration stage. By discussing their ideas with each other, learners gain a deeper understanding of the concept.

**STEP 5: Evaluate learners’ understanding of the concept**

In this stage, learners continue to elaborate on their understanding and evaluate what they now know and what they have yet to figure out. Although the key
word at this stage is ‘evaluate’, this does not indicate finality. Indeed, learners will continue to construct their understanding of each broad concept throughout their lives.

5.5 Assessment of inquiry-based teaching and learning

According to NSES, Assessment Standard D 1996, 84, making observations of student performance during instructional activities is an ongoing responsibility of the teacher. Assessment and learning are viewed as two sides of the same coin. In fact, “authentic assessment” is a term that is widely used in the wake of recent education reforms and it reflects this synergy. The national standards define an assessment as authentic when students are engaged in assessment tasks that are similar in form to tasks in which they will engage in their lives outside the classroom.

Assessment must be viewed in a broad context. The following statement appears in the Association for Supervision and Curriculum Development’s Clarifying Terms section of, A Practical Guide to Alternative Assessment.

The fundamental role of assessment is to provide authentic and meaningful feedback for improving student learning, instructional practice and education options.

(Herman, Ashbacher, & Winters, 1992)

The Family Maths programme makes use of informal formative assessment in which open-ended questioning, relevant clues and continuous discourse directs participants’ thinking in the problem solving activity.

6. THE RATIONALE FOR THIS STUDY

The Family Maths philosophy and principles promote a positive attitude towards mathematics and contributes to the restoration of a learning culture in our communities. The extremely poor teaching and learning in science and mathematics
has contributed significantly to the current South African national crisis in education. The Revised National Curriculum Statement (RNCS) aims to bring about changes to the mathematics curriculum, the teaching of it and the learners’ learning.

The RNCS encourages a learner-centered and activity-based approach to education (Department of Education, 2002). However, anxiety or apathy towards promoting a learner-centered approach in the classroom situation may possibly be attributed to the fact that many teachers have little knowledge or training of how to implement this in the classroom. Research suggests that educators who lack experience, confidence and general pedagogic content knowledge will resort to methods of expository teaching, rote learning, and avoiding classroom situations where something might go ‘wrong’ (Taylor & Vinjevold, 1999). While this traditional approach to teaching places a greater focus on the mastery of content, it places less emphasis on the development of skills, the nurturing of inquiring attitudes and conceptual understandings (Baxter, Bass & Glaser, 2000; Maree & Fraser, 2004).

The Family Maths programme supports current thinking on how mathematics teaching and learning should take place. Types of activities explored and the experiential aspect supports current philosophies of effective learning practice. The implementation of OBE, underpinned by inquiry-based education and constructivism is the required approach to develop learners who will meet the learning outcomes and the assessment standards of the RNCS. Inquiry-based teaching and learning assists teachers in the implementation of outcomes-based education as specified by the RNCS. Family Maths, therefore, holds important lessons for curriculum development, effective teaching and learning strategies and community building. Inquiry learning recognises and responds to student diversity and encourages all students to participate fully in the learning process (NSES, 1996).
7. SUMMARY

In this chapter various definitions of the concept of inquiry-based learning and teaching were outlined and the importance of this teaching and learning theory for both teachers and learners was highlighted. Current thinking on inquiry and its relevance for education nationally and internationally was discussed and the model of inquiry used in the Family Maths programme is given in detail.

The challenges faced by education in South Africa, particularly since the new dispensation in 1994 is discussed, as well as the attempts made by government to implement a curriculum which is relevant in content and context. As mentioned in chapter one, our South African government has been striving to root out the heavily entrenched traditional approaches to teaching and learning. The introduction of the Revised National Curriculum Statement, underpinned by an inquiry-based philosophy of teaching and learning, aims to transform education and empower all citizens. In spite of national concern regarding teachers’ low levels of motivation and the lack of appropriate implementation plans, teachers are presently charged with teaching by inquiry as required by the RNCS. An investigation into the Family Maths approach should be able to contribute to the debate in terms of promoting inquiry-based mathematics approaches in the South African context.

The new mathematics curriculum requires that understandings in mathematics extend beyond the knowledge of concepts. If the knowledge, processes, procedures, skills and values inherent in mathematics are to be taken seriously, and if inquiry-based teaching and learning is to be integrated into the curriculum successfully, the teachers’ understandings of inquiry needs to be urgently addressed. The Family Maths programme offers such an opportunity.
This study, undertaken in the Eastern and Southern Cape of South Africa, represents an attempt to investigate the extent to which the Family Maths programme contributes to teachers’ facilitation skills in inquiry-based teaching and learning.
CHAPTER THREE

METHODOLOGY

1. INTRODUCTION

In this methodology chapter I have provided an outline of Positivist, Interpretivist and Phenomenological research paradigms and explain how they embody the philosophy on which this research is based. I include reasons for particular research approaches and methods used. The differences between qualitative and quantitative research methods are discussed as well as the different types of data required and the instruments and techniques used for gathering the data. The reasons for the selection of specific data, instruments and techniques are explained in detail and attention is also given to methods of analysis of data. I have discussed the use of questionnaires, observation schedules and interviews as appropriate strategies for gathering data regarding inquiry-based teaching and learning. The sample type and size is discussed and justified. Issues of validity and reliability are addressed and ethical considerations discussed. The methodological limitations of the study are also outlined.

In this chapter I have considered the findings of others researchers with regard to the Family Maths Programme but there is no apparent research which directly addresses my research question.

2. RESEARCH PARADIGMS

Lincoln and Guba (1985:15) describe paradigms as representing “a distillation of what we think about the world, but cannot prove”. A few years later Guba (1990)
defined a paradigm as a basic set of beliefs that guide actions, specifically in terms of disciplined inquiry, but also in a wider sense. Denzin and Lincoln (1998) believe that the notion of paradigm encompasses epistemology, i.e., how we know the world, and ontology, the raising of basic questions about the nature of reality and methodology, thus focusing on how we gain knowledge about the world. Patton (1985) describes paradigms as being normative, informing practitioners of what to do without the necessity of long existential or epistemological consideration.

Clare (2003a) describes a paradigm as a set of assumptions that provide the researcher with philosophical and conceptual guidelines for the disciplined investigation of natural and social phenomena.

Burrel and Morgan (1979) claim that, because of the commonality of purpose that binds the work of a group of theorists together, sociological paradigms can be divided into four quadrants (Figure 3.1). The paradigm that they accept determines their research methods and dictates the research technique adopted (Mouton, 2001), McFarlane (2000) emphasises that research methodology should be grounded in the philosophical assumptions underpinning existing research.

Change

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<th>CRITICAL THEORY</th>
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<td>Objective</td>
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<td>INTERPRETIVE</td>
<td>POSITIVISM</td>
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Figure 3.1: Research paradigms (Burrel and Morgan, 1979)
As reflected in figure 3.1 both positivism and interpretivism are concerned with order, but what distinguishes the two is that positivism is supposedly objective, unlike the latter which is subjective. However, many philosophers and researchers feel that the positivist approach fails to recognize that social science, unlike natural science, stands in a subject-subject relation to its field of study, not a subject-object relationship (Cohen, Manion and Morrison, 2000).

Due to the nature of this empirical research of scientific inquiry I decided that I should work within the ambit of a positivist paradigm for aspects of this study (generating numerical data, statistical analyses, etc.). At the same time, working within an interpretive paradigm would be most appropriate for the interpretation of data generated to address the research question, namely, to what extent does the Family Maths facilitators’ training programme develop facilitators’ ability to implement inquiry-based learning? In order to explain this more fully I interrogate understandings of these two paradigms below.

2.1 Positivist Paradigm

According to Cohen et al. (2000), the 19th century French philosopher, Auguste Comte, is credited with being the first thinker to use the term positivism to describe the philosophical position in which explanation is done by means of scientific explanation. Positivism adopts an ontology which describes the world as an entity external to individual cognition and comprises hard, tangible and relatively immutable structures (Easterby-Smith et al., 1994). This led to the general doctrine, which stated that all genuine knowledge is based on sense experience, and progress in the accumulation of knowledge can only be made by means of observation and experiment (Cohen et al., 2000).
Goodman (1992) maintains that positivism is associated with the idea that social reality (like physical reality) is controlled by laws, and that these laws control the behaviour of people who in turn set up social systems that reflect these laws. According to McFarlane (2000), when used in the social sciences, the positivistic paradigm seeks to emulate the natural sciences in that it aims to find certainty, and to be objective and value free. This paradigm often makes use of quantitative methods with the objective to prescribe, predict and control situations. Variables can usually be identified as the causal factors for specific types of behaviour.

This research study makes use of instruments which provide numerical (quantitative) as well as qualitative data on aspects of the ‘social reality’ that participants bring to the mathematics workshops. It is the generation and analysis of the numerical data that places this aspect of the research within a positivistic framework, but it is the analysis and construction of understanding from these data in terms of ‘social reality’ that places the research within the interpretive paradigm.

2.2 Interpretive and Phenomenological Paradigms

The Interpretive Paradigm is an umbrella term for a host of different paradigms all of which share the same objective of understanding and interpreting social situations (McFarlane, 2000). The interpretive paradigm sees the world as “constructed rather than found” (Janse van Rensburg, 1998:6) and the interpretivist researcher understands that knowledge is internally constructed (Fien and Hillcoat, 1996). They, therefore see knowledge as understandable only through the participant’s frame of reference.

Interpretivism holds the view that human beings are not mechanistic and they have multiple realities, which need to be understood in context. The social world cannot be described without investigating how people use language, symbols and
meaning to construct social practice, and that no social explanation is complete unless it adequately describes the role of meaning in human actions (Le Roux, 2006).

Also, the interpretivist paradigm denies that there is an objective reality independent of the frame of reference of the observer; reality is mind-dependent and influenced by the process of observation. It therefore, does not concern itself with the search for broadly applicable laws and rules, but rather seeks to produce descriptive analyses that emphasise deep, interpretive understandings of social phenomena (Le Roux, 2006). The interpretivist paradigm generally leads to the use of qualitative research methods that enable the researcher to gain a descriptive understanding of, amongst others, the values, motivations and experiences of the participants in a study.

This approach to knowledge is also referred to as constructivism, which has the view that all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context (Golafshani, 2003).

For the purposes of this study, phenomenology is viewed as the philosophical base for the interpretivist stance taken. The definition of phenomenology is the study of phenomena: appearances of things, or things as they appear in our experience, or the ways we experience things, thus the meanings things have in our experience (Le Roux, 2006). Phenomenology in the classical sense uses three approaches, viz., describing an experience as it is found, interpreting an experience by relating it to relevant features of context, and analysing the form of experience by being open to the world in which it exists (Le Roux, 2006).
Phenomenologists see people as “active agents in the creation of reality” and that individuals interpret the world in which they live and act on these unique interpretations (Goodman, 1992:119). The key idea in phenomenology is based on the belief that reality is socially constructed. People construct meaning from their experiences. Research in this tradition seeks to understand and appreciate the different constructions and meanings people make of their experiences.

According to Johnson and Christensen (2004), the key element of a phenomenological research study is that the researcher attempts to understand how people experience a phenomenon from their own perspectives and experiences, which I have tried to do in this study.

3. RESEARCH DESIGN

The nature of the investigation justified the use of both quantitative and qualitative methodologies so as to ensure relevant, appropriate and sufficient data collection. According to Johnson and Christensen (2004), the use of multiple perspectives, theories and research methods is viewed as a strength in educational research. As such I have a mixed-method approach. However, researchers are cautioned about using different research methods in such a way that the resulting combination has complementary strengths and not overlapping weaknesses (Brewer & Hunter, 1989). This approach helps to improve the quality of research because the different research methods have different strengths and different weaknesses. In the case of this study the quantitative and qualitative research methods are viewed as complementary.
4. SAMPLE AND SETTING

The Family Maths programme offers a professional development course which gives teachers and teacher educators the opportunity to engage in inquiry-based experiences and to develop higher order thinking skills as they ask questions, conduct problem solving activities, and interpret and discover solutions while constructing mathematical understanding. Teachers are guided in the principles of inquiry-based teaching and learning so that they, in turn, may become effective facilitators of Family Maths workshops with parents, teachers and learners. Participants attend three hourly, quarterly training workshops over a period of seven quarters, and for data collection purposes during this study, were grouped according to the number of hours they have attended and participated in the Family Maths facilitators’ training programme. The groupings were:

- Novice facilitators (three to nine hours of participation which translates into one to three training workshops – less than one year)
- Intermediate facilitators (twelve to twenty one hours of participation which translates into five to seven training workshops – one to two years)
- Veteran facilitators (in excess of twenty one hours of participation which translates into eight or more workshops – more than two years)

This study investigates the effect of the Family Maths programme on facilitators’ ability to implement inquiry learning as they conduct workshops with learners and their parents. A sample of 39 facilitators - a sufficient sample size for meaningful statistical analyses of data (Gravetter, & Walnau, (2002) - who are predominantly in-service teachers, school principals and teacher educators in the Department of Education were selected to participate in the research. All of the participants have an intermediate phase teaching focus in the General Education and Training (GET) band
of the RNCS. The participating facilitators were selected from amongst the entire group of volunteer facilitators on the NMMU Family Maths programme. Selection of teachers was based firstly on their willingness to participate in the study and also on their availability at the time of the workshop observation by trainers of the Family Maths programme; as such they may be considered a convenience sample.

The 39 selected facilitators were drawn from a population of approximately a hundred teachers and Education Department officials who constitute the population of facilitators participating in the Nelson Mandela Metropolitan University (NMMU) Family Maths programme in the Eastern and Southern Cape. The participating facilitators were drawn from the geographical centres of East London, Port Elizabeth, George, Mossel Bay and Beaufort West. Data was collected from participants in each of the geographical areas and from each of the novice, intermediate and veteran facilitator categories as previously described. Each of the 39 facilitators was observed once during their presentation of a Family Maths workshop and interviewed immediately after the conclusion of the workshop.

5. DATA COLLECTION

Triangulation of data was used in this study, that is, a questionnaire, two observation instruments and an interview schedule were used to obtain data on the same issue. According to Cohen et al. (2000), triangulation has special relevance where the issue being studied is complex, as is the case in this research study which measures the belief systems and implementation strategies of inquiry-centered education.

Although 88 facilitators participating in the Family Maths professional development course completed the inquiry belief system questionnaire, a representative sample of thirty nine of the participants agreed to respond to all of the
research instruments used in this research study, that is, the questionnaire, two observation schedules and an interview.

5.1 Questionnaires

The initial instrument used for data collection was a questionnaire (Appendix A) which measured 88 participants’ understandings and beliefs regarding inquiry learning. Respondents completed the closed-question questionnaire individually and gave pencil and paper responses. Cohen et al. (2000), advocates that if general group responses are required a closed format is most suitable and statistical treatment and analysis can be performed more easily than open-ended format of questions. As such, the closed response items on the questionnaire used for this study was well suited to statistical data comparison of the three categories of facilitators, viz., novice, intermediate and veteran, who participated in the research.

Threats to the validity of this instrument were addressed by discounting any discrepant data, which included incomplete or ambiguous response questionnaires.

5.2 Observation Schedules

McMillan and Schumacher (1993) highlight the importance of post observation discussion between the observer and facilitator in order to reach a mutual understanding of the meaning and context of the events that took place during the workshop, and thus strengthen the validity of the observation. Facilitators were interviewed immediately after the workshop observation had been completed which provided an opportunity for the observer and participating facilitator to discuss observations made during the workshop.

Two observation instruments, described below, were used to observe and record workshop behaviour.
5.2.1 Workshop observation instrument

Each of the 39 volunteer facilitators were observed once while presenting Family Maths workshops and were measured against criteria on the observation instrument relating to the inquiry process. The observer assessed facilitators’ inquiry skills on a rating scale of one to four with coding representations of poor/no implementation of inquiry criteria (1), limited implementation of inquiry criteria (2), satisfactory implementation of inquiry criteria (3), and implementation of inquiry criteria exceeds expectations (4). One or two observers conducted the observation using the workshop observation instrument (Appendix B) to assess the extent to which the facilitator promoted inquiry learning with regard to the three consecutive steps of inquiry, namely, engaging participants, allowing participants to explore the concept and encouraging participants to explain the concept and define the terms. The observers completed the observation instruments by entering check marks in appropriate columns for each of the criteria relating to these three steps.

5.2.2 Workshop interaction coding system instrument

The 39 volunteer participants who were assessed against the workshop observation instrument criteria were simultaneously assessed by the same observers against criteria for the workshop interaction coding system instrument (Appendix C). This instrument was used to observe and record workshop behaviour in a systematic, objective manner. Facilitators’ verbal feedback techniques, with regard to inquiry skills were measured against criteria on the coding system instrument which had been identified by the Brophy and Good Dyadic Interaction System. Facilitator verbal feedback techniques were coded during question-and-answer interchanges. Whenever the participant responded to a facilitator’s question the observers coded information about the quality of the student’s response and about the nature of the facilitator’s
feedback to the participant. The observer recorded check marks in appropriate columns on the coding sheets.

In order to assess reliability of this instrument, observers coded in the company of one other observer, compared codes and cleared up ambiguities and misunderstandings through discussion. Once good reliability was established, observers coded independently, periodically coding together to recheck reliability. It was important to establish coder agreement so that reliable coded information could be used to draw inferences about facilitators’ inquiry feedback techniques.

The generation of data from this instrument focused on facilitator feedback techniques. The observer recorded check marks against four inquiry feedback techniques which were as follows: gives answer, repeats question, gives clue and rephrases question. The observer then counted the number of behaviours in each category for each of the groups of novice, intermediate and veteran facilitators. These frequency data were converted into percentages so that a more appropriate frame of reference could be used for the comparison of feedback techniques across the three categories of facilitators.

5.3 Facilitator interview instrument

A semi-structured interview instrument (Appendix D) provided qualitative data which was generated by probing facilitators’ understanding of their own implementation skills of inquiry learning. Interview questions enabled facilitators to reflect on their inquiry beliefs and practice. Thirty nine facilitators were interviewed at the conclusion of their respective Family Maths workshops once the observer had completed administration of both of the observation schedules described above.

The semi-structured interview, consisting of open-ended questions relating to criteria contained in the questionnaire and the workshop observation instrument,
allowed interviewers the opportunity to expand on issues raised and clarify responses. McMillan and Schumacher (1993) note that interviews have the advantage of being flexible, with a high response rate. They allow the interviewer to probe and clarify responses, which is not possible with written questionnaires.

Each interviewee was made to feel relaxed and the process was carefully explained, that there were no right or wrong answers, but that the responses would feed into the Family Maths training course with the purpose of improving the programme. The interviewer recorded answers given by the interviewees and read these responses to the interviewees so as to verify the responses given. These responses were organised into broad categories and a summary made of the responses given by facilitators for each of the categories of novices, intermediates and veterans.

The verbal responses given by the facilitators during the interview process were compared to the findings from the questionnaire and observation schedules to ascertain whether the verbal responses concurred with the data generated by these instruments.

The instruments used for data collection are fully described under the next heading, i.e. ‘Data collection instruments’.

6. DATA COLLECTION INSTRUMENTS

The measuring instruments described below were used in an attempt to address the primary research question in measuring the extent to which the Family Maths facilitator training programme develops facilitators’ ability to facilitate inquiry learning. The secondary questions which underpin the primary research question are also addressed by these instruments. The design and development of the measuring instruments was done in such a way as to allow the data generated to reach the goal of
valid knowledge which may lead to an improved Family Maths training programme which enables facilitators to master inquiry-based teaching and learning strategies.

A variety of measuring instruments were used, viz., a questionnaire, two observation schedules and an interview protocol. The four measuring instruments were:

- *Facilitators’ Inquiry Learning Belief System* questionnaire (Appendix A) which measured participants’ inquiry beliefs and understandings.
- *Workshop Observation Instrument* (Appendix B) which measured the facilitators’ ability to capture and focus parents and learners’ attention on critical parts of the problem solving process.
- *Workshop Interaction Coding System* (Appendix C) which measured the extent to which the facilitators used inquiry verbal feedback techniques.
- Facilitator *interview protocols* (Appendix D) which served the purpose of deeper probing into facilitators’ understandings and beliefs of inquiry learning.

Firstly, in order to gauge the participants’ inquiry beliefs and understanding of the concept of inquiry-based teaching and learning, a questionnaire, viz. the ‘*Facilitators’ Inquiry Learning Belief System*’ (Appendix A), was administered at the outset of this research study.

### 6.1 Facilitators’ Inquiry Learning Belief System Questionnaire

This questionnaire was designed using the characteristics and principles of inquiry learning as outlined by Brooks and Brooks (1993). These characteristics, adopted by teachers using this approach, are described under 4.1 in chapter two. Llewellyn (2005) believes that teachers should be able to articulate their understandings, attitudes and dispositions with regard to being an inquiry teacher.
This questionnaire provides teachers with the opportunity to reflect on their instructional beliefs and practices regarding inquiry learning as it applies to all learning areas of the RNCS. The three stage model, adapted from the NSES (1996), is used for the questionnaire, observation schedule and interview protocol and, as such, provided the methodological triangulation of data for this study.

A comparison between what was written in the questionnaire (i.e., what the facilitators said that they believed in) and what was observed during the workshops and the responses given during interviews regarding understandings of the concept of inquiry-based education was made to determine the extent that their beliefs and practice were matched.

This pre-workshop questionnaire was administered to novice facilitators (less than one year participation) on the Family Maths facilitators’ training course prior to discussion, debate or dissemination of information regarding inquiry-based learning. It was important to establish new participants’ understanding of inquiry-based teaching and learning prior to any participation in the training course. The questionnaire was also administered to intermediate facilitators (one to two years participation) and to veteran facilitators (more than two years participation). All categories of responses were then analysed and compared to the data collected regarding their facilitation of inquiry-based workshops and their responses given regarding their understanding of the concept of inquiry-based education in the post workshop interview. When initially designing this instrument I failed to take into consideration the fact that many of the research participants did not use English as their home language. After consultation with other researchers it was agreed that the language used in this measuring instrument needed to be simplified without altering the focus of any of the statements. A small group of experienced researchers from the
Nelson Mandela Metropolitan University reached consensus on how each statement should be rephrased to ensure natural, familiar, clear, concise and precise language that would provide clarity for the participant and the collection of reliable data. The adapted instrument was then administered to participants.

### 6.2 Observation Schedules

According to Johnson and Christensen (2004), observation is defined as the watching of behavioural patterns of people in certain situations to obtain information about the phenomenon of interest. Johnson and Christensen (2004) believe that observation is an important way of collecting information about people because people do not always do what they say they do. It was decided, therefore, that observational data would be used in this research study to provide data which could be compared to the responses given by participants in the questionnaires and interviews.

Two observation instruments were used in this study, viz. the Workshop Observation Instrument and the Interaction Coding System Instrument.

#### 6.2.1 Workshop Observation Instrument

The *Workshop Observation Instrument* (Addendum B) was adapted from the NSES (National Science Education Standards) of the USA, which identifies inquiry learning as a central goal for all students. This instrument measured the implementation of the first three stages of inquiry-centred instruction and gave guidance of the clear, logical developmental stages for the implementation of inquiry teaching and learning.

According to the NSES the goal of inquiry learning can not be met by having learners memorise and regurgitate facts and figures. It can only be met when learners frequently engage in active inquiries, in using high-level reasoning, in applying
existing understanding of scientific ideas and in communicating scientific information (NSES, 1996). This philosophy of education also applies to the teaching and learning of mathematics as a learning area according to the Revised National Curriculum Statement (2002) in South Africa.

The observers in this study took on the role of observer-as-participant, and time was spent observing research participants and conducting in-person interviews with them. The participants were fully aware that they were part of the research study.

The Workshop Observation Instrument makes use of quantitative observations in problem solving activities to measure the extent to which the facilitator engages the participants, allows participants to explore the concept and encourages participants to explain the concept and define the terms.

6.2.2 Workshop Interaction Coding System Instrument

The Interaction Coding System Instrument makes use of qualitative observations to measure the type of verbal feedback techniques used by facilitators. Facilitators were observed by trainers of the Family Maths programme while they presented a Family Maths workshop with learners and parents. During the workshop observers used the workshop interaction coding system instrument as well as the workshop observation instrument simultaneously. The workshop interaction coding system instrument clearly classified answers, questions, clues and rephrasing of questions used by the facilitator.

The coding instructions and coding sheets were adapted from the Brophy-Good Dyadic Interaction System developed by Brophy and Good during the 1970s. The coding sheets enabled information to be quickly recorded by entering check marks in appropriate places on the sheet. In coding a given interaction, the coder moved from left to right across the page. No writing or note taking was required.
which enabled observers to give full attention to observation of teacher-parent/learner interactions.

When codable instances were observed the behaviours of parents, learners and teachers were recorded on the coding sheet. However, for the purposes of addressing the research questions for this study, only data regarding the verbal feedback techniques of the facilitators was analysed and compared across the three categories of facilitators. When the teacher being observed facilitated a problem solving situation, the observer coded information about the:

- Sex of the learner/parent
- Quality of the learner’s response
- Nature of teacher’s feedback to the learner/parent

Teacher, learner and parent behaviours were coded during question and answer interchanges. The observer recorded whether the teacher praised (++), affirmed (+), gave no response (0), gave a negative response (-) or criticized the participant’s response (--). Once the teacher’s response to the learner’s answer, or failure to answer, had been coded, the information for that particular question-answer-feedback sequence was complete and the coders prepared for coding the next sequence. The next sequence might have been with the same learner; if, for example, the teacher repeated the question, rephrased or gave a clue, or asked a new question, thus giving the learner a second opportunity to respond, or it may have been with another learner. Each row, therefore, contained information about a single question-answer-feedback sequence and the interaction was reconstructed from the coding sheets.
6.3 Facilitator Interview Schedules

Dilley (2004), in his review on books on interview strategies, notes that interviewing is the key to many forms of qualitative educational research. The qualitative component of this study was enhanced by the use of facilitator interviews which expanded on data generated by the questionnaire.

It was decided to make use of in-person interviews in order to allow the interviewer opportunities to freely use probes to obtain response clarity, greater depth and additional information.

A predominantly qualitative interview consisting of standardized open-ended questions was used for the purpose of interviewing the facilitators. Standardization of the interview instrument was achieved as the same questions were asked to all interviewees so that results could be compared. The interviewees’ answers were recorded in the spaces provided on the interview schedule and, after each response by the interviewee, the interviewer read what had been written and the participant asked whether they agreed with what had been written.

As English was usually not the home language of the facilitators interviewed, simplification and rephrasing of questions was often necessary before interviewees completely understood what was being asked. In some instances, where language proved to be a barrier to valid communication between the interviewer and the interviewee, an interpreter who was familiar with the interviewees mediated the process. This was done in order to strengthen both the reliability and validity of the data.
7. **DATA ANALYSIS**

The data gathered by the questionnaire, workshop observation instrument and interview schedule were analysed according to the three stages of the inquiry process within the framework of the literature reviewed.

Data generated via the facilitators’ inquiry belief system questionnaire and the workshop observation instrument were statistically analysed according to the analysis of variance model (ANOVA) and comparisons of statistically significant mean facilitator scores were made across the three categories of facilitators in each of the three stages of the inquiry process.

The Workshop Interaction Coding System used in this study was adapted from the workshop interaction coding system of Brophy & Good, and as such, the data collected for this study were analysed within their framework. This research study focused on the facilitator verbal feedback techniques which were clearly classified according to the following four categories: gives answer, repeats question, gives clue and rephrases question. The check marks under each of the categories were counted and a summary constructed to analyse the findings.

After scrutinising the interview responses a frequency tally of facilitator responses to interview questions was generated and then grouped into broad categories. Basit (2003) explains that the coding or categorising of data is not synonymous with analysis, but has an important role in analysis and involves assigning categories. In creating categories a conceptual scheme, suitable to the data, is constructed.

Data collected from the questionnaire, observation and interview schedules, were used to build into the existing Family Maths training course those aspects which more effectively developed teachers and teacher educators in the knowledge and skills
of inquiry-based teaching and learning in mathematics education. As a result of the summarising, analysing and processing of the quantitative and qualitative data the results inevitably produced new information about the Family Maths programme which required further processing.

8. VALIDITY AND RELIABILITY

Kvale (1989) regards the most common definition of validity to be epitomised by the question ‘Are we measuring what we think we are measuring? According to Pervin (1989), validity generally refers to whether a method investigates what is intended to be investigated to ‘the extent to which our observations reflect the phenomena or variables of interest to us’.

In order to increase the reliability of all the instruments used in this study, two observers simultaneously observed and coded during the first workshop in each of the geographical areas in which data were being collected. This allowed the pair of observers to assess the reliability by comparing their coding and provided a basis for clearing up ambiguities and misunderstandings through thorough discussion and reaching of consensus regarding the data generated by each of the instruments. Once an acceptable degree of reliability had been established, the observers coded independently. However, in order to guard against the possible development of variable observation and coding, the observers continued to recheck reliability against one another on a regular basis, even after initial proficiency had been established.

9. ETHICAL CONSIDERATIONS

In keeping with the accepted professional ethics of research the aims of the study, research design and methodologies were communicated to the participants on the programme (Mouton, 2001). As such, those who agreed to participate in the study made an informed decision to do so. Communication was made with all principals
whose staff members were involved in the programme and they gave their willing and informed consent for observer visitations to their schools for the purposes of data collection.

The three trainers of the Family Maths professional development course took the role of observers and interviewers for the purposes of data collection. They were, therefore, familiar with the volunteer participants and rapport and trust had already been established before the commencement of the research study. These participants had all been informed of the nature of the research and that their participation was important for the integrity of the study. They had also been assured that their responses would be treated confidentially. The observers and interviewers were all experienced in observation and interview techniques and well trained in the proper use of the instruments.

10. LIMITATIONS OF THE STUDY

Limitations of the study are noted below in respect to the research instruments used for data collection and in terms of issues related to the participants in the research study.

10.1 Research Instruments

The language used in the Facilitators’ Inquiry Learning Belief System questionnaire had to be simplified to accommodate participants whose home language was not English. Participants completed the questionnaire individually and were encouraged to seek clarity from the facilitator should the meaning of any of the questions be unclear to them. However, there was still a risk that the participants did not fully understand the questions or seek clarification in spite of being invited to do so. This limitation also applied to the interview protocol, although this was probably
less of a risk as the interviewer could reformulate questions and probe answers more deeply when necessary.

10.2 Research Participants

The facilitator interviews were conducted in what was hoped to be a relaxed, non-threatening atmosphere immediately after the conclusion of each workshop. However, it was never established as to whether the respondents felt intimidated by the interviewer or, conversely, gave responses that they felt would please the interviewer. Also, the workshops were held in the late afternoon and evenings and it could be possible that participants were tired or in a rush to go home and failed to give substantiated answers to the questions asked as dictated by the interview protocol. Nevertheless, the reports given by the interviewers suggest that the data generated by the interviews are valid and reliable enough to draw reasonable conclusions and be used to assist the ongoing refinement of the design of the Family Maths training programme.

11. SUMMARY

This chapter dealing with the research design provides an overview of the research methodology used in this study. A brief review and discussion of methodological paradigms selected, as best suited to the nature of the research problem means that this empirical study is heavily influenced by the positivist and interpretivist paradigms. Motivations for this philosophical approach are provided in the content of this chapter.

The study uses both qualitative and quantitative methods for the collection of data in order to gain deeper insight into the participants’ beliefs, understanding and implementation skills of inquiry-based teaching and learning. Quantitative data was gathered from the Facilitators’ Inquiry Belief System Questionnaire and from the
Workshop Observation Schedule. Qualitative data was gathered from the Workshop Interaction Coding System Instrument and the Facilitator Interview Instrument. The use of these data collection instruments have been discussed as appropriate strategies of inquiry and the methods of collection in Family Maths workshops described.

The sample type and size are described and justified as sufficient for any statistical analyses of data. The ethical considerations included the participants’ right to withdraw from the research study at any time and to be fully informed of the nature and outcomes of the study.
CHAPTER FOUR

RESULTS

1. INTRODUCTION

This chapter undertakes a systematic examination of the data generated in this study using the methodology described in chapter three. The data addresses the research question, namely, \textit{to what extent does the Family Maths facilitator training programme develop facilitators’ ability to implement inquiry based learning?} Each sub question is dealt with individually and the data generated is reported sequentially as follows.

Quantitative statistical data were generated from the facilitator inquiry learning belief system questionnaire (n = 88) and the workshop observation instrument (n = 39). These data were analysed and subjected to analysis of variance (ANOVA) techniques to provide descriptive and inferential statistics. Quantitative data were also generated from the interaction coding system observation instrument (n=39).

Qualitative semi-structured interviews consisting of standardized open-ended questions held with 39 facilitators from the Family Maths facilitators’ training workshop were used in order to allow the interviewer opportunities to freely use probes to obtain response clarity, greater depth and additional information from the interviewees. A total of 39 facilitators were interviewed and the data generated were
classified into broad categories and analysed within the framework of the literature reviewed.

As such, this research study has made use of both qualitative and quantitative methods where data were analysed in order to probe the knowledge, understanding and skills of the respondents in an attempt to triangulate findings and answer the principle and subsidiary research questions posed in the study.

2. **STATISTICAL ANALYSES**

2.1 **Belief systems measured by questionnaires.**

The *Facilitators’ Inquiry Learning Belief System Questionnaire*, with closed response items, was administered to 88 facilitators who were all participants on the Family Maths facilitators’ training programme (Appendix A). Forty-eight facilitators were from the Eastern Cape region and 40 from the Western Cape. This sample of facilitators represented novice, intermediate and veteran categories. Facilitators from the novice category completed this questionnaire prior to discussion, debate or dissemination of information regarding inquiry-based learning as it was important that the novices’ own understanding of inquiry-based teaching and learning was determined prior to participation in the training course. Facilitators from the intermediate and veteran categories had already completed at least one year of training at the time of completing the questionnaire. The initial language design of the facilitator’s inquiry learning belief system questionnaire was simplified as most of the participants on the training course were not first language English speakers. For the purposes of maintaining the validity and authenticity of the instrument, it was decided to simplify the language so that all participants would have a clear understanding of the meaning of each statement on the questionnaire. This instrument assessed three
consecutive steps in relation to the inquiry process, viz., engaging the participants, allowing participants to explore the concept, and encouraging participants to explain the concept and define the terms. Each step comprised criteria against which the facilitator indicated their agreement or disagreement with the coding representations, which were, strongly disagree (SD), disagree (D), agree (A) and strongly agree (SA).

Analysis of the questionnaire responses suggested that facilitators’ understanding of inquiry learning improved as they progressed through the novice, intermediate and veteran categories of the Family Maths training programme. Analysis of variance (ANOVA) of the data generated by the inquiry learning belief system questionnaire indicated that facilitators from the novice group held an inquiry belief system which was the least developed in terms of criteria which promoted inquiry learning. Overall, the veteran group of facilitators were more advanced in their understanding of what criteria best promoted inquiry learning.

Not all criteria differed statistically significantly, but the mean scores of the novice, intermediate and veteran groups that were statistically significant are indicated in table 4.1.

Table 4.1 Comparison of respondents’ mean scores with regard to questions on the belief system questionnaire which showed a statistically significant difference

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Group mean scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novice</td>
</tr>
<tr>
<td>Encourages initiative (1b)</td>
<td>3.45</td>
</tr>
<tr>
<td>Encourages questioning (2c)</td>
<td>3.18</td>
</tr>
<tr>
<td>Poses contradictions (2e)</td>
<td>3.05</td>
</tr>
<tr>
<td>Allows time after questions (2f)</td>
<td>3.30</td>
</tr>
</tbody>
</table>
Possible reasons for the fact that, on occasions, the intermediate group achieved higher mean scores than the veteran group are discussed in chapter five. The statistical significance of these mean scores is indicated in table 4.2.

Table 4.2: Comparison of probability values indicating statistically significant differences between facilitator mean group scores for criteria on the belief system questionnaire for inquiry learning

<table>
<thead>
<tr>
<th></th>
<th>Novice</th>
<th>Intermediate</th>
<th>Veteran</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Encourages initiative (1b)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice</td>
<td>-</td>
<td>0.0595*</td>
<td>0.0286**</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.0595*</td>
<td>-</td>
<td>0.4126</td>
</tr>
<tr>
<td><strong>Encourages questioning (2c)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice</td>
<td>-</td>
<td>0.0198**</td>
<td>0.1871</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.0198**</td>
<td>-</td>
<td>0.7678</td>
</tr>
<tr>
<td><strong>Poses contradictions (2e)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice</td>
<td>-</td>
<td>0.0207**</td>
<td>0.0215**</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.0207**</td>
<td>-</td>
<td>0.5182</td>
</tr>
<tr>
<td><strong>Allows time after asking questions (2f)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice</td>
<td>-</td>
<td>0.0295**</td>
<td>0.3141</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.0295**</td>
<td>-</td>
<td>0.6498</td>
</tr>
<tr>
<td><strong>Seeks elaboration (3a)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice</td>
<td>-</td>
<td>0.0938*</td>
<td>0.0090***</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.0938*</td>
<td>-</td>
<td>0.1767</td>
</tr>
<tr>
<td><strong>Participants refine explanations (3d)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice</td>
<td>-</td>
<td>0.0002***</td>
<td>0.0122**</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.0002***</td>
<td>-</td>
<td>0.9091</td>
</tr>
</tbody>
</table>

* = statistically significant at the 90% level of confidence
** = statistically significant at the 95% level of confidence
*** = statistically significant at the 99% level of confidence
For all the criteria on the inquiry learning belief system questionnaire it is evident that there is a statistically significant difference in the mean value between the novice group of facilitators and either both or one of the other two groups of facilitators who have been participating on the programme for a longer period of time. This indicates that the majority of facilitators who first embark on the Family Maths training course do not appear to have much knowledge or experience in terms of inquiry learning as a teaching and learning strategy, a strategy recommended for all teachers by the South African Government (Department of Education, 2002).

2.2 Teacher practice measured by observations

As naturalistic observation of participants in the workshop setting took place, care was taken by the observer not to affect the observed situation in any way and to minimise preconceptions of what might be observed. In this way the researcher attempted to record and study the classroom behaviour of the facilitators in an authentic setting.

The National Science Education Standards (1996) acknowledges that the goal of inquiry learning can not be met by having learners memorise and regurgitate facts and figures. They believe that inquiry learning should be underpinned by learners’ engagement in active inquiries using high-level reasoning, application of existing understandings of scientific ideas, and in communication of scientific information. Brooks and Brooks (1993) outline a five stage instructional model for assessing inquiry teaching according to the goals of the NSES. Each stage comprises characteristics of teaching according to inquiry-based education. The workshop observation instrument used in this study (Appendix B) was adapted from the first three stages of this model to the learning cycle approach to instruction which is outlined in *Science for Life and Living* by Layman (1996).
Facilitators were observed once while facilitating Family Maths workshops and rated against criteria on the workshop observation instrument. This instrument assessed the first three consecutive steps of the five stage model in relation to the inquiry process, namely, the extent to which the facilitator promoted inquiry learning with regard to engaging the participants, allowing participants to explore the concept and encouraging participants to explain the concept and define the terms. The facilitators’ competence in terms of each of these steps was rated against a rating scale of one to four with the following coding representations, viz.; poor/no implementation of inquiry criteria (1); limited implementation of inquiry criteria (2); satisfactory implementation of inquiry criteria (3); and implementation of inquiry criteria that exceeds expectations (4).

The data generated by means of the workshop observation schedule were analysed statistically to provide descriptive and inferential statistics. The mean scores for each criterion in each of the three inquiry learning steps were calculated and are shown in tables 4.3 (Step 1: engages the participants), 4.4 (Step 2: allows participants to explore) and 4.5 (Step 3: encourages participants to explain the concept), while means scores and levels of statistically significant differences are indicated in tables 4.6 and 4.7 respectively. No statistically significant differences were recorded for a number of criteria observed during the workshops, indicating that levels of competence regarding these criteria were similar for all facilitators. However, comparison of the mean scores still suggests that progression is made as facilitators proceed from novices through to veterans. Criteria which showed no statistically significant differences included, ‘creates a relaxed, non-threatening environment’(1a), ‘uses manipulative, interactive and physical materials’(1b), ‘allows participants’ responses to drive lessons, shift instructional strategies and alter content’(2a),
‘encourages participant inquiry by posing thoughtful, open-ended questions’ (2b),
‘encourages participants to question each other’ (2c), ‘engages participants in
experiences that pose contradictions to their initial hypotheses’ (2d), ‘allows time after
posing questions’ (2e), ‘seeks elaboration of participants initial responses’ (3a),
‘encourages use of cognitive terminology such as classify, analyse, predict’ (3b), and
‘asks probing questions to elicit meaningful explanations’ (3c).

The probability levels of confidence are shown in table 4.4, and, for each the
statistically significant difference in the mean scores suggests a progression in
understanding and implementation of inquiry learning strategies as facilitators
proceed through the sequence of stages of novice, intermediate and veteran categories

**Step 1: Engages the participants**

During this stage the facilitators were expected to introduce activities that
engaged learners and parents with a problem or phenomenon. These types of activities
are expected to provide participants with an open-ended opportunity to interact with
the materials and each other.

Table 4.3: Comparison of mean facilitator scores, across facilitator categories, on
their ability to engage participants in problem solving activities

<table>
<thead>
<tr>
<th>Criteria for Step 1</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Veteran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creates a relaxed environment</td>
<td>2.97</td>
<td>3.00</td>
<td>3.21</td>
</tr>
<tr>
<td>Encourages student autonomy</td>
<td>2.60</td>
<td>3.10</td>
<td>3.14</td>
</tr>
<tr>
<td>Uses manipulative and physical materials</td>
<td>3.30</td>
<td>3.22</td>
<td>3.14</td>
</tr>
<tr>
<td>Familiarises self with partic’ understanding</td>
<td>2.40</td>
<td>2.70</td>
<td>2.86</td>
</tr>
<tr>
<td>Encourages participants’ discussion</td>
<td>2.47</td>
<td>2.50</td>
<td>2.93</td>
</tr>
<tr>
<td>Nurtures participants’ natural curiosity</td>
<td>2.40</td>
<td>2.50</td>
<td>2.86</td>
</tr>
<tr>
<td>Sum of mean scores</td>
<td>14.78</td>
<td>17.02</td>
<td>18.14</td>
</tr>
</tbody>
</table>
These activities are also aimed at capturing participant’s interest and enabling them to make connections with what they know and could do. As such, the ‘Step 1’ section of the workshop observation instrument attempts to identify the degree to which the facilitator engaged the participants in the problem solving activity according to specific criteria, as shown in table 4.3.

**Step 2: Allows participants to explore the concept**

Step 2 of the National Science Education Standards (1996) model of inquiry instruction identifies the degree to which the facilitator allows participants to explore the concept of the problem solving activity according to specific criteria. Data generated by the workshop observation schedule revealed the following mean scores for each group of facilitators for the second step of inquiry learning.

Table 4.4: Comparison of facilitator mean scores, across facilitator categories, on their ability to allow participants to explore the concept

<table>
<thead>
<tr>
<th>Criteria for Step 2</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Veteran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allows partic’ responses to drive lessons</td>
<td>2.47</td>
<td>2.70</td>
<td>2.64</td>
</tr>
<tr>
<td>Poses thoughtful, open-ended questions</td>
<td>2.40</td>
<td>2.50</td>
<td>2.79</td>
</tr>
<tr>
<td>Encourages participants to question</td>
<td>2.13</td>
<td>2.30</td>
<td>2.43</td>
</tr>
<tr>
<td>Poses contradictions to initial hypotheses</td>
<td>2.13</td>
<td>2.40</td>
<td>2.38</td>
</tr>
<tr>
<td>Allows time after posing questions</td>
<td>3.20</td>
<td>3.00</td>
<td>3.07</td>
</tr>
<tr>
<td>Focuses and supports inquiries</td>
<td>2.71</td>
<td>3.00</td>
<td>3.21</td>
</tr>
<tr>
<td>Sum of mean scores</td>
<td>15.04</td>
<td>15.90</td>
<td>16.52</td>
</tr>
</tbody>
</table>
Step 3: Encourages participants to explain the concept and define the terms

Step 3 of the National Science Education Standards (1996) model identifies the degree to which the facilitator encourages participants to explain the concept and define the terms related to the problem solving activity, according to specific criteria. Data generated by the workshop observations schedule revealed the following mean scores for each category of facilitators for the third step of inquiry learning.

Table 4.5: Comparison of facilitator mean scores, across facilitator categories, on their ability to encourage participants to explain the concept and define the terms

<table>
<thead>
<tr>
<th>Criteria for Step 3</th>
<th>Group mean score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Novice</td>
</tr>
<tr>
<td>Seeks elaboration of partic responses</td>
<td>2.47</td>
</tr>
<tr>
<td>Encourages use of cognitive terminology</td>
<td>2.13</td>
</tr>
<tr>
<td>Asks probing questions</td>
<td>2.47</td>
</tr>
<tr>
<td>Gives opportunity to refine explanations</td>
<td>2.20</td>
</tr>
<tr>
<td>Sum of mean scores</td>
<td>9.27</td>
</tr>
</tbody>
</table>

Overall mean scores for practices observed

The mean scores for the workshop observations in general, which includes all three steps of the NSES inquiry model, as indicated in figure 4.1, suggest a steady progression in the implementation skills of the facilitators on the Family Maths training course as they advance through the sequential stages; from novice, to intermediate to veteran.
Facilitator Categories

Figure 4.1: Overall mean scores of novice, intermediate and veteran groups in terms of inquiry-based practice.

Steps 4 and step 5 of the five stage instructional model includes ‘elaborating on the concept’ and ‘evaluating learners’ understanding of the concept’. These two steps did not form part of the Family Maths programme in which the research was being conducted. The Family Maths programme encourages facilitators to meet the requirements of steps four and five by engaging in further discussion and construction of conceptual knowledge within the classroom situation.

Analysis of variance

Statistical analyses (ANOVA) of the data generated by workshop observations reveal that there were statistically significant differences between the veteran, intermediate and novice groups in terms of ‘encouraging and accepting student autonomy and student initiative’, ‘familiarising themselves with the participants understandings of concepts’, ‘encouraging participants to engage in discussion with the facilitator and one another’, ‘nurturing participants natural curiosity’, ‘focusing
and supporting inquiry while interacting with the participants’, and ‘giving participants opportunities to refine their explanations and definitions’. In each case the veteran group scored the highest and the novice group the lowest. These data are reflected in table 4.6 below.

Table 4.6: Comparison of statistically significantly different mean facilitator scores on criteria observed during the workshops.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Veterans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encouraging autonomy (1b)</td>
<td>2.60</td>
<td>3.10</td>
<td>3.14</td>
</tr>
<tr>
<td>Participants understanding (1d)</td>
<td>2.40</td>
<td>2.70</td>
<td>2.86</td>
</tr>
<tr>
<td>Engaging discussion (1e)</td>
<td>2.47</td>
<td>2.50</td>
<td>2.93</td>
</tr>
<tr>
<td>Nurturing curiosity (1f)</td>
<td>2.40</td>
<td>2.50</td>
<td>2.86</td>
</tr>
<tr>
<td>Focusing/supporting inquiry (2.f)</td>
<td>2.71</td>
<td>3.00</td>
<td>3.21</td>
</tr>
<tr>
<td>Refining explanations (3d)</td>
<td>2.20</td>
<td>2.40</td>
<td>2.64</td>
</tr>
<tr>
<td>Sum of mean scores</td>
<td>14.78</td>
<td>16.20</td>
<td>17.64</td>
</tr>
</tbody>
</table>

As can be seen in table 4.6 the mean scores recorded increased sequentially, i.e. the novice group scored the lowest in each case, and the veterans scored the highest in each case. The statistical significance between these scores is portrayed in table 4.7 below.
Table 4.7: Probability values which indicate statistically significant differences between mean scores for criteria observed during facilitation of Family Maths workshops

<table>
<thead>
<tr>
<th></th>
<th>Novice</th>
<th>Intermediate</th>
<th>Veteran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encourages autonomy (1b)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novice</td>
<td>-</td>
<td>0.0056***</td>
<td>0.0012**</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.0056***</td>
<td>-</td>
<td>0.8047</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participants’ understanding (1d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Intermediate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engages discussion (1e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Intermediate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nurtures curiosity (1f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Intermediate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supports inquiries (2f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Intermediate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participants refine explanations (3d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Novice</td>
</tr>
<tr>
<td>Intermediate</td>
</tr>
</tbody>
</table>

* ** = statistically significant at the 95% level of confidence
*** = statistically significant at the 99% level of confidence

Table 4.7 reveals probability values at the 99% and 95% levels of confidence between the novice and intermediate groups and between the novice and veteran groups. This indicates significantly different levels in the ability level of facilitators to encourage and accept student autonomy and initiative as an important inquiry strategy as they progress through the two year Family Maths training course.
There is also a significant difference at the 95% level of confidence between the veterans and novices' ability in familiarising themselves with the participants’ understandings of concepts. The veteran group of facilitators show a much higher level of competence in familiarising themselves with workshop participants’ understanding of concepts than the novice group of facilitators.

The statistically significant difference in terms of encouraging participants to engage in discussion with the facilitator and one another is at the 99% and 95% levels of confidence between the veterans and novices and the intermediates and novices respectively. The data on the category ‘nurturing participants’ natural curiosity’ shows a statistically significant difference between the veterans and the novices, while there is a similar level of confidence between the scores of the veteran and novice group in terms of ‘focusing and supporting inquiry while interacting with the participants’.

The difference between the veterans and the novices in giving participants opportunities to refine their explanations and definitions is also significant at the 99% level of confidence.

2.3 Comparison of mean scores between facilitators’ inquiry learning belief system and implementation of inquiry learning

In all three categories of facilitators, viz. novice, intermediate and veteran, the novices show the least amount of understanding regarding inquiry learning (inquiry beliefs) and they also have the lowest rating with regard to implementation of inquiry learning strategies. The group of intermediate facilitators generally show a greater understanding than the novice group and also implement inquiry learning more effectively in the workshop situation. The veteran group of facilitators show the
greatest understanding of inquiry learning and also show the greatest skill in the implementation of inquiry learning strategies.

Table 4.8 below represents the mean scores of each of the categories of facilitators with regard to their inquiry belief system and their implementation of inquiry learning. The mean scores for each of the categories of encouraging participants to engage in the problem solving situation, explore the concepts and explain the concepts and terms is given for the purposes of comparing what facilitators say they believe regarding inquiry learning with their implementation skills of inquiry learning in the workshop situation.

Table 4.8: Comparison of facilitator mean scores with regard to inquiry learning belief versus practice

<table>
<thead>
<tr>
<th></th>
<th>Novice</th>
<th>Intermediate</th>
<th>Veteran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage</td>
<td>3.39</td>
<td>3.62</td>
<td>3.70</td>
</tr>
<tr>
<td>Explore</td>
<td>3.15</td>
<td>3.34</td>
<td>3.48</td>
</tr>
<tr>
<td>Explain</td>
<td>3.16</td>
<td>3.45</td>
<td>3.56</td>
</tr>
<tr>
<td>Total</td>
<td>9.70</td>
<td>10.41</td>
<td>10.74</td>
</tr>
</tbody>
</table>

Figure 4.2 graphically represents the extent to which facilitators implement inquiry learning in relation to their beliefs regarding inquiry learning.
Facilitator Categories

Figure 4.2: Comparison of participating facilitators’ beliefs and practice in terms of inquiry learning

In all categories of comparison in figure 4.2 the probability value is less than 0.05 ($p \leq 0.06$) and there is, therefore, a 95% level of confidence that the statistical difference in the mean scores of the belief system questionnaire and the workshop observation instrument scores are not due to chance. We conclude, therefore, that in all categories, namely, novice, intermediate and veteran, that facilitators’ inquiry learning workshop implementation strategies do not always support their stated belief system regarding inquiry learning.

2.4 Facilitator verbal response behaviour measured by observation

Facilitator feedback techniques were observed using criteria identified by the Brophy and Good Dyadic Interaction Coding System. Facilitators’ techniques were documented on coding sheets by observers as they entered check marks in appropriate columns as facilitators presented Family Maths workshops to parents and learners. Table 4.9 below indicates the criteria against which facilitators’ verbal feedback techniques were measured.
Table 4.9: Criteria identified by the Brophy and Good Dyadic Interaction System for measuring effective facilitator verbal feedback inquiry skills.

<table>
<thead>
<tr>
<th>Criteria for verbal feedback</th>
<th>Explanation of Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gives Answer</td>
<td>Facilitator provides correct answer</td>
</tr>
<tr>
<td>Repeats Question</td>
<td>Facilitator repeats original question</td>
</tr>
<tr>
<td>Gives Clue</td>
<td>Facilitator gives clue</td>
</tr>
<tr>
<td>Rephrases Question</td>
<td>Facilitator simplifies question by rephrasing</td>
</tr>
</tbody>
</table>

Data analysis from the workshop interaction coding system instrument revealed that, across all categories of facilitators, higher order responses of ‘giving clues’ and ‘rephrasing questions’ were more frequent responses than merely ‘repeating questions’. Giving answers to participants was strongly discouraged during the Family Maths training of inquiry-based facilitation skills. Table 4.10 shows the comparison of percentage scores of each of the verbal feedback criteria used by facilitators.

Table 4.10: Comparison of percentage scores for each criteria of the verbal feedback skills across three categories of facilitators

<table>
<thead>
<tr>
<th></th>
<th>Gives answer</th>
<th>Repeats question</th>
<th>Gives clue</th>
<th>Rephrases question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
<td>1</td>
<td>23</td>
<td>39</td>
<td>37</td>
</tr>
<tr>
<td>Inter</td>
<td>1</td>
<td>18</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>Vet</td>
<td>0</td>
<td>18</td>
<td>40</td>
<td>42</td>
</tr>
</tbody>
</table>
The percentage scores from table 4.10 suggest that facilitators’ verbal feedback techniques improve as they progress from novice facilitators to veteran facilitators. The intermediate and veteran scores indicate that facilitators have advanced from the feedback technique of merely repeating questions to giving clues and rephrasing questions in order to direct participants’ thinking regarding the problem activity.

3. INTERVEIWS

Qualitative semi-structured interviews (Appendix D) consisting of standardized open-ended questions were used in order to allow the interviewer opportunities to freely use probes to obtain response clarity, greater depth and additional information from the interviewees. A total of 39 facilitators were interviewed for the purposes of deeper probing into their beliefs and perspectives on inquiry-based learning, their understanding of mathematical problems and their facilitation skills of inquiry-based education. As English is not the home language of the majority of the interviewees the interviewer found it necessary to change the wording of some of the questions in the interview protocol for the purposes of simplifying the language to clarify meaning for the interviewee.

The data generated via questionnaires and interviews were classified into broad categories and analysed within the framework of the literature reviewed. Each of the interview questions from the facilitator interview schedule, given below, is followed by comments in italics reflecting the purpose of each question. A description of the interviewee responses and a brief summary of the most pertinent responses follow.
Do you believe that your facilitation skills promoted learning with parents and learners? Give reasons why or why not.

To ascertain whether the facilitators understood and perceived themselves as being able to effectively implement inquiry-based facilitation skills that promoted learning amongst participants. As most of the facilitators had a strong background in traditional teaching methods, it was important to know whether this view had been challenged by the inquiry-based teaching and learning strategies promoted on the Family Maths training course.

100% of all interviewees across the three categories, novice, intermediate and veteran, believed that their facilitation skills promoted learning with parents and learners. The most frequent response given was that they had guided the participants by giving clues when required and asking participants pertinent questions which would direct their thinking. An overall 83% of facilitators (58% novice, 100% intermediate and 100% veteran) gave the response to this question as ‘asked questions and gave clues’ which encouraged participants to persevere and enjoy the problem solving activity. This concurs with the Family Maths philosophy that if participants experience enjoyment and success in ‘doing’ maths activities, their confidence will improve, their attitude towards mathematics will become more positive and their mathematical ability, therefore, will develop and grow. Benefits derived from the Family Maths training course were evident by the following responses from facilitators, ‘without the training course I wouldn’t know what clues to give’, ‘It has changed my way of teaching’, ‘I realise that I need to encourage learners to question each other more’ and ‘inquiry learning is a brilliant concept’.

The responses from facilitators of the intermediate and veteran groups of facilitators intimated that the majority of them felt confident in implementing inquiry
learning as they had developed good questioning skills and had learnt how to give meaningful clues during their training course. However a large number of the novice group of facilitators felt that they needed more training and experience in questioning skills and giving meaningful clues to participants.

#2 How did you help the parents and learners solve the problem presented at your station? Give some examples.

To ascertain whether facilitators perceived themselves using guided discovery strategies, as promoted in the Family Maths training course, to enable participants to solve problems.

100% of all facilitators, novice, intermediate and veteran, said that they believed that they had encouraged parents and learners solve the problems presented by ‘giving clues and asking questions’. Other frequently recorded responses to this question included ‘made sure they understood the problem’ (63%) and ‘encouraged participants to keep trying’ (50%). The observer noted that many of the novice facilitators tended to rush the participants, whilst both the intermediate and veteran groups of facilitators mentioned the importance of giving the participants sufficient time to work at the problem. Some facilitators in the intermediate and veteran groups mentioned that they had found it necessary to use the participants’ mother tongue when in discussion with the participants. Many participants also felt more comfortable in reverting to their mother tongue during group discussions.

#3 Do you believe that the training course has helped you to assist workshop participants solve problems by engaging them? Explain how.

To ascertain whether facilitators believed they had implemented inquiry-based facilitation skills which fully engaged participants in problem solving scenarios.
The results of the responses from facilitators to this question indicated that 77% of facilitators across all three groups (novice 75%, intermediate 75%, veteran 80%) cited ‘creating a relaxed atmosphere’ as an important criterion for engaging participants in the problem activity. The second most frequent response was ‘asking questions and giving clues’ which got a 57% rating across the three categories (75% novice, 38% intermediate, 50% veteran). Facilitators across all categories said that they had developed confidence to engage participants in problem solving activities as a result of their own exposure to the activities and the discussion of relevant clues and questions during the Family Maths training course. A deeper understanding of facilitation skills by the intermediate and veteran facilitators was illustrated by the following interview responses, ‘I encourage co-operative strategies’, ‘hands on materials promote engagement’, ‘I didn’t rush the participants’, ‘I encouraged discussion by asking questions’.

78% of facilitators from both the intermediate and veteran groups mentioned the importance of allowing participants sufficient time to work at the problem after posing questions, whereas none of the novice group facilitators mentioned the importance of this criterion for engaging participants in inquiry learning. All groups of facilitators made statements which suggest that they realised the importance of maximising the use of apparatus and creating a relaxed atmosphere as conducive to participants’ engagement in the activity.

#4 Do you believe that the training course has helped you to assist workshop participants solve problems by encouraging them to explore the concept?

Explain how.

To ascertain whether facilitators believed they had implemented inquiry-based facilitation skills which allowed participants to fully explore the problem situation.
70% of facilitators, across all three categories (50% novice, 63% intermediate, 100% veteran), responded that the most important criteria for encouraging participants to explore the problem was by ‘giving clues and asking questions’.

Although the importance of discussion was frequently cited as an important criterion for encouraging participants to explore the concept, both novice and intermediate groups of facilitators realised that much of the discussion had taken place between the facilitator and participants and that they had not sufficiently encouraged discussion amongst the participants themselves. Facilitators from the veteran group expressed confidence that they had encouraged participants to explore the problem solving activities by applying the strategies with which they had become familiar during training workshops. 50% of facilitators, across all three groups, mentioned that they had encouraged participants to use their own methods to solve the problem activity.

#5 Do you believe that the training course has helped you assist workshop participants to solve problems by encouraging them to explain the concept and define the terms? Explain how.

To ascertain whether facilitators had implemented inquiry-based facilitation skills which encouraged participants to explain their understanding of the problem and how they solved it using mathematical terminology.

This was the only question of the five interview questions where the response of ‘giving clues and asking questions’ was not a relevant response.

83% of the thirty facilitators said that they believed that they had encouraged participants to explain how they had solved the problem. However, all three groups of facilitators felt that they had not maximised on the opportunity of asking participants
to explain their thinking or define mathematical terms. The reason frequently given was that, as English was not the mother tongue of many of the participants, the focus on mathematical concepts and terminology would possibly undermine the relaxed, non-threatening atmosphere that was characteristic of Family Maths workshops. It was felt that Family Maths workshops should focus on the enjoyment of solving mathematical problems and that the formalising of the mathematical content would be more appropriate in the classroom situation. As many of the participants at the workshops were unable to explain how they solved the problem, facilitators gave them the opportunity of demonstrating how they had arrived at their solution, using the apparatus and manipulatives at each respective station.

**#6 What is your perception of inquiry-based learning?**

*To understand facilitators’ perceptions of inquiry-based learning, it was important to ask probing questions as to how inquiry-based strategies differed from traditional teaching and learning strategies.*

Responses to the above question indicated that 92% of facilitators perceived that ‘giving clues and asking questions to find solutions’ underpinned inquiry learning (novice 75%, intermediate 100%, veteran 100%). It was interesting to note that although a variety of responses were given to this question; all responses were correct descriptions of characteristics of inquiry learning. Other frequently given characteristics of inquiry-based learning included ‘co-operative learning (45%) and discovery learning (37%). The descriptions given by facilitators concurred with the characteristics which underpin inquiry-based instruction given by Layman (1996) and Brooks and Brooks (1993) as stated in chapter one.
Although the majority of the thirty nine facilitators, from all groups, said that they had gained confidence during the training course with regard to giving meaningful clues and posing open-ended questions, two facilitators said that they felt that they needed more guidance in this regard and did not feel confident in posing open-ended questions. They felt that there should be more focus on open-ended questioning skills during the training workshops. Three facilitators felt that, as English was not the mother tongue of many of the participants, the introduction of mathematical concepts and terminology could undermine the relaxed, non-threatening atmosphere that was characteristic of Family Maths workshops. Facilitators felt that the Family Maths workshops should focus on the enjoyment of solving mathematical problems and that the formalising of the mathematical content would be more appropriate in the classroom situation. They said that many of the participants were unable to explain how they solved the problem and facilitators gave them the opportunity to demonstrate, using the apparatus and manipulatives at each station, how they had arrived at their solution. In many instances facilitators asked participants questions in order to guide their thinking and assist them in the explanation of their solutions to the problem activity.

During the interview process some of the facilitators shared their feelings and personal experiences regarding implementation of inquiry learning. Facilitator responses included, ‘I still find it hard to move away from the teacher-centered approach’, ‘inquiry learning has changed my way of teaching’ and ‘inquiry-based learning has made me think differently about my own teaching strategies’. These comments indicate that although the paradigm shift from teacher-centered to learner-centred teaching had presented many challenges for teachers, they were taking up the challenges.
All facilitators interviewed were in favour of adopting inquiry-based teaching and learning approaches, but many said, as described above, that they had found it difficult to make the paradigm shift from a teacher centred approach. Llewellyn (2005) states that, in order to establish inquiry-centred environments teachers need to accept changes in their role and in the atmosphere of the classroom. Many facilitators from the intermediate and veteran groups acknowledged that inquiry-based learning had changed their way of teaching both in the workshop situation and in the classroom. These responses reveal an important achievement for the intermediate and veteran groups. A novice facilitator said that inquiry learning was ‘a whole different way of teaching to what we are used to and we like it’.

**Giving clues and asking questions**

Five of the six questions asked during the interview had ‘giving clues and asking questions’ as an appropriate response. This response was applicable for questions one, two, three, four and six. For four of these five questions, the respondents cited ‘giving clues and asking questions’ as the most important skill in motivating and assisting participants in solving problems.

Table 4.11 provides the percentage of the 39 interviewees who gave ‘giving clues and asking questions’ as the most important skill in motivating and assisting participants in solving problems (the overall percentage for each question, as well as the percentage for each category of facilitator - novice, intermediate or veteran – is given). Question three is the only case in which the facilitators did not identify ‘giving clues and asking questions’ as the most important criteria for inquiry learning. Instead, responses from facilitators to question 3 indicated that 77% of facilitators (novice 75%, intermediate 75%, veteran 80%) cited ‘creating a relaxed atmosphere’ as more important than ‘giving clues and asking questions’. In all other relevant
questions the criteria of ‘giving clues and asking questions’ was rated as the most important criteria for inquiry learning.

The facilitators’ response to questions one, two, four and six show an increase in the percentage of facilitators identifying ‘giving clues and asking questions’ as they progressed from novice to the veteran group.

Table 4.11: Comparison of facilitator responses citing ‘giving clues and asking questions’ as the most frequent response to the interview questions.

<table>
<thead>
<tr>
<th>Question</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Veteran</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>58</td>
<td>100</td>
<td>100</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>63</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>6</td>
<td>75</td>
<td>100</td>
<td>100</td>
<td>90</td>
</tr>
</tbody>
</table>

4. SUMMARY

Both qualitative and quantitative methods were used to generate the data in this study. Quantitative statistical data were generated from the facilitator inquiry learning belief system questionnaire (n = 88) and the workshop observation instrument (n = 39). These data were analysed and subjected to analysis of variance (ANOVA) techniques to provide statistically significant mean scores for comparison across the three categories of facilitators. Quantitative data were generated from the workshop interaction coding system instrument (n = 39) and qualitative data generated from the interview schedules (n = 39). These data were analysed according to broad categories to provide descriptive and inferential statistics.
Analysis of the questionnaire data on facilitators’ beliefs reveal that for the criteria on the inquiry learning belief system questionnaire it is evident that there is a statistically significant difference in the mean value between the novice group of facilitators and either both or one of the other two groups of facilitators who have been participating on the programme for a longer period of time. This suggests that the majority of facilitators who first embark on the Family Maths training course do not have in-depth knowledge or experience in terms of inquiry learning as a teaching and learning strategy.

Workshop observation data suggest a steady progression in the implementation skills of the facilitators on the Family Maths training course as they advance through the sequential stages; from novice, to intermediate to veteran. This indicates significantly different levels in the ability level of facilitators to encourage and accept student autonomy and initiative as an important inquiry strategy, as they progress through the two year Family Maths training course.

Statistical analyses (ANOVA) of the data generated by workshop observations reveal that there were statistically significant differences between the veteran, intermediate and novice groups in terms of ‘encouraging and accepting student autonomy and student initiative’, ‘familiarising themselves with the participants understandings of concepts’, ‘encouraging participants to engage in discussion with the facilitator and one another’, ‘nurturing participants natural curiosity’, ‘focusing and supporting inquiry while interacting with the participants’, and ‘giving participants opportunities to refine their explanations and definitions’. In each case the veteran group scored the highest and the novice group the lowest.

Comparison of mean scores between facilitators’ inquiry learning belief system and implementation of inquiry learning indicate that in all three categories of
facilitators, viz. novice, intermediate and veteran, the novices show the least amount of overall understanding regarding inquiry learning (their beliefs) and they also have the lowest rating with regard to implementation of inquiry learning strategies. The group of intermediate facilitators generally show greater understanding than the novice group does and they also implement inquiry learning more effectively in the workshop situation. The veteran group of facilitators show the greatest understanding of inquiry learning and also show the greatest skill in the implementation of inquiry learning strategies.

Qualitative semi-structured interviews consisting of standardized open-ended questions held with 39 facilitators from the Family Maths facilitators’ training workshop were used in order to allow the interviewer opportunities to freely use probes to obtain response clarity, greater depth and additional information from the interviewees. The most frequent response given by the facilitators was that they had guided the participants by giving clues when required and asking participants pertinent questions which would direct their thinking. The responses from facilitators of the intermediate and veteran groups intimated that the majority of them felt confident in implementing inquiry learning as they had developed good questioning skills and had learnt how to give meaningful clues during their training course. However a large number of the novice group of facilitators felt that they needed more training and experience in questioning skills and giving meaningful clues to participants. A discussion of the implications of the data generated by the study in terms of seeking an answer to the research question is described in the final chapter.
CHAPTER FIVE

INTERPRETATION AND DISCUSSION

1. INTRODUCTION

Llewellyn (2005) argues that inquiry involves active explorations by students in which they use critical, logical and creative thinking to raise and engage in questions of personal interest. The degree to which these objectives were realised in this study is examined in this chapter as I interpret the results obtained and discuss the data in terms of the principal research question.

*To what extent does the Family Maths facilitator training programme develop facilitators’ ability to implement inquiry based learning?*

The categories developed from the quantitative statistical analysis and the descriptive qualitative data in chapter four are related to the theoretical underpinnings noted in chapter two in an attempt to provide answers to the research subsidiary questions, viz.:

- *Is there a difference in facilitators’ beliefs regarding inquiry learning as they proceed from novice to veteran category?*
- *Is there a difference between the ability to facilitate inquiry learning amongst facilitators who have completed the two year training programme, those who are in their second year of training and those who are still in their first year of training*
• How do facilitators’ approaches to facilitating Family Maths workshops change as they engage in the programme?

• What aspects of the programme are effective in developing an inquiry based approach?

Possible implications of the findings for curriculum reform of the Family Maths training programme are discussed as well as implications for the teaching and learning of mathematics. An overview of the relevance and significance of using inquiry-based teaching and learning as the appropriate strategy for the Family Maths programme is provided and the results generated by data collected via questionnaires, observations and semi-structured interviews are discussed.

2. STATISTICAL ANALYSES

Statistical analyses were made of the data generated by the belief system questionnaires, workshop observations and the semi-structured interviews of the facilitators participating in this study.

2.1 Belief systems measured by questionnaire

In designing the questionnaire to determine facilitators’ beliefs and understanding regarding inquiry-based teaching and learning, the use of jargon and technical terms was carefully avoided and the use of familiar language enabled facilitators to complete the questionnaire without feeling threatened in any way. In order to be able to clarify issues when necessary, the programme coordinator was present at all times while the facilitators completed the questionnaire.

The quantitative data generated by the facilitators’ responses to the questionnaire for each of the three inquiry steps focused on in this study and presented in the questionnaire were treated via the analysis of variance model (ANOVA). These
steps, viz., the significance of engaging participants in the problem situation, allowing participants to explore the concept and encouraging participants to explain the concept and define the terms, are an integral part of the Family Maths training programme and the results of the statistical treatment yielded insightful and meaningful information for the research study.

The analysis of the data generated by the facilitators’ inquiry belief system questionnaire revealed that, on occasions, the intermediate facilitators achieved slightly higher mean scores than the veteran facilitators. Possible reasons for this could be that, while intermediate facilitators participate in regular training workshops and benefit by regular support from Family Maths trainers, many of the veteran facilitators, having successfully completed the training course, present Family Maths workshops independently without ongoing support from the Family Maths facilitators and co-ordinators with a possibly a tendency to regress to the more traditional beliefs which they may have held over a period of many years. In other words, over time the significance of some of the important principles of inquiry learning could become vague, less important in the minds of the facilitators, and be overlooked. This suggests that it is important that longer and more ongoing support for Family Maths workshop presenters be provided once they have completed the training course. This matter is discussed in chapter six which deals with conclusions and recommendations.

Examination of the mean scores revealed a statistically significant difference between the three groups of facilitators in terms of ‘encouraging initiative’ (1b), ‘encouraging questioning’ (2c), ‘posing contradictions’ (2e), ‘allowing time after questions’ (2f), ‘seeking elaboration’ (3a) and ‘allowing participants to refine explanations’ (3d). The data suggest that it is these criteria, which involve higher order thinking skills, which are least developed in novice facilitators and that these
inquiry skills generally improve over time as facilitators practice them and reflect on them during the two year training programme.

Criteria, which may be considered to relate to more fundamental skills, such as ‘creating a relaxed, friendly environment (1a), ‘using teaching and learning aids’ (1d), ‘finding out participants’ understanding of concepts (1e), ‘encouraging participants to discuss their understanding’ (1f), ‘encouraging participants natural curiosity (1h), ‘allowing participants answers to drive lessons’ (2a), ‘encouraging participants inquiry by asking thoughtful, open-ended questions’ (2b), encouraging participants to think by making them use terms like classify, analyse, predict’ (3c) revealed no statistically significant differences. These criteria were focused on and formed an integral part of the Family Maths training content from the outset of the programme as they are regarded as a prerequisite to becoming an inquiry-based teacher. The fact that most of the facilitators seem able to internalise and implement these skills without much difficulty is the most probable and realistic explanation for the lack statistically significant differences being shown amongst the categories of facilitators for these criteria.

2.2 Teacher Practice measured by observation

As discussed in the literature review, South African teachers traditionally have relied predominantly on close-ended questions with only one correct answer, or which simply require learners to recall information. This research investigated whether facilitators are able to capture and focus the learners’ attention on critical parts of the problem solving process using open-ended questions which facilitate meaningful discussion and which require that the facilitator engage participants in a problem solving activity in which they are asked to communicate their responses.
According to Abrami et al., (1995), competent facilitators who successfully combine inquiry-based teaching and learning strategies within a relaxed, non-threatening learning environment transform workshops into vibrant, enthusiastic experiences of collaborative discussion and learning, with significant gains in both cognitive and non-cognitive goals being accomplished as students actively challenge and engage with each other, thereby honing their interpersonal and verbal skills during the learning experience.

Naturalistic observation of participants in the workshop setting, as described in chapters three and four, enabled the researcher to record and study these behaviours and interactions between the facilitators and participants within an authentic workshop setting. The facilitators’ competences in engaging participants in the problem solving activity are tabled in chapter four, table 4.3. Overall scores for each of the categories of facilitators suggest that their ability to engage participants in problem activities improve as they progress from the novice to the veteran category. Johnson and Johnson’s (1990) review of 48 studies, reports higher achievement was characteristic of cooperative mathematics classes. It is, therefore, realistic to expect that more learning would take place during discussion and debate of the problem solving situations participants experienced in the Family Maths workshops, an expectation which is borne out by the data generated by the observation schedules and interviews.

2.2.1 Workshop Observation Instrument

Step 1: Engaging the participants

The purpose of the engagement stage is to introduce activities intended to engage learners and their parents with a problem solving situation, and to capture the
participants’ interest and enable them to make connections with what they knew and could do before participating in the programme. Learners and parents were given the opportunity to interact with each other and with carefully chosen sets of materials. While teams of participants engaged in the problem and explored ways of solving it, the facilitator responded to calls for clarification and guidance, only giving clues when requested to do so.

During the engagement stage it was expected that the facilitator would set the stage for learning and introduce activities that would engage learners and parents with a problem or phenomenon. These activities were intended to provide participants with an open-ended opportunity to interact with the materials and each other. Activities were aimed at capturing participants’ interest and enabling them to make connections with what they knew and could do. From a constructivist perspective the engagement phase provides an opportunity for the facilitator to activate learning, assess prior knowledge, current beliefs and understandings and have participants share their experiences about the topic. Step one of this observation instrument identified the degree to which the facilitator engaged the participants in the problem solving activity according to specific criteria. It was evident from analysis of data that there are statistically significant differences in the mean values between the novice group of facilitators and the other two groups of facilitators who had been on the training course for a longer period of time. This suggests that the majority of facilitators who embark on the Family Maths training course have little knowledge or experience in inquiry-based teaching and learning in terms of engaging their participants.

Table 4.3 in chapter four presents a comparison of the facilitators’ mean scores in terms of their ability to engage participants in problem solving activities. For five of the six criteria in the engagement stage the mean scores indicated that
facilitators improved in their ability to engage participants in the problem solving activity as they progressed from the novice to veteran category. The only criterion which indicated that the veteran facilitators’ mean scores were the least and novice facilitators’ mean scores the highest was ‘uses manipulative and physical materials’ (1c). A possible explanation for this could be that the novice facilitators are more dependent on concrete materials when facilitating group engagement in problem solving activities and therefore focus more on the use of manipulatives and physical materials than their more skilled colleagues. As the facilitators build confidence in their mathematical ability and facilitation skills, they are likely to become less dependent on concrete materials (but which is still an important focus of the Family Maths training programme).

It was noted in chapter four that there were no statistically significant differences amongst the three groups of facilitators for some of the criteria, which suggests that it is important to examine the strategies of the Family Maths training programme as well as the teaching styles and mathematical content knowledge that the facilitators brought with them to the training sessions. The emphasis on creating a relaxed, non-threatening environment is modelled throughout the training programme and teachers are constantly reminded of the importance of this for developing positive attitudes and confidence in mathematics. It is not surprising, therefore, that for this particular criterion, viz., ‘creates a relaxed, non-threatening environment’ (1a), no significant difference amongst the three categories of facilitators was noted. The other criteria where there are no statistically significant differences between the groups are all specific to inquiry-based learning and which most teachers do not normally practice in their classroom situations and are therefore, through the Family Maths training course, introduced and strongly developed right at the beginning of the
programme. This heavy emphasis at the beginning of the programme may possibly explain why there is no statistically significant differences were found between the three groups of participating facilitators.

Table 4.4 in chapter four indicates that the sum of the mean scores for each of the categories of facilitators, that is, novice, intermediate and veteran, showed a statistically significant difference and suggests a progression in understanding and implementation of inquiry strategies with regard to engaging participants in the problem solving situation.

**Step 2: Allowing participants to explore the concept**

The purpose of the exploration stage was for participants to raise questions, develop hypotheses to test, and work without direct instruction from the facilitator. Learners and parents were encouraged to participate in hands-on experiences through which they explored the concept further. They received little explanation or mathematical terminology at this point because it was important that they first defined the problem or phenomenon in their own words. During this stage of the learning process facilitators were encouraged to give participants considerable time for group discussion where group members would have the opportunity to articulate individual understanding and listen to one another’s points of view. It was envisaged that learners and parents would help one another make sense of the concept. According to Brooks and Brooks (1993), a very powerful way students come to change or reinforce conceptions is through social discourse. Having an opportunity to present one’s own ideas, as well as being permitted to hear and reflect on the ideas of others, is an empowering experience. They further suggest that the benefit of discourse with others, particularly with peers, facilitates the meaning-making process. An inquiry-
based framework challenges teachers to create environments in which they and their students are encouraged to think, engage and explore problem situations.

Many teachers mistakenly believe that when they talk to learners and learners respond to their questions, that discussion has taken place. However, Shuard (1984) suggests that what is meant by discussion is extended joint exploration by the learners, under the guidance of the teacher, in which the teacher does not force the direction and pace of the oral exchange, and in which ideas are explored and argued with mutual respect for each other’s point of view.

Step two of this observation instrument measured the degree to which the facilitators allowed participants to explore the concept in the problem solving activity according to specific criteria. Data generated from the workshop observations, for each of the three categories of facilitators, is described in chapter four. Table 4.4 in chapter four shows a comparison of facilitator the mean scores across the three categories of facilitators with regard to their ability to encourage exploration of the problem solving activity. The mean scores of five of the six criteria suggested that facilitators improved in their ability to encourage participants to explore the problem activity as they progressed across the facilitator categories. The only criterion, which indicated that the intermediate facilitators were more competent in implementing exploration strategies than the veteran facilitators, was ‘poses contradictions to their initial hypotheses’. A possible explanation could be that many of the veteran facilitators, having already completed the training programme, no longer benefit from regular interaction with Family Maths trainers and other course participants. This could result in possible neglect of this important inquiry skill. As was the case with facilitators’ ability to engage participants in the problem solving activity, the overall
mean scores for each category of facilitators indicate a steady progression in the ability of facilitators to encourage exploration of the problem solving activity.

During observation of the Family Maths workshops it became evident that the ability of participants to meaningfully explore the problem solving activity was adversely affected by language barriers. Family Maths workshops were presented in either English or Afrikaans, depending on the medium of instruction of the respective schools in the community. Recurring incidences of code switching was evident during the exploration stage where first language Xhosa speakers frequently felt that they could express themselves more articulately in their mother tongue. The possible negative implications that the medium of instruction has for second-language speakers is recognised widely in international and South African literature as a contributing factor in learning and understanding mathematical concepts and terminology. Research which emphasises learner-centred practice (Black & Atkin, 1996) and models of bilingual education (Taylor & Vinjevold, 1999) view code-switching between English and the vernacular as a key strategic practice for effective teaching and learning in classes where the learners are learning in their second language.

Occasionally the facilitator interrupted the participants and asked for further explanations with regard to interesting questions that they had come up with. This often inspired a good deal of enthusiasm for solving the problem at hand. Learners and parents often drew on their past mathematical experiences, but usually found that, with a practical activity with no set procedures to guide them, they could develop their own ideas and rely on one another for support.

*Step 3: Encouraging participants to explain the concept and define the terms*
During the explanation stage it was expected that facilitators would encourage participants to explain their understanding of the mathematical concepts related to the problem solving situation and also explain how they arrived at a solution for each of the problem-solving activities. Facilitators were encouraged, once participants had explored the concept, to introduce relevant mathematical terms as participants refined their explanations of concepts and solutions. Participants were then expected to use these terms to describe what they had experienced and begin to examine how the explanation fitted with what they already knew. The purpose of this stage was that participants ‘construct’ new meaning from their experience at co-operative problem solving. Facilitators were encouraged to help the participants refine their language but make sure that participants were using terms they understood and did not rely on terminology merely for the sake of sounding ‘mathematical’.

Facilitators were often hesitant to introduce too much mathematical terminology that might threaten the relaxed atmosphere they had created to promote enjoyment, discussion and exploration. Most facilitators believed that it would be more beneficial for participants to understand, solve and explain concepts and their solutions to problems during the workshop without introducing them to all of the appropriate mathematical terminology. Many of the facilitators felt strongly that too much emphasis on mathematical terminology would undermine the enjoyment of doing the mathematics. They felt that this was especially threatening for parents who attended Family Maths workshops to enjoy a relaxed time with their children. Consensus amongst facilitators indicated that it would be more appropriate to focus on relevant mathematical terminology with learners in the classroom situation.

Step 3 identified the degree to which the facilitator encouraged participants to explain the concept and define the terms related to the problem solving activity
according to specific criteria. The sum of the mean scores for each of the facilitator categories is shown in table 4.5 of chapter four. As was the case with the previous two steps of ‘engagement’ and ‘exploration’, the mean scores for step three suggests a consistently improved ability to encourage participants to ‘explain the concept and define the terms’ as they progress through the two year training programme.

### 2.2.2 Workshop Interaction Coding System Instrument

The workshop interaction coding system instrument was used to observe and record classroom behaviour of both facilitators and participants as they interacted co-operatively in group problem solving situations. According to Boekarts (1996) it has become evident that effective teaching is not about putting information across to a group of students. It is more about initiating behavioural change that occurs in every student. It is not only about knowledge and skills acquisition, but also the influence of affective variables. This reaffirms Spady’s (1994) comment that these aspects are ingredients that make learning successful as learners learn in dynamic social learning environments in which various interactions continuously take place.

The interaction between the facilitator and participants was carefully monitored as described in chapter four and the facilitators’ attempts to create a relaxed learning environment in which participants felt comfortable about taking risks and making mistakes were recorded. Analysis of these data suggest that creating a relaxed atmosphere was important to facilitators across all categories that facilitators attempted to ensure that an atmosphere that was conducive to optimal learning was created during their facilitation sessions.
The interest the facilitator took in participants’ understanding included welcoming and working with their questions, comments and opinions. Most facilitators agreed during interviews that their participants’ progress was enhanced if they did not give them an answer or even tell them how to get an answer. According to Brooks & Brooks (1993) a very powerful way students come to change or reinforce conceptions is through social discourse. Having an opportunity to present one’s own ideas, as well as being permitted to hear and reflect on the ideas of other, is an empowering experience. The Family Maths programme embraces this philosophy and this approach forms an intrinsic part of the modelling process employed in the facilitator training sessions. The data generated in this study suggest that this approach is a powerful teaching and learning strategy in terms of the Family Maths training programme.

Focus on the verbal responses of facilitators indicated that only one percent of both the novice and intermediate groups of facilitators succumbed to giving participants solutions to problems before participants had been given the opportunity to solve the problem within the group situation. None of the veteran facilitators gave solutions to the participants, but persevered with repeating the question, giving clues and rephrasing the question. ‘Giving clues’ and ‘rephrasing questions’ are regarded as higher order skills and it is encouraging to note, according to table 4.12 in chapter four, that ‘giving clues’ and ‘rephrasing questions’ is a more frequent response by facilitators than ‘repeating the question’.

3. INTERVIEWS

The value of conducting interviews to probe the experiences, attitudes and perceptions of facilitators and workshop participants towards inquiry-based teaching
and learning is noted by Weissglass (1990), who believes that both affective opinions and more technical responses are important aspects of the data gathering process.

The semi-structured interviews used in this study included content found in the questionnaire and observation schedules. The research interviews with facilitators, learners and parents all took place at the conclusion of each workshop in which facilitators and participants had been observed. As described in chapter three, the interviews were semi-structured as this gave the interviewer the flexibility to rephrase questions so as to ensure that the interviewees fully comprehended each question being asked and to be able to probe for further understanding and clarification of facilitator responses. The verbal responses given by the facilitators were compared with the observation schedule findings and the belief system questionnaires. This provided triangulation with regard to respondents’ inquiry knowledge, understanding, skills and attitudes in each of the categories of facilitators.

The interviewers were all trainers on the Family Maths programme and had, therefore, already established rapport and developed a trust relationship with each of the interviewees, enabling the interviews to take place in a relaxed atmosphere in which facilitators felt comfortable to respond to the interview questions. At all times the interviewers attempted to remain impartial and unbiased to the responses received. In order to gain an understanding of the interviewee’s perspective the interviewer allowed sufficient time for interviewees to consider each question and formulate an appropriate response and used probes to obtain response clarity or additional information.

All participants were informed at the commencement of each workshop regarding the nature and purpose of the research study. They were assured that their
voluntary participation in the interview process would be both valued and confidential and would directly impact on the quality of the Family Maths programme.

Facilitator Interviews

The research interviews with facilitators took place at the conclusion of each workshop in which facilitators and participants had been observed. As noted above the interviews used a semi-structured approach which gave the interviewer the flexibility to rephrase questions so as to ensure that interviewees fully comprehended each question being asked and to probe for further understanding and clarification of responses. It was considered important that the interviewer found levels of understanding with which interviewees were comfortable and that they gave interviewees sufficient time to think through or reconsider their responses. The open ended questions presented to facilitators gave them the opportunity to express their own perceptions and ideas, as opposed to responding to a list of criteria, as was the case in the belief system questionnaire administered an the inception of the research survey.

Lerman (2002) believes that it is in reflection that a teacher recognises the conflict between what one wishes to do and what is happening in reality and it is this that brings about change. The facilitator interview, therefore, served the purpose of providing facilitators with an opportunity for reflection. It also provided the researcher the opportunity of probing and evaluating facilitators’ knowledge, perceptions and attitudes to inquiry-based teaching and learning and to determine whether these perceptions and attitudes were evident in their presentation of Family Maths workshops. However, in this study lonely limited feedback was given to each facilitator in terms of suggestions for improving performance and encouragement of effort after the interview process for the purpose of guiding and enhancing their
inquiry-based teaching and learning skills because of the time constraints imposed by the fact that the participants were eager to return home after the facilitation sessions which were held in the evening.

The verbal responses given by the facilitators were compared with the observation schedule findings conducted during the course of the workshops. The interviews thus provided triangulation with regard to respondents’ inquiry knowledge, understanding, skills and attitudes in each of the three categories of facilitators’, viz., novice, intermediate and veteran.

Interviews were conducted with learners and parents but were not directly considered for the findings of this research study. However, the data generated by the learner and parent interviews were used for a broad validation of the data generated by the facilitators participating in this study, e.g., whether they that the facilitator had assisted them in engaging in the activity, exploring the problem and explaining the concepts relevant to the problem. No feedback was given to learners or parents for the reason given above. However, they were assured that their input would directly impact on the quality and value of the Family Maths programme in their context.

4. DISCUSSION OF THE RESEARCH QUESTIONS

The degree to which the objectives of the primary research question as well as the subsidiary research questions were realised in this study can be discussed in the light of the analysis of the data generated as triangulation of the data obtained from questionnaires, observation schedules and interviews provided valuable insights into the belief systems and implementation skills of facilitators in terms of inquiry-based teaching and learning.
4.1 *The extent to which the Family Maths facilitator training programme develops facilitators’ ability to implement inquiry-based learning*

During the Family Maths training programme teachers learned about constructivism via modelling techniques and were given opportunities to use high levels of discussion, peer to peer tutoring, and learning by doing. Trainers introduced teachers to constructivist and inquiry experiences and they observed that one of the most powerful influences for change was the facilitator-to-facilitator encounters within their cohort groups as they used co-operative strategies for problem solving activities. Overall mean scores for each of the measuring instruments used to gather data clearly indicate a progression in both the beliefs and implementation skills of facilitators regarding inquiry-based teaching and learning according to cohort level. The data suggests that facilitators enter the training programme with very little knowledge or skills in terms of inquiry instruction, and exited the programme two years later, with a significantly improved body of knowledge and skills.

4.2 *The differences in facilitator’s beliefs between the novice, intermediate and veteran categories*

The data generation generated in this study suggest that the facilitator’s belief changed over time and allows us to infer that they acquired a better understanding of the philosophical and psychological underpinnings of inquiry learning as they progressed through the training programme from novice to veteran stages.

4.3 *The differences in facilitation skills amongst facilitators from the novice, intermediate and veteran categories*

Data generation showed that, as with their beliefs, the facilitator’s classroom practice improved over time, which suggests an increased ability to apply their
understandings of inquiry learning in terms of skills as they progressed through the training programme from novice to veteran stages. However, across all three categories of facilitators, their practice did not match up to what could be expected from the level of understanding revealed by the data generated from their responses to the questions on the beliefs questionnaire.

4.4 Changes in facilitators’ implementation skills as they engage in the programme

Apart from data analysis revealing consistently significant differences in overall mean values across the novice, intermediate and veteran categories, and suggesting that the majority of facilitators enter the Family Maths training course with minimal knowledge or experience in inquiry-based teaching and learning, analysis of the workshop interaction coding system instrument strongly suggests that the facilitators’ verbal response techniques are poorly developed amongst the novice category of facilitators. However, the data does suggest that the longer the facilitators are on the programme, the more they progress from merely repeating questions, to giving clues and rephrasing questions to direct participants’ thinking regarding the problem activity.

4.5 Effective aspects of the programme in developing an inquiry-based approach

The interview data support the questionnaire and observation data in that they suggest that the facilitators’ perceptions and attitudes regarding inquiry learning had strengthened with their ongoing involvement in the training programme. Many of the facilitators in the intermediate and veteran groups provided thorough and confident responses to the interview questions and commented on how much they had enjoyed and succeeded at the various problem solving activities using inquiry learning
strategies. This concurs with the research of Davidson (1990) who found that mathematics concepts and skills are best learned as part of a dynamic process with active engagement on the part of the students. Johnson and Johnson (1990) suggest that active learning is generated by intellectual challenge and curiosity that are often aroused during peer discussion.

When the participants were involved in building their group community, they appeared to be empowered by the notion that their ideas count – this is the foundation of inquiry. Also, co-operative work in groups seemed to foster a sense of community amongst all group members as they built on each others’ ideas by using probing questions such as ‘How do you know that?’ This process is important in the development of mathematical thinking, as indicated by the huge body of research available which demonstrates that students learn best through focussed discussion, not by passive listening. According to Layman (1996) teachers enter their profession with a desire to communicate knowledge and the temptation to supply an answer is sometimes very strong. Layman further believes that the teacher who perseveres is the one who realises that the really ‘dumb’ mistakes that learners make in the course of doing mathematics are not meaningless, but intrinsic to the process of understanding mathematics. Traditional teaching methods rely heavily on exposition by the teacher followed by consolidation and practice by learners. Recent moves towards more active forms of learning place emphasis on practical work, investigational approaches and problem solving. This change in emphasis has become particularly important in the South African context with the introduction of the Revised National Curriculum Statement and Outcomes Based Education (OBE). The constructivist underpinnings of these approaches are clearly supported by inquiry learning strategies which create opportunities for learners to work cooperatively to exchange views and ideas.
Although many facilitators found it difficult to make the paradigm shift from traditional to inquiry based teaching and learning, they expressed that they, and the learners, had found their teaching more enjoyable as a result of participating in the Family Maths programme.

Many of the teachers in this study believe that rigid curricula, unsupportive administrators and inadequate educational experiences have prevented them from using inquiry-based teaching and learning. Many of the facilitators agreed that prior to attending the Family Maths training course they would have provided much of the structure and background information for the Family maths activities. However, the difference is that they felt (post intervention) that by building on knowledge and skills that learners bring to class, the learners themselves can create the structure for these activities and solve the problems by discussion and exploration. Many of the facilitators acknowledge that the inquiry-based strategies that they were exposed to have changed the way they teach and they have subsequently enthusiastically embraced the hands-on, minds-on, process oriented, approach of inquiry-based investigations.

Jones and Fennimore (1990) describes participants of a workshop working together as a community of learners, with the facilitator ensuring that they listen to each other with respect, reflect and build on one another’s ideas, demand evidence to support opinions, assist each other in drawing conclusions and challenge the facts, assumptions and arguments underlying different points of view. Many of the participants felt that it was this approach as used in the Family Maths programme which was effective in terms of allowing them to develop their ability to understand and apply an inquiry-based approach. It is also possible that deeper learning occurred
as a result of misconceptions being addressed and remediation occurring naturally with context, as was the case in studies by Crabill (1990) and Shulman et al. (1998).

5. SUMMARY

Data analysis of all research instruments used in this study indicate that inquiry beliefs and practices improve over time as facilitators progress across the facilitator categories of the Family Maths training course.

On occasion, according to tables in chapter four, the intermediate group achieved higher mean scores than the veteran group. A possible explanation for this could be that many of the veteran facilitators, who have already successfully completed a Family Maths training course, are no longer attending training workshops and therefore are no longer exposed to the dissemination and discussion of inquiry-based criteria. The inquiry-based teaching and learning skills need to be transferred into classroom situation and become an integral part of one’s teaching strategy.

Analysis of all the data generated in this research study indicate that inquiry beliefs and practices improve over time as facilitators progress from the novice to veteran category on the Family Maths training course. There is also clear evidence from the data analysis that most facilitators enter the programme with very little knowledge or skills regarding inquiry learning.
5. INTRODUCTION

Llewellyn (2005) argues that inquiry involves active explorations by students in which they use critical, logical and creative thinking to raise and engage in questions of personal interest. The degree to which these objectives were realised in this study is examined in this chapter as I interpret the results obtained and discuss the data in terms of the principal research question.

To what extent does the Family Maths facilitator training programme develop facilitators’ ability to implement inquiry based learning?

The categories developed from the quantitative statistical analysis and the descriptive qualitative data in chapter four are related to the theoretical underpinnings noted in chapter two in an attempt to provide answers to the research subsidiary questions, viz.:

- Is there a difference in facilitators’ beliefs regarding inquiry learning as they proceed from novice to veteran category?

- Is there a difference between the ability to facilitate inquiry learning amongst facilitators who have completed the two year training programme, those who are in their second year of training and those who are still in their first year of training

- How do facilitators’ approaches to facilitating Family Maths workshops change as they engage in the programme?
• *What aspects of the programme are effective in developing an inquiry based approach?*

Possible implications of the findings for curriculum reform of the Family Maths training programme are discussed as well as implications for the teaching and learning of mathematics. An overview of the relevance and significance of using inquiry-based teaching and learning as the appropriate strategy for the Family Maths programme is provided and the results generated by data collected via questionnaires, observations and semi-structured interviews are discussed.

6. **STATISTICAL ANALYSES**

Statistical analyses were made of the data generated by the belief system questionnaires, workshop observations and the semi-structured interviews of the facilitators participating in this study.

2.1 **Belief systems measured by questionnaire**

In designing the questionnaire to determine facilitators’ beliefs and understanding regarding inquiry-based teaching and learning, the use of jargon and technical terms was carefully avoided and the use of familiar language enabled facilitators to complete the questionnaire without feeling threatened in any way. In order to be able to clarify issues when necessary, the programme coordinator was present at all times while the facilitators completed the questionnaire.

The quantitative data generated by the facilitators’ responses to the questionnaire for each of the three inquiry steps focused on in this study and presented in the questionnaire were treated via the analysis of variance model (ANOVA). These steps, viz., the significance of engaging participants in the problem situation, allowing participants to explore the concept and encouraging participants to explain the
concept and define the terms, are an integral part of the Family Maths training programme and the results of the statistical treatment yielded insightful and meaningful information for the research study.

The analysis of the data generated by the facilitators’ inquiry belief system questionnaire revealed that, on occasions, the intermediate facilitators achieved slightly higher mean scores than the veteran facilitators. Possible reasons for this could be that, while intermediate facilitators participate in regular training workshops and benefit by regular support from Family Maths trainers, many of the veteran facilitators, having successfully completed the training course, present Family Maths workshops independently without ongoing support from the Family Maths facilitators and co-ordinators with a possibly a tendency to regress to the more traditional beliefs which they may have held over a period of many years. In other words, over time the significance of some of the important principles of inquiry learning could become vague, less important in the minds of the facilitators, and be overlooked. This suggests that it is important that longer and more ongoing support for Family Maths workshop presenters be provided once they have completed the training course. This matter is discussed in chapter six which deals with conclusions and recommendations.

Examination of the mean scores revealed a statistically significant difference between the three groups of facilitators in terms of ‘encouraging initiative’ (1b), ‘encouraging questioning’ (2c), ‘posing contradictions’ (2e), ‘allowing time after questions’ (2f), ‘seeking elaboration’ (3a) and ‘allowing participants to refine explanations’ (3d). The data suggest that it is these criteria, which involve higher order thinking skills, which are least developed in novice facilitators and that these inquiry skills generally improve over time as facilitators practice them and reflect on them during the two year training programme.
Criteria, which may be considered to relate to more fundamental skills, such as ‘creating a relaxed, friendly environment (1a), ‘using teaching and learning aids’ (1d), ‘finding out participants’ understanding of concepts (1e), ‘encouraging participants to discuss their understanding’ (1f), ‘encouraging participants natural curiosity (1h), ‘allowing participants answers to drive lessons’ (2a), ‘encouraging participants inquiry by asking thoughtful, open-ended questions’ (2b), encouraging participants to think by making them use terms like classify, analyse, predict’ (3c) revealed no statistically significant differences. These criteria were focused on and formed an integral part of the Family Maths training content from the outset of the programme as they are regarded as a prerequisite to becoming an inquiry-based teacher. The fact that most of the facilitators seem able to internalise and implement these skills without much difficulty is the most probable and realistic explanation for the lack statistically significant differences being shown amongst the categories of facilitators for these criteria.

2.3 **Teacher Practice measured by observation**

As discussed in the literature review, South African teachers traditionally have relied predominantly on close-ended questions with only one correct answer, or which simply require learners to recall information. This research investigated whether facilitators are able to capture and focus the learners’ attention on critical parts of the problem solving process using open-ended questions which facilitate meaningful discussion and which require that the facilitator engage participants in a problem solving activity in which they are asked to communicate their responses.

According to Abrami et al., (1995), competent facilitators who successfully combine inquiry-based teaching and learning strategies within a relaxed, non-threatening learning environment transform workshops into vibrant, enthusiastic
experiences of collaborative discussion and learning, with significant gains in both
cognitive and non-cognitive goals being accomplished as students actively challenge
and engage with each other, thereby honing their interpersonal and verbal skills
during the learning experience.

Naturalistic observation of participants in the workshop setting, as described
in chapters three and four, enabled the researcher to record and study these behaviours
and interactions between the facilitators and participants within an authentic
workshop setting. The facilitators’ competences in engaging participants in the
problem solving activity are tabled in chapter four, table 4.3. Overall scores for each
of the categories of facilitators suggest that their ability to engage participants in
problem activities improve as they progress from the novice to the veteran category.
Johnson and Johnson’s (1990) review of 48 studies, reports higher achievement was
characteristic of cooperative mathematics classes. It is, therefore, realistic to expect
that more learning would take place during discussion and debate of the problem
solving situations participants experienced in the Family Maths workshops, an
expectation which is borne out by the data generated by the observation schedules and
interviews.

2.3.1 Workshop Observation Instrument

Step 1: Engaging the participants

The purpose of the engagement stage is to introduce activities intended to
engage learners and their parents with a problem solving situation, and to capture the
participants’ interest and enable them to make connections with what they knew and
could do before participating in the programme. Learners and parents were given the
opportunity to interact with each other and with carefully chosen sets of materials.
While teams of participants engaged in the problem and explored ways of solving it, the facilitator responded to calls for clarification and guidance, only giving clues when requested to do so.

During the engagement stage it was expected that the facilitator would set the stage for learning and introduce activities that would engage learners and parents with a problem or phenomenon. These activities were intended to provide participants with an open-ended opportunity to interact with the materials and each other. Activities were aimed at capturing participants’ interest and enabling them to make connections with what they knew and could do. From a constructivist perspective the engagement phase provides an opportunity for the facilitator to activate learning, assess prior knowledge, current beliefs and understandings and have participants share their experiences about the topic. Step one of this observation instrument identified the degree to which the facilitator engaged the participants in the problem solving activity according to specific criteria. It was evident from analysis of data that there are statistically significant differences in the mean values between the novice group of facilitators and the other two groups of facilitators who had been on the training course for a longer period of time. This suggests that the majority of facilitators who embark on the Family Maths training course have little knowledge or experience in inquiry-based teaching and learning in terms of engaging their participants.

Table 4.3 in chapter four presents a comparison of the facilitators’ mean scores in terms of their ability to engage participants in problem solving activities. For five of the six criteria in the engagement stage the mean scores indicated that facilitators improved in their ability to engage participants in the problem solving activity as they progressed from the novice to veteran category. The only criterion which indicated that the veteran facilitators’ mean scores were the least and novice
facilitators’ mean scores the highest was ‘uses manipulative and physical materials’ (1c). A possible explanation for this could be that the novice facilitators are more dependent on concrete materials when facilitating group engagement in problem solving activities and therefore focus more on the use of manipulatives and physical materials than their more skilled colleagues. As the facilitators build confidence in their mathematical ability and facilitation skills, they are likely to become less dependent on concrete materials (but which is still an important focus of the Family Maths training programme).

It was noted in chapter four that there were no statistically significant differences amongst the three groups of facilitators for some of the criteria, which suggests that it is important to examine the strategies of the Family Maths training programme as well as the teaching styles and mathematical content knowledge that the facilitators brought with them to the training sessions. The emphasis on creating a relaxed, non-threatening environment is modelled throughout the training programme and teachers are constantly reminded of the importance of this for developing positive attitudes and confidence in mathematics. It is not surprising, therefore, that for this particular criterion, viz., ‘creates a relaxed, non-threatening environment’ (1a), no significant difference amongst the three categories of facilitators was noted. The other criteria where there are no statistically significant differences between the groups are all specific to inquiry-based learning and which most teachers do not normally practice in their classroom situations and are therefore, through the Family Maths training course, introduced and strongly developed right at the beginning of the programme. This heavy emphasis at the beginning of the programme may possibly explain why there is no statistically significant differences were found between the three groups of participating facilitators.
Table 4.4 in chapter four indicates that the sum of the mean scores for each of the categories of facilitators, that is, novice, intermediate and veteran, showed a statistically significant difference and suggests a progression in understanding and implementation of inquiry strategies with regard to engaging participants in the problem solving situation.

**Step 2: Allowing participants to explore the concept**

The purpose of the exploration stage was for participants to raise questions, develop hypotheses to test, and work without direct instruction from the facilitator. Learners and parents were encouraged to participate in hands-on experiences through which they explored the concept further. They received little explanation or mathematical terminology at this point because it was important that they first defined the problem or phenomenon in their own words. During this stage of the learning process facilitators were encouraged to give participants considerable time for group discussion where group members would have the opportunity to articulate individual understanding and listen to one another’s points of view. It was envisaged that learners and parents would help one another make sense of the concept. According to Brooks and Brooks (1993), a very powerful way students come to change or reinforce conceptions is through social discourse. Having an opportunity to present one’s own ideas, as well as being permitted to hear and reflect on the ideas of others, is an empowering experience. They further suggest that the benefit of discourse with others, particularly with peers, facilitates the meaning-making process. An inquiry-based framework challenges teachers to create environments in which they and their students are encouraged to think, engage and explore problem situations.

Many teachers mistakenly believe that when they talk to learners and learners respond to their questions, that discussion has taken place. However, Shuard (1984)
suggests that what is meant by discussion is extended joint exploration by the learners, under the guidance of the teacher, in which the teacher does not force the direction and pace of the oral exchange, and in which ideas are explored and argued with mutual respect for each other’s point of view.

Step two of this observation instrument measured the degree to which the facilitators allowed participants to explore the concept in the problem solving activity according to specific criteria. Data generated from the workshop observations, for each of the three categories of facilitators, is described in chapter four. Table 4.4 in chapter four shows a comparison of facilitator the mean scores across the three categories of facilitators with regard to their ability to encourage exploration of the problem solving activity. The mean scores of five of the six criteria suggested that facilitators improved in their ability to encourage participants to explore the problem activity as they progressed across the facilitator categories. The only criterion, which indicated that the intermediate facilitators were more competent in implementing exploration strategies than the veteran facilitators, was ‘poses contradictions to their initial hypotheses’. A possible explanation could be that many of the veteran facilitators, having already completed the training programme, no longer benefit from regular interaction with Family Maths trainers and other course participants. This could result in possible neglect of this important inquiry skill. As was the case with facilitators’ ability to engage participants in the problem solving activity, the overall mean scores for each category of facilitators indicate a steady progression in the ability of facilitators to encourage exploration of the problem solving activity.

During observation of the Family Maths workshops it became evident that the ability of participants to meaningfully explore the problem solving activity was adversely affected by language barriers. Family Maths workshops were presented in
either English or Afrikaans, depending on the medium of instruction of the respective schools in the community. Recurring incidences of code switching was evident during the exploration stage where first language Xhosa speakers frequently felt that they could express themselves more articulately in their mother tongue. The possible negative implications that the medium of instruction has for second-language speakers is recognised widely in international and South African literature as a contributing factor in learning and understanding mathematical concepts and terminology. Research which emphasises learner-centred practice (Black & Atkin, 1996) and models of bilingual education (Taylor & Vinjevold, 1999) view code-switching between English and the vernacular as a key strategic practice for effective teaching and learning in classes where the learners are learning in their second language.

Occasionally the facilitator interrupted the participants and asked for further explanations with regard to interesting questions that they had come up with. This often inspired a good deal of enthusiasm for solving the problem at hand. Learners and parents often drew on their past mathematical experiences, but usually found that, with a practical activity with no set procedures to guide them, they could develop their own ideas and rely on one another for support.

*Step 3: Encouraging participants to explain the concept and define the terms*

During the explanation stage it was expected that facilitators would encourage participants to explain their understanding of the mathematical concepts related to the problem solving situation and also explain how they arrived at a solution for each of the problem-solving activities. Facilitators were encouraged, once participants had explored the concept, to introduce relevant mathematical terms as participants refined their explanations of concepts and solutions. Participants were then expected to use these terms to describe what they had experienced and begin to examine how the
explanation fitted with what they already knew. The purpose of this stage was that participants ‘construct’ new meaning from their experience at co-operative problem solving. Facilitators were encouraged to help the participants refine their language but make sure that participants were using terms they understood and did not rely on terminology merely for the sake of sounding ‘mathematical’.

Facilitators were often hesitant to introduce too much mathematical terminology that might threaten the relaxed atmosphere they had created to promote enjoyment, discussion and exploration. Most facilitators believed that it would be more beneficial for participants to understand, solve and explain concepts and their solutions to problems during the workshop without introducing them to all of the appropriate mathematical terminology. Many of the facilitators felt strongly that too much emphasis on mathematical terminology would undermine the enjoyment of doing the mathematics. They felt that this was especially threatening for parents who attended Family Maths workshops to enjoy a relaxed time with their children. Consensus amongst facilitators indicated that it would be more appropriate to focus on relevant mathematical terminology with learners in the classroom situation.

Step 3 identified the degree to which the facilitator encouraged participants to explain the concept and define the terms related to the problem solving activity according to specific criteria. The sum of the mean scores for each of the facilitator categories is shown in table 4.5 of chapter four. As was the case with the previous two steps of ‘engagement’ and ‘exploration’, the mean scores for step three suggests a consistently improved ability to encourage participants to ‘explain the concept and define the terms’ as they progress through the two year training programme.
2.3.2 Workshop Interaction Coding System Instrument

The workshop interaction coding system instrument was used to observe and record classroom behaviour of both facilitators and participants as they interacted cooperatively in group problem solving situations. According to Boekarts (1996) it has become evident that effective teaching is not about putting information across to a group of students. It is more about initiating behavioural change that occurs in every student. It is not only about knowledge and skills acquisition, but also the influence of affective variables. This reafirms Spady’s (1994) comment that these aspects are ingredients that make learning successful as learners learn in dynamic social learning environments in which various interactions continuously take place.

The interaction between the facilitator and participants was carefully monitored as described in chapter four and the facilitators’ attempts to create a relaxed learning environment in which participants felt comfortable about taking risks and making mistakes were recorded. Analysis of these data suggest that creating a relaxed atmosphere was important to facilitators across all categories that facilitators attempted to ensure that an atmosphere that was conducive to optimal learning was created during their facilitation sessions.

The interest the facilitator took in participants’ understanding included welcoming and working with their questions, comments and opinions. Most facilitators agreed during interviews that their participants’ progress was enhanced if they did not give them an answer or even tell them how to get an answer. According to Brooks & Brooks (1993) a very powerful way students come to change or reinforce conceptions is through social discourse. Having an opportunity to present one’s own ideas, as well as being permitted to hear and reflect on the ideas of other, is an empowering experience. The Family Maths programme embraces this philosophy and
this approach forms an intrinsic part of the modelling process employed in the facilitator training sessions. The data generated in this study suggest that this approach is a powerful teaching and learning strategy in terms of the Family Maths training programme.

Focus on the verbal responses of facilitators indicated that only one percent of both the novice and intermediate groups of facilitators succumbed to giving participants solutions to problems before participants had been given the opportunity to solve the problem within the group situation. None of the veteran facilitators gave solutions to the participants, but persevered with repeating the question, giving clues and rephrasing the question. ‘Giving clues’ and ‘rephrasing questions’ are regarded as higher order skills and it is encouraging to note, according to table 4.12 in chapter four, that ‘giving clues’ and ‘rephrasing questions’ is a more frequent response by facilitators than ‘repeating the question’.

7. **INTERVIEWS**

The value of conducting interviews to probe the experiences, attitudes and perceptions of facilitators and workshop participants towards inquiry-based teaching and learning is noted by Weissglass (1990), who believes that both affective opinions and more technical responses are important aspects of the data gathering process.

The semi-structured interviews used in this study included content found in the questionnaire and observation schedules. The research interviews with facilitators, learners and parents all took place at the conclusion of each workshop in which facilitators and participants had been observed. As described in chapter three, the interviews were semi-structured as this gave the interviewer the flexibility to rephrase questions so as to ensure that the interviewees fully comprehended each question.
being asked and to be able to probe for further understanding and clarification of facilitator responses. The verbal responses given by the facilitators were compared with the observation schedule findings and the belief system questionnaires. This provided triangulation with regard to respondents’ inquiry knowledge, understanding, skills and attitudes in each of the categories of facilitators.

The interviewers were all trainers on the Family Maths programme and had, therefore, already established rapport and developed a trust relationship with each of the interviewees, enabling the interviews to take place in a relaxed atmosphere in which facilitators felt comfortable to respond to the interview questions. At all times the interviewers attempted to remain impartial and unbiased to the responses received. In order to gain an understanding of the interviewee’s perspective the interviewer allowed sufficient time for interviewees to consider each question and formulate an appropriate response and used probes to obtain response clarity or additional information.

All participants were informed at the commencement of each workshop regarding the nature and purpose of the research study. They were assured that their voluntary participation in the interview process would be both valued and confidential and would directly impact on the quality of the Family Maths programme.

**Facilitator Interviews**

The research interviews with facilitators took place at the conclusion of each workshop in which facilitators and participants had been observed. As noted above the interviews used a semi-structured approach which gave the interviewer the flexibility to rephrase questions so as to ensure that interviewees fully comprehended each question being asked and to probe for further understanding and clarification of
responses. It was considered important that the interviewer found levels of understanding with which interviewees were comfortable and that they gave interviewees sufficient time to think through or reconsider their responses. The open ended questions presented to facilitators gave them the opportunity to express their own perceptions and ideas, as opposed to responding to a list of criteria, as was the case in the belief system questionnaire administered at the inception of the research survey.

Lerman (2002) believes that it is in reflection that a teacher recognises the conflict between what one wishes to do and what is happening in reality and it is this that brings about change. The facilitator interview, therefore, served the purpose of providing facilitators with an opportunity for reflection. It also provided the researcher the opportunity of probing and evaluating facilitators’ knowledge, perceptions and attitudes to inquiry-based teaching and learning and to determine whether these perceptions and attitudes were evident in their presentation of Family Maths workshops. However, in this study limited feedback was given to each facilitator in terms of suggestions for improving performance and encouragement of effort after the interview process for the purpose of guiding and enhancing their inquiry-based teaching and learning skills because of the time constraints imposed by the fact that the participants were eager to return home after the facilitation sessions which were held in the evening.

The verbal responses given by the facilitators were compared with the observation schedule findings conducted during the course of the workshops. The interviews thus provided triangulation with regard to respondents’ inquiry knowledge, understanding, skills and attitudes in each of the three categories of facilitators’, viz., novice, intermediate and veteran.
Interviews were conducted with learners and parents but were not directly considered for the findings of this research study. However, the data generated by the learner and parent interviews were used for a broad validation of the data generated by the facilitators participating in this study, e.g., whether they that the facilitator had assisted them in engaging in the activity, exploring the problem and explaining the concepts relevant to the problem. No feedback was given to learners or parents for the reason given above. However, they were assured that their input would directly impact on the quality and value of the Family Maths programme in their context.

8. DISCUSSION OF THE RESEARCH QUESTIONS

The degree to which the objectives of the primary research question as well as the subsidiary research questions were realised in this study can be discussed in the light of the analysis of the data generated as triangulation of the data obtained from questionnaires, observation schedules and interviews provided valuable insights into the belief systems and implementation skills of facilitators in terms of inquiry-based teaching and learning.

4.1 The extent to which the Family Maths facilitator training programme develops facilitators’ ability to implement inquiry-based learning

During the Family Maths training programme teachers learned about constructivism via modelling techniques and were given opportunities to use high levels of discussion, peer to peer tutoring, and learning by doing. Trainers introduced teachers to constructivist and inquiry experiences and they observed that one of the most powerful influences for change was the facilitator-to-facilitator encounters within their cohort groups as they used co- operative strategies for problem solving activities. Overall mean scores for each of the measuring instruments used to gather
data clearly indicate a progression in both the beliefs and implementation skills of facilitators regarding inquiry-based teaching and learning according to cohort level. The data suggests that facilitators enter the training programme with very little knowledge or skills in terms of inquiry instruction, and exited the programme two years later, with a significantly improved body of knowledge and skills.

4.6 The differences in facilitator’s beliefs between the novice, intermediate and veteran categories

The data generation generated in this study suggest that the facilitator’s belief changed over time and allows us to infer that they acquired a better understanding of the philosophical and psychological underpinnings of inquiry learning as they progressed through the training programme from novice to veteran stages.

4.7 The differences in facilitation skills amongst facilitators from the novice, intermediate and veteran categories

Data generation showed that, as with their beliefs, the facilitator’s classroom practice improved over time, which suggests an increased ability to apply their understandings of inquiry learning in terms of skills as they progressed through the training programme from novice to veteran stages. However, across all three categories of facilitators, their practice did not match up to what could be expected from the level of understanding revealed by the data generated from their responses to the questions on the beliefs questionnaire.

4.8 Changes in facilitators’ implementation skills as they engage in the programme

Apart from data analysis revealing consistently significant differences in overall mean values across the novice, intermediate and veteran categories, and
suggesting that the majority of facilitators enter the Family Maths training course with minimal knowledge or experience in inquiry-based teaching and learning, analysis of the workshop interaction coding system instrument strongly suggests that the facilitators’ verbal response techniques are poorly developed amongst the novice category of facilitators. However, the data does suggest that the longer the facilitators are on the programme, the more they progress from merely repeating questions, to giving clues and rephrasing questions to direct participants’ thinking regarding the problem activity.

4.9 Effective aspects of the programme in developing an inquiry-based approach

The interview data support the questionnaire and observation data in that they suggest that the facilitators’ perceptions and attitudes regarding inquiry learning had strengthened with their ongoing involvement in the training programme. Many of the facilitators in the intermediate and veteran groups provided thorough and confident responses to the interview questions and commented on how much they had enjoyed and succeeded at the various problem solving activities using inquiry learning strategies. This concurs with the research of Davidson (1990) who found that mathematics concepts and skills are best learned as part of a dynamic process with active engagement on the part of the students. Johnson and Johnson (1990) suggest that active learning is generated by intellectual challenge and curiosity that are often aroused during peer discussion.

When the participants were involved in building their group community, they appeared to be empowered by the notion that their ideas count – this is the foundation of inquiry. Also, co-operative work in groups seemed to foster a sense of community amongst all group members as they built on each others’ ideas by using probing questions such as ‘How do you know that?’ This process is important in the
development of mathematical thinking, as indicated by the huge body of research available which demonstrates that students learn best through focussed discussion, not by passive listening. According to Layman (1996) teachers enter their profession with a desire to communicate knowledge and the temptation to supply an answer is sometimes very strong. Layman further believes that the teacher who perseveres is the one who realises that the really ‘dumb’ mistakes that learners make in the course of doing mathematics are not meaningless, but intrinsic to the process of understanding mathematics. Traditional teaching methods rely heavily on exposition by the teacher followed by consolidation and practice by learners. Recent moves towards more active forms of learning place emphasis on practical work, investigational approaches and problem solving. This change in emphasis has become particularly important in the South African context with the introduction of the Revised National Curriculum Statement and Outcomes Based Education (OBE). The constructivist underpinnings of these approaches are clearly supported by inquiry learning strategies which create opportunities for learners to work cooperatively to exchange views and ideas. Although many facilitators found it difficult to make the paradigm shift from traditional to inquiry based teaching and learning, they expressed that they, and the learners, had found their teaching more enjoyable as a result of participating in the Family Maths programme.

Many of the teachers in this study believe that rigid curricula, unsupportive administrators and inadequate educational experiences have prevented them from using inquiry-based teaching and learning. Many of the facilitators agreed that prior to attending the Family Maths training course they would have provided much of the structure and background information for the Family maths activities. However, the difference is that they felt (post intervention) that by building on knowledge and skills
that learners bring to class, the learners themselves can create the structure for these
activities and solve the problems by discussion and exploration. Many of the
facilitators acknowledge that the inquiry-based strategies that they were exposed to
have changed the way they teach and they have subsequently enthusiastically
embraced the hands-on, minds-on, process oriented, approach of inquiry-based
investigations.

Jones and Fennimore (1990) describes participants of a workshop working
together as a community of learners, with the facilitator ensuring that they listen to
each other with respect, reflect and build on one another’s ideas, demand evidence to
support opinions, assist each other in drawing conclusions and challenge the facts,
assumptions and arguments underlying different points of view. Many of the
participants felt that it was this approach as used in the Family Maths programme
which was effective in terms of allowing them to develop their ability to understand
and apply an inquiry-based approach. It is also possible that deeper learning occurred
as a result of misconceptions being addressed and remediation occurring naturally
with context, as was the case in studies by Crabill (1990) and Shulman et al. (1998).

5. SUMMARY

Data analysis of all research instruments used in this study indicate that
inquiry beliefs and practices improve over time as facilitators progress across the
facilitator categories of the Family Maths training course.

On occasion, according to tables in chapter four, the intermediate group
achieved higher mean scores than the veteran group. A possible explanation for this
could be that many of the veteran facilitators, who have already successfully
completed a Family Maths training course, are no longer attending training workshops
and therefore are no longer exposed to the dissemination and discussion of inquiry-based criteria. The inquiry-based teaching and learning skills need to be transferred into classroom situation and become an integral part of one’s teaching strategy.

Analysis of all the data generated in this research study indicate that inquiry beliefs and practices improve over time as facilitators progress from the novice to veteran category on the Family Maths training course. There is also clear evidence from the data analysis that most facilitators enter the programme with very little knowledge or skills regarding inquiry learning.
CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

1. INTRODUCTION

As noted in chapter two, the literature embraces the basic principle that learning is not a passive receiving of ready-made knowledge but a process of construction in which the students themselves have to be the primary actors (von Glassersfeld, 1995). The Family Maths programme endeavours to equip teachers to embrace and make this principle a reality in South African schools. In an attempt to investigate the extent to which the Family Maths programme is achieving this goal, this study used a number of measuring instruments to enable triangulation of data generated while researching the participating facilitators’ beliefs and practices around the first three instructional stages of inquiry learning as they progressed through the Family Maths programme offered by SMATE at the Nelson Mandela Metropolitan University (NMMU).

In this final chapter I draw conclusions and make inferences as to the extent to which the Family Maths facilitator training programme has affected the participating facilitators’ beliefs and developed their ability to implement inquiry-based learning. Conclusions are also drawn with regard to the subsidiary research questions regarding the development of facilitators as they progress through the training course as well as what aspects of the programme are most effective in developing inquiry-based teaching and learning strategies.
Implications based on the study’s findings and the conclusions drawn are discussed regarding the professional development of teachers in terms of inquiry-based teaching and learning strategies.

2. IMPLICATIONS FOR REFORM

Analysis of the questionnaire data and observation data revealed that the majority of facilitators who first embark on the Family Maths training course do not appear to have much knowledge or experience in terms of inquiry learning as a teaching and learning strategy. However, the workshop observation data does suggest a steady progression in the beliefs and implementation skills of the facilitators on the Family Maths training course as they advance through the sequential stages; from novice, to intermediate to veteran. An important point to consider is that analysis of the data generated by the facilitators’ inquiry belief system questionnaire revealed that, on occasions, the intermediate facilitators achieved slightly higher mean scores than the veteran facilitators. The possible reasons given for this could be that while intermediate facilitators participate in regular training workshops and benefit by regular support from Family Maths trainers, while many of the veteran facilitators, having successfully completed the training course, presented Family Maths workshops independently without ongoing support from the programme. This may have resulted in a tendency to regress to the more traditional beliefs which they may have held over a period of many years. In other words, over time the significance of some of the important principles of inquiry learning could become vague, less important in the minds of the facilitators, and be overlooked. This suggests that continuing professional development (CPD) curriculum developers designing in-service interventions should be aware of both the low base of understanding and experience in terms of inquiry-based teaching and learning from which South African
teachers are starting and that it is important that sustained and ongoing support should be provided for participants both during and after the implementation of such CPD programmes.

Also, the fact that changes in the participating facilitators’ belief systems do not always translate into classroom practice has implications for evaluating the effect of CPD programmes which promote inquiry-based teaching and learning strategies. It is therefore suggested that evaluation techniques must include direct observation of practice and as many other success indicators as possible.

3. **RECOMMENDATIONS**

Johnson (1998) highlights the many challenges to educationists who subscribe to constructivist principles which encourage students to engage in active learning with teachers, peers and the material. On a more positive note, the findings of this study suggest that the Family Maths training programme offered by the NMMU not only promoted a change in the participants’ beliefs (i.e., moved them towards subscribing to inquiry-based principles), but also played a role in developing skills and enabling the facilitators to implement inquiry teaching and learning.

The findings described above, plus other data generated in this study and the findings of both international research and research carried out in the South African context, provide the warrants, backings and general framework to allow the following recommendations to be made.

Firstly, as the implementation of inquiry-based teaching and learning as a strategy for the Family Maths training programme has yielded greater than expected positive outcomes, it can be inferred that the Family Maths programme approach of modelling inquiry-based teaching and learning strategies and focusing on engaging
teachers’ participation, promoting discussion and allowing time for reflection and internalization of new knowledge and skills is a successful one and should be considered when developing other CPD programmes of this nature.

Secondly, it was encouraging to note the confidence and positive attitudes that developed amongst the participants as they progressed through the training course. Developing confidence and positive attitudes is another key focus of the Family Maths programme and many teachers acknowledged that their confidence in their subject knowledge has been greatly improved as a result of their participation in the training course. One teacher noted that ‘This course has changed the way I teach’ and another can be quoted as saying ‘Maths is fun’. As such, affective aspects such as these should be borne in mind when developing inquiry-based training programmes for teachers.

Thirdly, as mentioned in the literature review, research suggests that teachers who lack experience, confidence and general pedagogic content knowledge will resort to methods of expository teaching, rote learning, and avoiding classroom situations where something might go ‘wrong’ (Taylor & Vinjevold, 1999). This research study suggests that the Family Maths programme has the potential to be a powerful catalyst in the process of restoring a culture of learning in schools, by helping teachers reshape their instructional practices in mathematics and promoting a deeper understanding of mathematical principles via inquiry strategies, a method which may have applications to other contexts and subject areas.

Fourthly, group discussion was greatly encouraged in the implementation of the Family Maths approach to inquiry-based instruction and much evidence of both cognitive and non-cognitive goals, such as confidence and self esteem, were accomplished as learners and parents actively challenged and engaged with each
other, thereby honing their interpersonal and verbal skills during the learning experience. Findings of this nature are echoed by the reports of Mercer et al. (1999) and Abrami, et al. (1995) and a number of other researchers of discussion and exploratory talk. For these reasons the active development of classroom discussion techniques should be the aim of South African CPD programmes if we are to break the shackles of expository teaching and rote learning.

Finally, code switching was common practice during exploratory talk in group problem solving activities in many sessions of the Family Mathematics programme observed in this study and the use of this language strategy is widely quoted in the South African literature as a prerequisite for success in contexts where the medium of instruction is English and the teachers and learners are second-language English speakers. As such it is recommended that the issues of second language teaching and learning be carefully considered in the design and development of materials for the development of CPD programmes of this nature in order to allow teachers and learners to maximise the opportunity to implement inquiry learning in their workshop and classroom situations.

4. CAVEATS

Sharan (1994) cautions that too much emphasis should not be placed on any one instructional approach as even the most brilliantly designed instructional method cannot circumvent the competence of the teacher and the impact of the leaning environment. However, for the purposes of the Family Maths programme, as revealed in this study, the implementation of an inquiry-based strategy, together with a focus on developing a positive climate conducive to optimal learning, has yielded positive outcomes which appear to be both relevant and significant.
Generally, the facilitators who participated in this study have been exposed to outcomes-based education, but still practiced predominantly traditional methods of instruction in their overcrowded classrooms where their learners have little or no opportunity for participation in the learning process. This type of situation remains the common lot of a large number of South African teachers (Sharwood, 1998).

Also, although the philosophies and mission statements of many schools concur with the philosophy of inquiry education to develop students to be thinking, exploring individuals, the organizational and management structures of many schools militate against these goals. So, if autonomy, initiative and leadership are to be nurtured, it will often have to be done in individual classrooms.

Furthermore, it has been found that some facilitators still resist constructivist, inquiry-based pedagogy. According to Brooks and Brooks (1993), resistance is usually for one of three reasons – commitment to their present instructional approach, concern about student learning or concern about classroom control. If current instructional practices are perceived to be working, there is little incentive to experiment with new methodologies. Conscientious learners who are accustomed to receiving information passively will study and memorise what their teachers tell them is important.

Although it has become evident through this study that all students appear to benefit from practical work, whatever their age or their ability, the fact is that in many South African schools there is a tendency to minimise the importance of practical work once learners exit the Foundation Phase of the General Education and Training band of the National Qualifications Forum structure (Taylor & Vinjevold, 1999). Also, in school mathematics teaching there have sometimes been tendencies to move too quickly into abstractions and symbols without allowing sufficient time to explore
and understand the real situations from which they arise. These tendencies are not restricted to South Africa schools and the GCSE National Criteria for Mathematics explains that attempts to avoid this have been at the root of many important developments in teaching, including the recognition of the importance of discovery, discussion and concrete experience.

5. CONCLUSION

The insights provided by the participants’ responses, and other data generated in this study, helped reveal the shortcomings and strengths of the NMMU Family Maths training programme and its ability to effectively address the implementation of inquiry-based teaching and learning strategies. Through my interactions with facilitators and my observations of Family Maths workshops I have come to realise that for many teachers the decision to adopt inquiry as a teaching and learning strategy can be a frightening experience. Nevertheless, many teachers who previously had a fear of mathematics and the teaching thereof, experienced enjoyment and success in mathematics problem solving activities, and developed the confidence to transfer this positive attitude, knowledge and skills into their classrooms.

Although, most teachers were not educated in these settings nor trained to teach in these ways, many found that making the paradigm shift was not as overwhelming as they initially thought. As such, I believe that the descriptors of inquiry learning used in this research study provides a usable framework within which teachers can experiment as they come to accept the benefit of this teaching and learning strategy. It should be noted at this point that no participant on the Family Maths programme employs an inquiry-based approach as the sole pedagogical technique. They balance inquiry teaching and learning with other strategies, such as whole class teaching, peer teaching and individual work.
In general the participants on the Family Maths training course found it extremely beneficial to observe other teachers in action and to compare different teaching styles. They have also found the training helpful in providing new activities and materials appropriate for classroom use, in providing alternative instructional strategies to the textbook-based curriculum, and in motivating or re-motivating the teachers’ interest in teaching mathematics.

The positive outcomes of this research study encourage me to hope and believe that, as students begin to enjoy mathematics more through intervention strategies such as the Family Maths programme, and as their intrinsic motivation grows, the likelihood of them selecting more advanced mathematics courses will improve, a situation that is currently particularly desired, both in this country and internationally for female, disadvantaged and minority students.
REFERENCES


In N. Davidson (Ed.), *cooperative learning in mathematics. A handbook for teachers* (pp.103-125). Menlo Park, California: Addison-Wesley.


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University Press.


# Workshop Interaction Coding System

(Adapted from dyadic intersection observation system of Brophy and Good, 1970s)

<table>
<thead>
<tr>
<th>Facilitator Name</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Facilitator Category</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Veteran</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade(s) of Learners</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learner's Sex</th>
<th>Learner Response</th>
<th>Teacher Affective Feedback</th>
<th>Teacher Feedback Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. M F</td>
<td>✓ ✓ x o</td>
<td>✓ ✓ o x ✓</td>
<td>GIVES ANSWER</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td>REPEATS QUESTION</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td>GIVES CLUE</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td>REPHRASES QUESTION</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parent's Sex</th>
<th>Parent's Response</th>
<th>Teacher Affective Feedback</th>
<th>Teacher Feedback Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. M F</td>
<td>✓ ✓ x o</td>
<td>✓ ✓ o x ✓</td>
<td>GIVES ANSWER</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td>REPEATS QUESTION</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td>GIVES CLUE</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td>REPHRASES QUESTION</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BRIEF DEFINITIONS OF VARIABLES CODED</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Learner/Parent Response</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Male</td>
<td>The Learner/Parent answering the question is male.</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Female</td>
<td>The Learner/Parent answering the question is female.</td>
<td></td>
</tr>
<tr>
<td>✓</td>
<td>Correct</td>
<td>Teacher accepts the learner/parent’s response as correct/satisfactory.</td>
<td></td>
</tr>
<tr>
<td>✗</td>
<td>Partially Correct</td>
<td>Teacher considers learner/parent’s response to be partially correct.</td>
<td></td>
</tr>
<tr>
<td>x</td>
<td>Wrong</td>
<td>Teacher considers learner/parent’s response to be incorrect.</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>No Answer</td>
<td>Learner/Parent makes no response.</td>
<td></td>
</tr>
<tr>
<td><strong>Teacher Affective Feedback</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>✗</td>
<td>Praise</td>
<td>Teacher praises learner/parent in words or by expressing a warm, excited manner.</td>
<td></td>
</tr>
<tr>
<td>✓</td>
<td>Affirm</td>
<td>Teacher affirms that the response is correct.</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>No Reaction</td>
<td>Teacher makes no response.</td>
<td></td>
</tr>
<tr>
<td>✗</td>
<td>Negative</td>
<td>Teacher indicates that response is incorrect.</td>
<td></td>
</tr>
<tr>
<td>✗ ✗</td>
<td>Criticise</td>
<td>Teacher criticizes response verbally or by expressing a frustrated or angry manner.</td>
<td></td>
</tr>
<tr>
<td><strong>Teacher Verbal Feedback</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gives Answer</td>
<td>Teacher provides correct answer for learner.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeats Question</td>
<td>Teacher repeats original question.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gives Clue</td>
<td>Teacher gives a clue.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rephrases Question</td>
<td>Teacher simplifies question by rephrasing.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WORKSHOP OBSERVATION INSTRUMENT
(Measuring implementation of first three stages of inquiry centred instruction)
Adapted from the NSES 1996

Name of Facilitator: ........................................ Name of Observer: ........................................
Category: [Novice] [Intermediate] [Veteran] Area: ........................................ Date: .........................

<table>
<thead>
<tr>
<th>STEP 1: ENGAGES THE PARTICIPANTS</th>
<th>SD 1</th>
<th>D 2</th>
<th>A 3</th>
<th>SA 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creates a relaxed, non threatening environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encourages and accepts student autonomy and initiative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uses manipulative, interactive and physical materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Familiarises him/herself with participants’ understandings of concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encourages participants to engage in discussion with facilitator and with one another</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurture participants’ natural curiosity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STEP 2: FACILITATOR ALLOWS PARTICIPANTS TO EXPLORE THE CONCEPT</th>
<th>SD 1</th>
<th>D 2</th>
<th>A 3</th>
<th>SA 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allows participants responses to drive lessons, shift instructional strategies and alter content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encourages participant inquiry by posing thoughtful, open-ended questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encourages participants to question each other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engages participants in experiences that pose contradictions to their initial hypotheses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allows time after posing questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focuses and supports inquiries while interacting with students</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STEP 3: FACILITATOR ENCOURAGES PARTICIPANTS TO EXPLAIN THE CONCEPT AND DEFINE THE TERMS</th>
<th>SD 1</th>
<th>D 2</th>
<th>A 3</th>
<th>SA 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeks elaboration of participants initial responses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encourages use of cognitive terminology such as classify, analyse, predict</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asks probing questions to elicit meaningful explanations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gives participants the opportunity to refine their explanations and definitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Many of the criteria listed in the workshop observation instrument are adapted from the NSES, 1996, Teaching Standards B, 31 and from Brooks and Brooks 1993, 102-118.
**FACILITATORS’ INQUIRY LEARNING BELIEF SYSTEM**

Area: ....................  Date: .............  Category of Facilitator: [Novice | Intermediate | Veteran]

On a scale of 1-4, rate your beliefs about inquiry learning by ticking in the appropriate column.

<table>
<thead>
<tr>
<th></th>
<th>SD</th>
<th>D</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree with the statement</td>
<td>Disagree with the statement</td>
<td>Agree with the statement</td>
<td>Strongly Agree with the statement</td>
</tr>
</tbody>
</table>

### STEP 1: I BELIEVE IT IS IMPORTANT TO ENGAGE PARTICIPANTS BY:

- Creating a relaxed, non-threatening environment
- Encouraging and accepting student autonomy and initiative
- Telling them how to solve the problem at hand
- Using manipulative, interactive and physical materials
- Familiarising myself with participants’ understanding of concepts
- Encouraging participants to engage in discussion with me and one another
- Creating a certain amount of tension amongst participants to keep them focused on the activity at hand
- Nurturing participants’ natural curiosity
- Minimal use of manipulatives so as to encourage learners to develop skills in abstract thinking

### STEP 2: I BELIEVE IT IS IMPORTANT TO ALLOW PARTICIPANTS TO EXPLORE THE CONCEPT BY:

- Allowing participants’ responses to drive lessons, shift instructional strategies and alter content
- Encouraging participant inquiry by posing thoughtful, open-ended questions
- Encouraging participants to question each other
- Asking questions which have specific answers only
- Engaging participants in experiences that pose contradictions to their initial hypothesis
- Allowing time after posing questions
- Discouraging participants from asking questions which may change what I have planned to cover in the workshop
- Focusing and supporting inquiries

### STEP 3: I BELIEVE IT IS IMPORTANT TO ENCOURAGE PARTICIPANTS TO EXPLAIN THE CONCEPT AND DEFINE THE TERMS BY:

- Seeking elaboration of participants’ initial responses
- Encouraging participants to learn explanations of terminology as given by textbooks or teachers
- Encouraging use of cognitive terminology such as classify, analyse, predict
- Asking probing questions to elicit meaningful explanations
- Accepting participants’ responses without probing for further explanations
- Giving participants the opportunity to refine their explanations and definitions
### POST WORKSHOP SUMMARY OBSERVATION INSTRUMENT

Measuring implementation of first three stages of inquiry centred instruction

(Adapted from NSES 1996)

Name of Facilitator: ........................................... Name of Observer: ...........................................

Category:  
- Novice
- Intermediate
- Veteran

Area: ...................... Date: ......................

---

#### STEP 1

<table>
<thead>
<tr>
<th>Engages the participant</th>
<th>Learner □</th>
<th>Parent □</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does not engage the participant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Engages the participant some of the time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Engages the participant most of the time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Fully engages the participant</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comment: .................................................................................................................................

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#### STEP 2

<table>
<thead>
<tr>
<th>Explores the concept</th>
<th>Learner □</th>
<th>Parent □</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Participants make no attempt to explore the concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Participants make a superficial attempt to explore the concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Participants make a good attempt at exploring the concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Participants fully explore the concept</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comment: .................................................................................................................................

---

#### STEP 3

<table>
<thead>
<tr>
<th>Explains the concept and defines the terms</th>
<th>Learner □</th>
<th>Parent □</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Participants make no attempt, use mathematical terms incorrectly, unable to explain the concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Participants use some of the mathematical terms correctly and show some confusion in explaining the concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Participants use most of the mathematical terms correctly and make a good attempt at explaining the concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Participants use mathematical terms correctly and confidently explain the concept</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comment: .................................................................................................................................
FACILITATOR INTERVIEW

Name of Facilitator: ........................................ Name of Interviewer: .....................................................

Name of School: ........................................ Area: ........................................ Date: ...............................

Category:  Novice  Intermediate  Veteran

1. Do you believe that your facilitation skills promoted learning with parents and learners? Give reasons why or why not.

2. How did you help the parents and learners solve the problem presented at your station? Give some examples.

3. Do you believe that the training course helps to prepare you to assist workshop participants solve problems by:

   3.1 Engaging participants? Explain how.

   3.2 Encouraging participants to explore the concept? Explain how.

   3.3 Encouraging participants to explain the concept and define the terms? Explain how.

4. What is your perception of inquiry based learning?
PARENT/LEARNER INTERVIEW

Name of Parent/Learner: ........................................... Name of Interviewer: ...........................................

Date: .................................................. Area: ...................................................................................................

1. Which station did you most enjoy during the workshop? Explain why?

2. Did you feel comfortable in asking questions to help you solve the problem? Explain your answer.

3. Did the teacher assist you in solving the problem at the station by:
   3.1 Engaging you in the activity? Explain your answer.
   3.2 Encouraging you to explore the concept? Explain your answer.
   3.3 Encouraging you to explain the concept and define the terms? Explain your answer.

4. Give one word that would explain how you felt at the beginning of the workshop.

5. Give one word that would explain how you felt at the end of the workshop.