AN INVESTIGATION INTO THE NATURE OF GRADE 4 LEARNERS' EVOLVING MATHEMATICS LEARNING DISPOSITIONS: A CASE STUDY OF 3 LEARNERS PARTICIPATING IN AN AFTER SCHOOL MATHEMATICS CLUB

A thesis submitted in fulfillment of the requirement for the degree

of

MASTER OF EDUCATION

of

RHODES UNIVERSITY, GRAHAMSTOWN, SOUTH AFRICA

(Faculty of Education)

by

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Declaration

I declare that this Research Project represents my original work. It is being submitted for the degree of Master of Mathematics Education at Rhodes University, Grahamstown. It has not been submitted for any degree or examination at any university.

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(Signature of candidate)

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Lastly, I give my appreciation to the South African Numeracy Chair Project hosted by Rhodes University in Grahamstown where Professor Mellony Graven holds the Chair, which is jointly funded by FirstRand Foundation, with the (RMB) Rand Merchant Bank, the Anglo American Chairman's Fund & the Department of Science and Technology (administered by the National Research Foundation) for such a grand opportunity in my life time to have this fellowship and conduct my research within this Chair project. Without your funds I would have never got hold of this life-changing possibility, thank you very much.

Dedication

I dedicate this writing to my grand-mother Rebecca Hewana who passed on in 1997 at the age of 93. Her uninterrupted contribution and efforts in my life as I went through relentless challenges will never be taken for granted by me. I also take this opportunity to thank my mother Maude Planga for her prayers from the start of this study and most importantly, to my wife Wali Hewana for her encouragement and support in my work. In the same way, I give thanks to my children Monwabisi, Nombasa and Zuko Hewana for their positive attributions from which my strength was founded to keep on keeping on.

Publications & Presentations during the research process

During the research process I had an opportunity to present my work at various conferences and also to publish a journal article with fellow Chair team members and my supervisor. These opportunities allowed me to be inducted into the professional and research communities. I have listed my publication and presentations below:

Presentations:

1. Title: ‘What Do Grade 4 Eastern Cape Learners Think Maths is? Poster presentation at the 19^{th} AMESA conference at the University of the Western Cape, Cape Town (June 2013).
2. Title: Grade 4 learners’ mathematical dispositions: a case study of three learners participating in an after school mathematics club. Presentation at SAARMSTE Eastern Cape regional conference, September 2013, Rhodes University Grahamstown.

Accredited journal publication:

Graven, M., Hewana, D., & Stott, D. 2013. The Evolution of an Instrument for Researching Young Mathematical Dispositions. *African Journal of Research in Mathematics, Science and Technology Education*, 17(1-2), pp.26–37.

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Nomenclature

AR:	Adaptive Reasoning
ANA:	Annual National Assessment
AMESA:	Association of Mathematics Educators of South Africa
BNF:	Basic Number Facts
CAPS:	Curriculum and Assessment Policy Statement
CU:	Conceptual Understanding
DBE:	Department of Basic Education
DET:	Department of Education and Training
DOE:	Department of Education
DST:	Department of Science & Technology
ECDOE:	Eastern Cape Department of Education
HL:	Home Language Learning
FSMAS:	Fennema-Sherman Mathematics Attitude Scales
FP:	Foundation Phase (Grades 1-3)
LDG:	Learning Disposition Grid
LDP:	Learning Disposition Portfolio
LFIN:	Learning Framework in Number
FET:	Further Education and Training
IP:	Intermediate Phase (Grades 4-6)
LOLT:	Language of Learning and Teaching
LTSM:	Learning and Teaching Support
NAEP:	National Assessment of Educational Progress
NCS:	National Curriculum Statement
NICLE:	Numeracy Inquiry community of leader educators
NRF:	National Research Foundation
PC:	Productive Disposition
PF:	Procedural Fluency
NAEP:	National Assessment of Educational Progress
RMB:	Rand Merchant Bank
SACMEQ:	South African Consortium for Monitoring Education Quality
CASS:	South African Curriculum and Assessment Statements
SANC:	South African Numeracy Chair
SGB:	School Governing Body
SC:	Strategic Competency
TIMSS:	Third International Mathematics & Science Study
UNESCO:	United Nations Educational, Science and Cultural Organization

Abstract

Through a qualitative case study approach this research investigated the nature of three Grade 4 learners' mathematical learning dispositions. It further explored how these dispositions evolve within the context of their participation in a weekly after school mathematics club over time. Of particular significance the research drew on the dispositional frameworks of Kilpatrick, Swafford and Findell's (2001) and Carr & Claxton (2002) and pointed to ways in which these framework can be usefully brought together to provide a richer picture of learning dispositions.

Kilpatrick, Swafford and Findell's (2001) framework of mathematical proficiency involves five interrelated strands of which productive disposition is the fifth strand and largely under-researched (Graven, 2012). This strand is defined as 'the tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics' (Kilpatrick, Swafford and Findell, 2001, p. 131). Carr & Claxton (2002) similarly argue for the importance of learning dispositions and point to the importance of resilience, playfulness and resourcefulness as three key indicators.

The research outlines findings of the three case study learners in terms of data obtained from a questionnaire and interview about students' learning dispositions. The interview asked learners various questions including for example, complete the sentence 'Maths is…', describe an effective learner of mathematics and say what you do if you don't know an answer. The instrument was first administered orally and learners were asked to write their answers (in May 2012) and a year later it was administered as an interview by the club facilitator (in May 2013). While there is the limitation of comparison due to the different ways in which learners responded in 2012 (written) and 2013 (oral) the shifting nature of responses in certain respects provides some indication of shifts towards increasingly productive dispositions. Additionally the research analysed detailed transcripts of video recordings of several club sessions over a five-month period. Findings suggest ways of extending dispositional frameworks and that learners have restricted dispositions particularly in terms of sense making and resourcefulness across time. The findings also suggest shifts in dispositions over time especially in terms of seeing steady effort as paying off.

Chapter 1: Introduction

1.1 Introduction

In the Third International Mathematics & Science Study TIMSS (1999), it is stated that South African political history is well-known and the impact on the education system and the disadvantaged youth who have passed through this system is especially devastating. TIMSS confirms that grades 7 and 8 pupils performed very poorly overall and were ranked last out of 41 countries for both mathematics and science. Likewise, South Africa's grade 12 pupils obtain a significantly lower average score of in comparison with the other participating countries. Fleisch (2008) refers to this as a 'crisis' in South Africa especially, in the early stages of numeracy education. For many years, interventions have focused on improving performance of learners in Further Education and Training (FET) and, in particular, improving matric results. Also, the Report on the Qualitative Analysis of Annual National Assessment (ANA) 2011 Results (DoE, 2012), show that the average score in percentage, dropped from 63% at Grade 1 to just above 31% at Grade 6 level. The lowest average score, as a percentage, was 28% for both Grades 4 and 5. Like in language, performance in mathematics tended to decline both quantitatively and qualitatively across the grades. This is supported by references to some international studies of maths that show significantly poor performance in South Africa (*cf.* Fleisch, 2008; DoE, 2008; SACMEQ, 2010; Carnoy, Chisholm, Addy, Arends, Baloyi, Irvin & Raab, 2011). In the UNESCO (2012) report, it is stated that the research on mathematics teaching in South Africa has major contextual challenges that impact on the quality of mathematics education. UNESCO claims that socio-economic, cultural, linguistic and gender diversities play a major role. They offer many examples of such factors that weaken the student culture of learning and achievement.

1.2 Context of the study

One of the more recent responses to this 'maths crisis' has been the establishment of six mathematics education Chairs. These are funded by the SA Department of Science & Technology, private funders together with the National Research Foundation and Rand Merchant Bank (RMB). Two of these focus on numeracy development in primary school. The reasons for this is that, more recently, there has been increasing acknowledgement that interventions need to begin much earlier in schooling (Wright & Stafford, (2006). Professor

Hamsa Venkatakrishnan holds one such Chair at Wits University while Professor Mellony Graven holds the SA Numeracy Chair (SANC) at Rhodes University. I am a Masters fellow within the latter Chair project. The focus of these Chairs is to nurture research in the field of Numeracy education and, in particular, to seek sustainable ways forward to address the current crisis. Secondly, the Rhodes Chair projects have partnered with numeracy teachers (ranging from grade 0-6) in 12 schools in the broader Grahamstown area to work towards the improvement of numeracy teaching and learning. Additionally the projects have established after school mathematics clubs in several schools. This partnership with Grahamstown schools provides researchers an opportunity to do research work in these schools and clubs. A central aim of the clubs is to develop learner sense-making, shifting learner dispositions from being passive learners to becoming active participators (Graven & Stott, 2012). Learner clubs are discussed further in the literature review section. I am a full time master's fellow in this Chair and have been involved in running two maths clubs in 2012. This involvement shaped my research as indicated in the rationale below.

1.3 After school mathematics clubs

The after school weekly maths club tends to be a second site of learning and informal in its design. Typically these clubs range between 6 to 12 participators and the central objective is to develop learner sense-making in numeracy, 'shifting learner dispositions from being passive learners to becoming active participators' (Graven & Stott, 2012). Thus the club is destined to be the hub of increasing sense-making and an obliging learning base, where learners mathematically engage with content and with one another. To that extent our project has developed a variety of resources and programs to follow during out-of-school-time (an extra 1 hour after school) each week by our club mentors. The program is expected to create an environment that is less structured that can offer opportunities and more affordances for the creation of active engagement, negotiation and participation for learners.

At the same time the clubs are not intended to overshadow in any way the normal and structured school curricula or program but clubs come in to 'provide more freedom to focus on the deliberate construction of positive participatory mathematical identities, at the expense of covering the range of skills and knowledge required to 'get through' the curriculum' (Graven & Stott, 2012, p. 96). Thus I adopted one of these SANC run clubs in Grahamstown, where I had run a pilot study in 2012 between July and December, as my study location and some of the participating children as my unit of analysis for the research study.

1.4 Rationale for the study

I have been a grade 6 and 7 mathematics teacher in a primary school in Grahamstown for more than 20 years. In my experience with these grades, the majority of the learners had little conceptual understanding and this limited their ability to think adaptively and strategically. The learners lacked independence in that they were not willing to take risks to voice their thoughts. Time consuming probing and pausing for responses was not always fruitful because most learners would remain silent, and be scared to make mistakes in the full view of others. It took time and deliberate effort to shift learners toward more active and independent participation. My experience was thus that most of the learners I taught were overly dependent on my teacher instruction and as such were victims of passive learning. Contrary to this, Kilpatrick, Swafford & Findell (2001, p. 116) argue that:

> *Helping children acquire mathematical proficiency calls for instructional programs that address all the strands. As they go from pre-kindergarten to eighth grade, all students should become increasingly proficient in mathematics. That proficiency should enable them to cope with the mathematical challenges of daily life and enable them to continue their study of mathematics in high school and beyond. (Kilpatrick et al, 2001, p.133).*

It was the prospect of seeing and understanding this kind of teaching and learning that appealed to me in the after-school maths clubs. Since August 2012, I became involved in running two of the Maths after school clubs within the SA Numeracy Chair projects. Through participation in the clubs I was also inducted into the academic concepts of learning dispositions and became interested in observing the students' learning dispositions that were evidenced in what they say about mathematics and how they act and participate in the clubs. I noticed in my club that learners' ways of participation and dispositions were not fixed but evolved with time as they become more comfortable to 'expose' their ideas.

Another major rationale for my study arose from the 'unfinished business' or interesting questions now raised by a study conducted by the SA Numeracy Chair into their after school maths clubs. It was a benchmark study across 614 students in 12 schools in Grahamstown District to start opening up an exploration of productive disposition in mathematics. I was fortunately also involved as one of several data collectors administering the Chair's productive disposition instrument and then in the subsequent analysis of the data. The productive disposition instrument is given in *Figure.* 1 below:

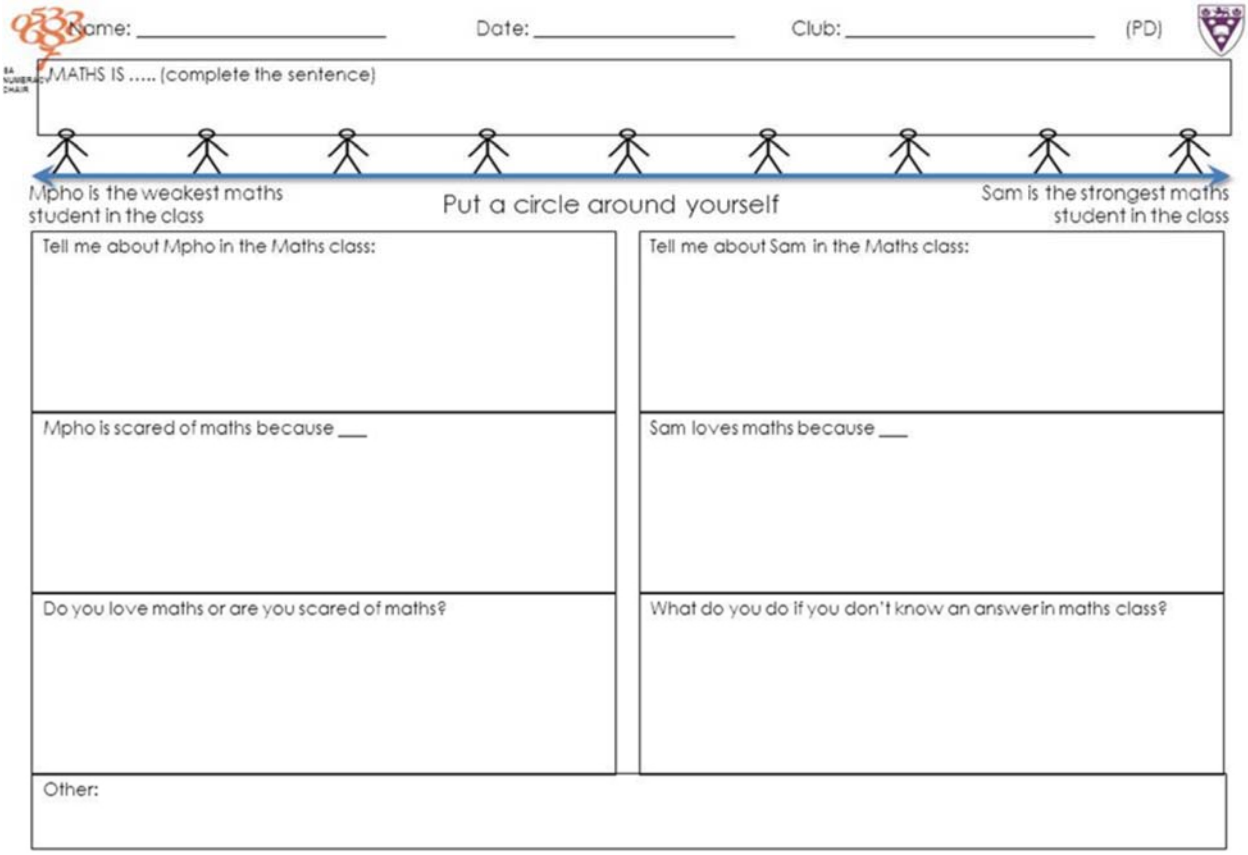

Figure 1. Revised Mathematics Learning Disposition Instrument (Graven, 2012, 55).

Looking at the character of the data, I had the opportunity of transcribing and coding 614 Grade 4 learner responses to this instrument across 12 schools in the broader Grahamstown area, using a program Textalyser for coding and categorizing the responses. My supervisor checked 10% of these codes to support reliability of coding and 25% percent of the finished analysis. If a word only appeared once in the entire sample it was classified under 'other.' Across all schools the vast majority of learners provided only one word responses to the item (the average number of words used in answers was only 1). A small number of learners provided more than one word and so their response could have been recorded in two categories in the table, for example: Maths is: 'sums and good.'

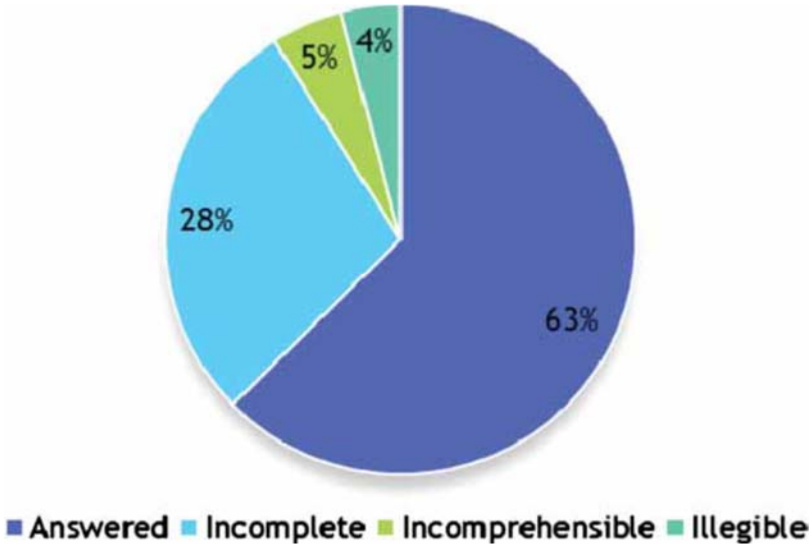

Figure 2. Completeness of responses from learners

We also found (see *Figure. 2* above) that 37% of the responses to the question *'Maths is…'* were incomprehensible or incomplete or illegible, thus indicating a major limitation of the design or administration of the instrument in this way.

The results of this survey of learners responses across these clubs to the question 'Maths is…" is summarized in Table 1 below and in the bar graphs in *Figure.* 3 below.

The results of the responses by category in Table 1 are also presented in bar graph form in Figure 3. This table is also given in Appendix A.

Table 1

Table of categorization of the responses on 'Maths is…

School	Teacher	No. of learners	No. answered	'Maths is ...' Categories														
				Hard/ difficult	Easy	Counting	Numbers	sums or + - x ÷	Cool	Good/ pleasant/ fine/ likeable/ lovely/ fun/ nice	The best/ best thing/ right thing/ subject	Thinking/ you think	Reading	Tests	Other	Incomplete	Incomprehensible	Illegible
Totals		614	386	17	29	39	13	80	15	122	10	1	2	4	54	174	30	25
% out of 614			63%													28%	5%	4%
% of total No. answered				4.4%	7.5%	10.1%	3.4%	20.7%	3.9%	31.6%	2.6%	0.3%	0.5%	1.0%	14.0%	N/A		

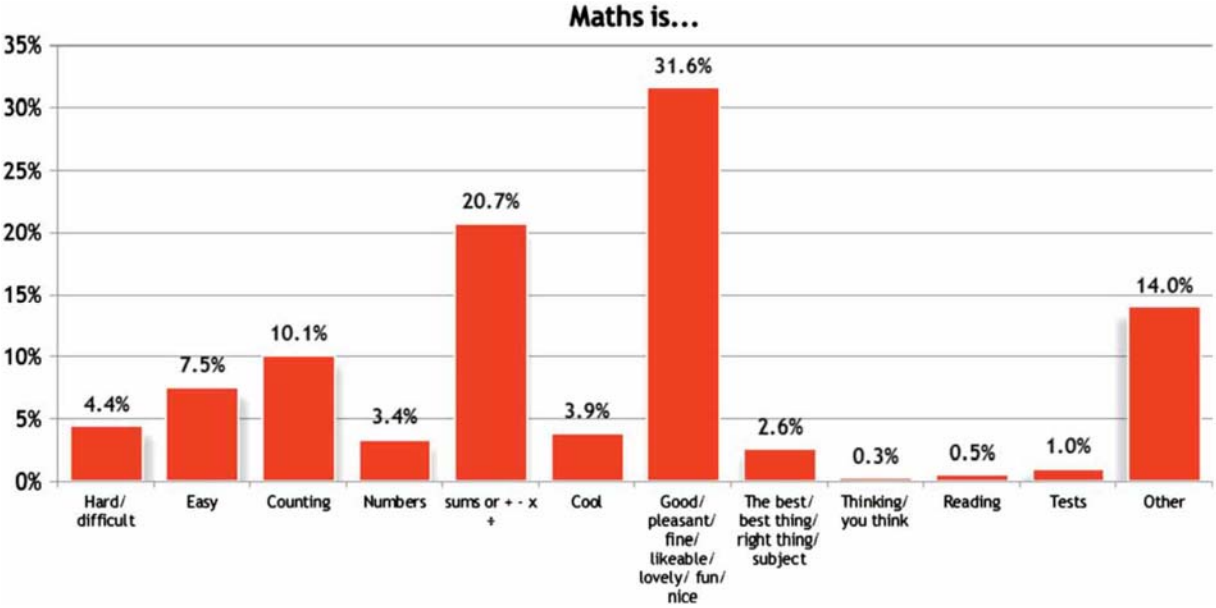

Figure. 3 Bar graph of categorization of 'Maths is…'

Table 1 and *Figure* 3 show that about one third of the learners (31.6%) have 'positive' attitudinal responses to mathematics, such as: fun, good, nice, pleasant, likeable, lovely and even for a small percentage (3.9%) 'Cool.' Another 7.5% of learners describe maths as easy while almost half of that (4.4%) indicate that it is hard or difficult. About a fifth of the learners (20.7%) see maths as sums or one or a combination of the four operations while another 10.1% see it as counting or simply describe it as numbers (3.4%). While the predominance of learners who see mathematics as fun, nice, good, and so forth, is pleasing in the virtual absence of research on young learners' mathematical learning dispositions.

The extremely low frequency of responses that indicate mathematics as involving thinking (0.3%) or solving problems (0%) is cause for concern and could indicate constrained or limited learning dispositions as argued from the smaller case study interview data on this same item.

The high percentage of unanswered, incomprehensible or illegible answers, particularly in some schools is cause for concern and also indicates an enormous limitation of this instrument when not used on a one to one interview basis. The result is that the instrument has only managed to gather data on dispositions from learners who have language and literacy levels that enable them to respond and thus cannot be generalized as data across all grade 3 and 4 learners in our project schools. However the recurrent themes which emerge from those learners who were able to respond provide us with interesting information about learner dispositions which can help inform our work with learners and schools. For example the absence of learners who indicate that maths is about thinking, problem solving or sense making is cause for concern. If the 'tendency to see sense in maths' is absent across responses of learners then this indicates perhaps that our learners' mathematical dispositions are restricted. Similarly themes emerging from other questions indicate restricted dispositions in terms of belief in 'steady effort.' See also Graven, Hewana & Stott (2013).

From my new experience of gathering the above research with the SANC project team my sense was that through conducting as an interview with probing questions much richer data can be captured and enables learners with low literacy levels will be able to contribute verbally. It is from my above experiences that I have chosen to conduct an in-depth case study of three learners' dispositions for this research. Of my three case study learner one has a particularly low literacy level.

While this benchmark study began to cast some light onto dispositions and measuring them it was just the beginning of this research journey.

Graven (2012) argues that 'while productive disposition is considered as one of five equally important strands of mathematical proficiency, as presented in the influential work by Kilpatrick et al (2001), to date it has received the least attention in relation to research and is generally unassessed.' The same is also evident in the influential national *Effective Teachers of Numeracy* Study carried out in Britain that emphasised that effective teachers of numeracy must give attention to knowledge of content and relationships (connections and sense-making) but generally overlooked the aspect of developing in learners a productive disposition (Askew et al, 1997).

Graven (2012) asserts that there is little (research) that elaborates on the nature of the relationship between learners' knowledge base (procedural fluency and conceptual understanding), problem solving strategies (adaptive reasoning and strategic competence) and learner dispositions. Such an understanding might be used to support the design of rich learning opportunities across the strands of proficiency. Thus, there is a gap in the maths education research on this strand (Graven, 2012; Graven, Hewana, Stott, 2013).

Arising from the above the research team at the SA Numeracy Chair decided to frame a series of studies into various facets of production dispositions. There were and still are a number of gaps in our understanding of productive dispositions, in addition to those mentioned by Graven above, such as how productive dispositions might evolve over time, the varied ways in which productive dispositions might be manifest, the relationship between dispositions, the practices of the learning community, and importantly the methodologies and instruments that might be used or developed to observe and analyse these.

Thus my study was framed to explore a few of these gaps.

1.5 Implications of the research

This research study should indicate the implications for teaching mathematics and the role of dispositions in the learning process. A range of literature proposes that the more learners are involved and engaged in mathematics tasks, the more their learning dispositions are strengthened (Kilpatrick et al.' 2001). Such activities need classroom learning environments that encourage learners to question what teachers and peers say about a particular mathematical concept. Drawing on (Cobb, 1995), learners should be encouraged to investigate, argue, justify and test conjectures. In this regard, this research hopes to contribute to improved understanding of factors that might positively influence the creation of a productive disposition in young learners, an area that is to date under-researched and not clearly understood. For all intents and purposes, this study will attempt to contribute to the emerging knowledge of learning within after school maths programmes that are founded on socio-cultural perspective and above all pertaining to early numeracy.

Furthermore, this study will seek to lay foundations for other researchers in advancing research work into ways that influence and improve mathematics learning (productive) dispositions of young learners. In this research my objective is to work towards adapting and extending the indicators proposed by Carr & Claxton (2002, p.30) for assessing and accessing learner dispositions in term of what learners believe about mathematics, how they are disposed to act and also, to develop further the learning disposition grid proposed by Carr and Claxton so that it becomes operational and usable for this study.

In doing so, the study will contribute to the absence of research on young learners' mathematical learning dispositions. In addition, the data that the instruments generate might suggest ways in which Kilpatrick, Swafford & Findell's (2001, p. 116) definition of productive disposition below should be extended. They define productive dispositions as:

> *The tendency to see in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics.*

Absent from this definition is Carr & Claxton's (2002) notion of playfulness and reciprocity as key learning dispositions.

Learning dispositions are increasingly noted as important elements of mathematics proficiency (Kilpatrick, Swafford & Findell, 2001, p. 131). Kilpatrick, et al.'s (2001) five learning strands of mathematical proficiency include: *adaptive reasoning; strategic competence; conceptual understanding; procedural fluency* and lastly, p*roductive dispositions,* (p.117*).*

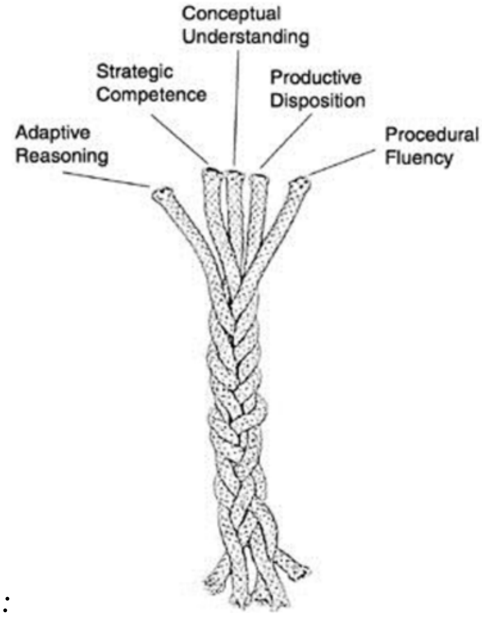

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Figure 4. Intertwined strands of mathematical proficiency

(Kilpatrick, et al, 2001, p. 116)

Learning dispositions became particularly prominent through this influential work as productive disposition is noted in this framework as one of the five equally important interrelated strands discussed in details in chapter 2.

Thus, it is important to note that concentrating on any one of these five strands and disregarding the others would be problematic in view of the fact that *'the five strands are interwoven and interdependent in the development of proficiency in mathematics'*, according to Kilpatrick et al., (2001, p. 116).

Drawings on these authors, the SANC project adopts the following definition of mathematical proficiency as:

> *The ability to process, communicate and interpret numerical information in a variety of contexts overlaid with strands of numeracy proficiency: understanding numeracy concepts, computing fluently (practically, mentally and procedurally), applying concepts to solve problems (in creative and inventive ways), reasoning logically (in creative and inventive ways) and engaging with mathematics – seeing it as sensible, useful and do-able (enjoyment and passion)* (Graven and Schafer (2011, p. 20).

1.6 Research goals

The goal of this research study is to investigate grade 4 learners' (evolving) mathematical learning dispositions through an in-depth case study of 4 learners participating in an after school mathematics club and through this to suggest possible elaborations/adaptations for current definitions and instruments available for assessing young learner dispositions.

1.7 Research Questions

To achieve the above goal, I will endeavour to answer the following questions:

1. What is the nature of 4 learners' mathematical learning dispositions? How might these dispositions evolve within the context of their participation in a weekly after school mathematics club over time?
2. What adaptations/elaborations of existing dispositional instruments are required to access and assess learner dispositions?
3. What are the implications of the research for adapting/extending Kilpatrick, Swafford and Findell's (2001) definition of productive disposition?

1.8 Significance of the study

My research will work towards adapting and extending the current instruments available for accessing and assessing learner dispositions in terms of:

(a) What learners believe about mathematics?

(b) How they are disposed to act, and

(c) To develop further the instrument proposed by Carr & Claxton's (2002) learning disposition grid, so that it becomes operational.

Within the SANC project at Rhodes University there is on-going research on mathematical proficiency across Grade 3 and 4 learners in participating schools and in the Chair clubs. Instruments are adapted from internationally designed assessments; however, since productive disposition is not assessed within these instruments, an instrument was designed for this purpose. Initially, the SANC project piloted various versions of the instrument and a revised instrument was then developed, which has been used with Grade 3 and 4 learners across the schools and in the clubs (discussed above). The instrument is however limited in that it only deals with what learners say – or are able to articulate. Largely the questions relate to dispositions of how learners view mathematics and mathematical success rather than learner dispositions on how to act or respond in a certain way. Only the last question on the instrument, relating to what learners do if they do not know an answer, requires them to respond in relation to how they act (See Appendix D).

Lahire (2003, p. 337) argues that ‘a distinction must be made between dispositions to act and dispositions to believe.’ Interestingly, Kilpatrick et al.’s (2001) definition focuses on dispositions to see and believe as elaborated above. In order to address dispositions in terms of how learners act, rather than simply their attitudes and beliefs, the instrument currently used in the SANC projects could be adapted as an individually oral based interview. This could include questions which enable learners to demonstrate in the interview how they respond to certain mathematical questions. Thus, how they are disposed to act in relation to the question can be recorded. For example, non-standard questions such as ‘Is the number 0 even or odd?’ could, with prompts, yield interesting data on how learners are disposed to respond to uncertainty in mathematics. Thus, the instrument could be extended to include task-based interview type items so as to yield more data on how learners are disposed to act. However, such data would not provide data on learning dispositions within more natural learning situations involving mentors and other learners. It is for this reason that I have a desire to research learner dispositions through supplementing interview data with on-going observation within a club environment.

In doing so, the study will contribute to the absence of research on young learners’ mathematical learning dispositions. In addition, the data that the instruments will generate suggest ways in which Kilpatrick, Swafford & Findell’s (2001) definition of productive disposition below should be extended.

Lahire’s (2003) argues that:

> *If one reduces beliefs to tendencies to act in a certain way, one cannot understand why such actions do not occur or why they appear difficult to realize. Conversely, if one sees beliefs as thin layers of ‘veneer’ one cannot understand such phenomena as a guilt, discomfort, shame, or ‘complexes’ resulting from the asymmetries between beliefs and dispositions to act. Such asymmetries, and sometimes contradictions, between (i) different (strong or weak) beliefs individual agents have internalized in different contexts, (ii) different (strong or weak) habits or dispositions to act, and (iii) beliefs and dispositions to act complicate sociological research; they require that researchers*

always ask themselves what specific effects of what type of socialization they have in fact been measuring (Lahire, 2003, p. 338).

Thus, this study should indicate implications for teaching mathematics and the role of dispositions in the learning process. For example, Carr & Claxton's (2002, p.50) view is that 'teachers [among other things] personal learning dispositions such as goal-directedness, infectious enthusiasm for learning, and joy in emerging capabilities and how well teachers themselves model life-long learning to the charges may well turn out to be key factors in how effective educational programmes can promote learning dispositions.'

Drawing on Claxton 1999a (cited in Carr & Claxton 2002, pp. 9-10)

> *Crudely, we might say that this real-life 'learning power' consist of two interrelated facts: capabilities and dispositions. Capabilities are the skills, strategies and abilities which learning requires: what you might think of as the 'toolkit' of learning. To be a good learner you have to be able. But if such capabilities are necessary, they are not of themselves sufficient. One has to be disposed to learn, ready and willing to take learning opportunities, as well as able.*

It is noted and continuously stressed that, 'forms of assessment, whether we like it or not, are the most powerful drivers of forms of teaching and learning' (Broadfoot, 1996). 'But the relationship is an uncertain one: capabilities does not always produce disposition, nor vice versa. Education for lifelong learning has, therefore, to attend to the cultivation of positive learning dispositions, as well as effective learning skills' (Carr & Claxton, 2002, p. 10). Therefore, dispositions to learn are inclinations towards learning, i.e. being 'ready and willing' as a volitional (conscious choice) activity. Additionally, capabilities and dispositions not only interact but also frequently reinforce each other. In this regard, drawing on Graven (2012) my research contributes to improved understanding of factors that might positively influence the creation of a productive disposition in young learners, an area that is to date, under-researched and not clearly understood.

Boud (cited in Carr & Claxton, 2002, p. 9) argues that:

> *The focus of education is shifting to a concern with the development of aptitudes and attitudes that will equip young learners to function well under conditions of complexity, uncertainty and individual responsibility: to help them become, in other words, good*

life-long learners. If learners are not positively disposed towards learning, progress will be stunted even when the necessary learning skills may have been mastered.

Essentially, this study contributes to the emerging knowledge of learning within maths learning environments, particularly pertaining to early numeracy. Also, this study is anticipated to lay foundations for other researchers to further research work into ways that influence and possibly improve mathematics learning (productive) dispositions of young learners. Thus, I have argued that research into learning dispositions is an indispensable complement to research into the skills of learning.

1.9 Structure of this study in terms of chapter sequencing

This study consists of 6 chapters. In chapter 1, I have largely talked about the background/context of the study, the implications and the rational of the study, its research goals and research questions, and the significance of the study. In chapter 2, I present the theoretical perspective that is underpinned by a socio cultural perspective of learning. In chapter 3, I provide a detailed review of the range of literature that informs this study as it relates to learner dispositions both generally and more specifically in mathematics education.
In chapter 4, I present my research approach and the various methods used to gather data. I also discuss ethical considerations. In chapter 5, I provide a brief background of learners' including of their mathematical fluency levels and the mathematics clubs run by the SANC Project.

Chapter 2

Theoretical Perspective

2.1 Introduction

In this chapter I present the theoretical perspective that frames this study and provide a detailed review of the range of literature that informs this study as it relates to learner dispositions both generally and more specifically in mathematics education.

2.2 Theoretical perspective

My study is underpinned by a socio cultural perspective of learning. An emergent body of literature (see Schoenfeld, 1992; Schoenfeld & Kilpatrick, 2008; Lerman, 2000) conceives of mathematics learning as an inherently social activity, an essentially constructive activity instead of an absorbtive one. Lerman (2000, p.23) in his paper titled 'The Social Turn in Mathematics Education Research' writes that the social turn is intended to signal:

> *The emergence into the mathematics education research community of theories that see meaning, thinking and reasoning as products of social activity. This goes beyond the idea that social interaction provides a spark that generates or stimulates an individual's internal meaning-making activity.*

Lerman (2000) suggests that the origins of this social turn are in three general fields outside of mathematics education—anthropology (from, e.g., Lave), sociology (from, e.g., Walkerdine), and cultural psychology (from Nuñes; Crawford). For these researchers, knowledge and identity are intricately linked and situated in specific practices.

In further support of this learning perspective, Resnick (1989, p.39), tracing contemporary work to antecedents in the work of George Herbert Mead (1934) and Lev Vygotsky (1978), states [that],

> *Several lines of cognitive theory and research point toward the hypothesis that we develop habits and skills of interpretation and meaning construction through a process more usefully conceived of as socialization than instruction.*

The notion of socialization as identified by Resnick et al., (1989) or, as he prefers to calls it, enculturation - entering and picking up the values of a community or culture, is central in that it highlights the importance of the development of habits through socialization in learning environments as a core aspect of knowledge.

Schoenfeld (1992) declares that, while this cultural perspective is well grounded anthropologically, it is relatively new to mathematics education and that the main points from this perspective are that:

> *The community to which one belongs shapes the development of one's point of view, their values and perspectives as well, includes a way of thinking, a way of seeing, and having a set of values and perspectives. Learning is culturally shaped and defined; people develop their understandings of any enterprise from their participation in the community of practice within which that enterprise is practiced. The lessons students learn about mathematics in our current classrooms are broadly cultural, extending far beyond the scope of the mathematical facts and procedures (the explicit curriculum) that they study* (Schoenfeld, 1992, p.22).

Drawing on Lave & Wenger, (1991) this study considers that learning is located in the process of co-participation and not in the heads of individuals; not located in the acquisition of structure but in the increased access of learners to participation, and it is an interactive process on which learners perform various roles. Lave and Wenger (1991) prioritize the importance of *participation* in the practice of a community. They write: 'learning is an integral part and inseparable aspect of social practice' (p.31). Their perspective encourages me to pay attention to the complexity of the many social factors impacting on the study. Lave and Wenger (1991, p.43) emphasize the importance of 'shifting the analytic focus from the individual as learner to learning as participation in the social world, and from the concept of cognitive process to the more encompassing view of social practice.'

Thus as Graven (2004, p.182) notes 'for Lave & Wenger learning is not located in the acquisition of structure but in increased access of learners to participating roles in expert performances.' In this respect their perspective on learning has implications for ways for enabling learning. That is, learning is maximized if one maximizes learners' access to participation in, and the resources of, a community of practice in which the development of identities in relation to that community are supported, Graven (2004.p. p.182). Lave & Wenger (1991) argue that particular tools and techniques for learning are replaced with 'ways of becoming a participant' 'ways of participating.' In this respect 'learning and a sense of identity are inseparable: They are aspects of the same phenomenon' (p.115). They further argue that learning implies: 'becoming a different person with respect to the possibilities enabled by the systems of relations' (p.53). Since my research is focused on dispositions, which are one aspect of learner identities (since they refer to the habitual tendency to respond to situations and thus participate in certain ways), the notion of learning in relation to evolving 'ways of becoming and being a participant' is relevant to my study.

Following on from this earlier work with Lave, Wenger's (1998) seminal work on communities of practice is also useful for thinking about student learning within an after school maths club as it *focuses* on and the importance of developing positive participatory ways of being (relating to productive learning dispositions) with learners. Wenger's (1998) work is based on the premise that people are social beings and knowing is about active engagement in the world. Wenger declares that 'since learning changes who we are, it is an experience of identity, we define who we are through our participation and by the way we and others reify ourselves' (p.149). In relation to Wenger's notion of identities (1998) he notes:

> *As trajectories, our identities incorporate the past and the future in the very process of negotiating the present… Learning events and forms of participation are thus defined by the current engagement they afford, as well as by their location on a trajectory* (p.155).

Additionally, Wenger (1998) argues that identity formation involves a dual process of identification and negotiability. Identification provides 'experiences and material for building identities through an investment of the self in relations of association and differentiation' (p.188), and, negotiability is 'the ability, facility, and legitimacy to contribute to, take responsibility for, and shape meanings that matter in a social configuration' (p.197). Thus my research within the Chair after schools maths clubs intends to explore the relationship between learners' mathematical histories and their evolving dispositions, forms of participation and possible changing 'ways of being' in the maths clubs activities.

In the sense that productive disposition involves 'seeing oneself' as an effective learner and doer of mathematics, and, that dispositions commonly refer to a habitual tendency to act in a certain way, they relate to learner forms of participation and ways of being in mathematics classes and to learner identities. One way in which we access how learners 'see themselves' is through listening to the stories they tell about mathematics and their learning and participation with it. Thus, my research foregrounds a participationist perspective rather than an acquisitionist perspective on learning (Sfard, 2006, p.6). Within this perspective:

> *The learner should be viewed as a person interested in participation in certain kinds of activities rather than in accumulating private possessions. To put it differently, learning a subject is now conceived of as a process of becoming a member of a certain community. This entail, above all, the ability to communicate in the language of this community and act according to its particular norms…for obvious reasons this new view of learning can be called the participation metaphor* (Sfard, 2006).

This participationist view coheres with my focus specifically on learner dispositions within a club community and with Carr and Claxton's (2002) notion of dispositions and conceptualization of their proposed learning disposition grid (discussed below). Carr and Claxton (2002) point towards the situated nature of social learning dispositions and, drawing on the work of Wenger (1998) that assessment of learning dispositions must focus on participation in relationships within the communities of practice. Similarly, the notion of dispositions builds on a framework where the focus is on the development of learning trajectories rather than acquiring knowledge, skill and understanding (Claxton and Carr, 2004, p. 87-97).

Sfard and Prusak (2005) provide an operational definition of identity, defining it as '[a] collection of reifying, endorsable and significant stories'(p.16). They distinguish between first person and second person stories. In this study I rely on first person stories told in club sessions as well as those stories produced in interviews and questionnaires. Teacher/ mentor stories (or in this case the 'stories' about learners told by the club mentor within club sessions) expressed with reference to what the individual learner does during club sessions are considered 2nd person stories (subjectifying) and significant for this study. Heyd-Metzuyanim and Sfard (2012, p.2) introduced a new set of conceptual tools for studying identifying talk, in mathematical learning situations, namely two concurrent processes: mathematizing (talking about mathematical objects) and subjectifying (talk about the participants of the discourse). What I have learnt from Heyd-Metzuyanim and Sfard's (2012) work is that 'teacher-learner talk' is vital and should be deliberately focused on building and shaping the learner's self-confidence and identity. Thus mentor-learner talk will be a key focus of my club observations and analysis of transcripts. Additionally and drawing on Heyd-Metzuyanim (2013) I should pay particular attention to possible taken-for-granted traditions about who the child and who the teacher is (identifying statements) and should concentrate on how the communication between the three agents (child, teacher and content) enables learning.

2.2.1 Framework of mathematical proficiency and the role of disposition

In the Internationally Influential Report *Adding it up*, (Google scholar indicates the report has over 1 200 international citations) Kilpatrick, Swafford & Findell (2001, p.116) present five interrelated strands of mathematical proficiency, namely:

- *Adaptive reasoning* – capacity for logic thought, reflection, explanation and justification,
- *Strategic competency* – ability to formulate, represent, and solve mathematical problems,
- *conceptual understanding* – comprehension of mathematical concepts, operations, and relations,
- *Procedural fluency* – skills in carrying out procedures flexibly, accurately, efficiently and appropriately and lastly,
- *Productive disposition* – habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

They emphasise the interrelatedness of the strands and that all work together to enable mathematical proficiency. The importance of learning dispositions, as the fifth strand, became highlighted through this work. They define productive disposition as*:*

> *'the tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics'* (Kilpatrick, Swafford and Findell, 2001, p.131).

Additionally, Kilpatrick et al., (2001) refer to the five strands as providing a framework for discussing the knowledge, abilities, and beliefs that constitute mathematical proficiency. Also, this framework has some similarities with the one used in recent mathematics assessments by the National Assessment of Educational Progress (NAEP, 2012), which features the following three mathematical abilities namely, conceptual understanding, procedural knowledge and problem solving, and comprise additional specifications for reasoning, connections and communication. This framework of mathematical proficiency frames this study.

Above I have elaborated on the theoretical framework and assumptions about learning that inform the study as well as on the conceptualisation of mathematical proficiency that form the basis of this research. Learner dispositions or productive disposition as discussed in Kilpatrick's framework above is one of five equally important strands of proficiency. In the next section I turn to review relating to this aspect of proficiency.

Chapter 3

Literature review

3.1 Introduction

In this chapter I have provided a detailed review of the range of literature that informs this study as it relates to learner dispositions both generally and more specifically in mathematics education.

According to Kilpatrick et al., (2001, p.131), developing a productive disposition requires 'frequent opportunity to make sense of mathematics, to recognise the benefit of perseverance and to experience the rewards of sense making in mathematics.' They argue that productive disposition develops when other strands develop. For example, as students build strategic competence in solving non-routine problems, their attitudes and beliefs about themselves as mathematics learners become more positive. The more mathematical concepts they understand, the more sensible mathematics becomes. In contrast, when students are seldom given challenging mathematical problems to solve, they come to expect that memorising rather than sense making paves the road to learning mathematics, and they begin to lose confidence in themselves as learners. Conversely, when students see themselves as capable of learning mathematics and using it to solve problems, they are able to develop further their procedural fluency or their adaptive reasoning abilities (Kilpatrick et al., 2001). This coheres with the South African Curriculum and Assessment Statements for Foundation and Intermediate Phase (DBE, 2011a, 2011b) which also connects sense making and conceptual understanding and says that mathematics is a creative part of human activity and that learners should develop a deep conceptual understanding in order to make sense of mathematics.

3.2 Researching dispositions and identifying a gap in research literature

The Mathematics Framework for National Assessment (NAEP, 2007, p.8) in the USA indicates that each level of mathematical complexity includes aspects of knowing and doing mathematics, such as reasoning, performing procedures, understanding concepts and solving problems. The levels are ordered, so that items at a low level would demand that students perform simple procedures, understand elementary concepts, or solve simple problems. Items at the high end would ask students to reason or communicate about sophisticated concepts, perform complex procedures, or solve non-routine problems. Ordering of the levels is not intended to imply a developmental sequence or the sequencing in which teaching or learning occurs. Rather, it is a description of the different demands made on students by particular test items. However this document does not mention the importance of developing and assessing productive disposition among learners.

Schoenfeld et al., (1992, p.3), mention five goals of mathematics which link to some of Kilpatrick et al., 's (2001) strands of mathematical proficiency but there is no mention of a productive disposition although their goal of beliefs does connect with one aspect of a productive disposition. Their five goals include: The knowledge base; problem solving strategies; monitoring and control, beliefs and effects, and, practice.

Additionally, Graven (2012) asserts that there is little (research) that elaborates on the nature of the relationship between learners' knowledge base (procedural fluency and conceptual understanding), problem solving strategies (adaptive reasoning and strategic competence) and learner dispositions. Such an understanding might be used to support the design of rich learning opportunities across the strands of proficiency. Thus, there is a gap in the maths education research on this strand (Graven, 2012; Graven, Hewana, Stott, 2013). However Katz (1993) argues that in relation to research on dispositions we need to still determine which dispositions are key:

> *Much research is needed to determine which dispositions merit attention, and whether dispositions of a general or specific focus should be addresses by educational goals. If the desirable dispositions listed among the goals are very specific, the list is likely to be unmanageably long. However if dispositions are too general, they become too difficult to observe and therefore, to assess. Ideally, educational goals should include dispositions that strike an optimal balance between generality and specificity* (p.20).

Resnick (1987, p.40-43) argues that 'dispositions are critical to developing high order thinking in students and the term *'disposition'* should not be taken to imply a biological or inherited trait but it is more of the same kind to a habit of thought, one that can be learned and, therefore taught.' Furthermore it should be noted that dispositions, according to Carr & Claxton (2002, p.10) are referred to as 'imprecise' and as such, they are a different type of learning from knowledge, skills and understanding and can be thought of as 'habits of mind', 'tendencies to respond' to 'situations in a certain way' (p.10). Similarly Kilpatrick et al., (2001, p.131), declare that 'If students are to develop conceptual understanding, procedural fluency, strategic competency, and adaptive reasoning abilities, they must believe that mathematics is understandable, not illogical, that with diligent effort, it can be learned and used; and that learners are capable of figuring it out.'

Across these authors Kilpatrick et al., (2001, p.116), Resnick, (1987, p.41) and Carr & Claxton (2002, p.10) there is agreement that productive learning dispositions are *'habits of the mind or thought.'*

Graven (2012, p.53) sums up the absence of attention paid to accessing and assessing learner mathematical dispositions, i.e. Kilpatrick, Swafford and Findell's fifth strand as follows:

> *While it is acknowledged that knowledge of students involves knowing learners' levels of mathematical competence, and what they are able to do and not do, knowledge of student mathematical learning dispositions is generally ignored. Similarly, Mathematics assessments tend to ignore this aspect…. If this strand is, as Kilpatrick, Swafford and Findell (2001) suggest, one of five equally important interrelated strands of proficiency, then surely we need to find ways to support teachers to access and assess learner dispositions, in order to remediate and reinforce as needed. Assessing competence in the other strands may of course point towards a productive (or the absence of a productive) disposition, but the way in which dispositions relate to the other strands requires further investigation.*

3.3 Developing Productive Dispositions

Developing a productive disposition as mentioned above pertaining to my research questions requires frequent opportunity to make sense of mathematics, to recognise the benefit of perseverance and to experience the rewards of sense making in mathematics. Kilpatrick et al., (2001) argue that productive disposition develops when the other strands do help each of them develop. For example, as students build strategic competence in solving non-routine problems, their attitudes and beliefs about themselves as mathematics learners become more positive. The more mathematical concepts they understand, the more sensible mathematics becomes. In contrast, when students are seldom given challenging mathematical problems to solve, they come to expect that memorising rather than sense making paves the road to learning mathematics, and they begin to lose confidence in themselves as learners, Kilpatrick et al., (2001, p. 131). Similarly, when students see themselves as capable of learning mathematics and using it to solve problems, they are able to develop further their procedural fluency or their adaptive reasoning abilities (Kilpatrick et al.,, 2001). Schoenfeld et al., (1992) quoting Resnick

(1989, p.58) note that 'becoming a good mathematical problem solver, becoming a good thinker in any domain one needs to develop the habits and dispositions of interpretation and sense-making as of acquiring any particular set of skills, strategies, or knowledge.' If this is so, we may do well to conceive of mathematics of education less as an instructional process (in the traditional sense of teaching specific, well define skills or terms of knowledge) than as socialization process.'

3.4 The Relationship between dispositions and the practices of the learning community

Gresalfi (2009, p.327) notes that the National Mathematics Advisory Board in the USA in 2008 places emphasis on 'social, motivational and affective influences on learning as a point of importance.' His view is that 'although this work has identified areas commendable of further enquiry, it has not stimulate the scrutiny of how classroom practice could boost learners learning practice and motivation.' He further argues that 'the literature does not help to explain why classroom practice does not impact all learners the same way or which aspects of classroom practice serve to support the development of various dispositions towards learning among learners who are members of the same classroom.'

Gresalfi (2009, p.330), puts emphasis on the notion that:

> *The individual-and-context perspective considers context as a factor that impacts the experiences that a leaner may have. An example of such work might include a study wherein students are asked about characteristics of their maths classes, which are then considered to be as factors impacting students' perceptions of their own competence. Finally the individual-with-context perspective considers the individual and the context in which the individual is interacting as interdependent. If the individual is taken out of the environment, neither the individual nor the context is the same. An example of such a study might consider how classroom norms are established and taken up by participants in the classroom by attending to the ways individuals interact within the constraints of those norms while also shaping those norms.*

Gresalfi & Cobb (2006, p.329) asserts 'thus learning is a process of developing *dispositions;* that is, ways of being in the world that involves ideas about perspectives on, and engagement with information that can be seen both in moments of interaction and in more enduring patterns over time.' Similarly, (Lave & Wenger 1991; Wenger, 1998; Wortham, 2004) maintain that 'learning is therefore considered to be change in participation, through which one 'becomes' a different person with respect to the practices of that activity setting.' Suggestions are made to consider the notion of habitual behaviours or dispositions by both practitioners and researchers as a component of learning (p.329).

Thomas & Brown (2007, p.8) noted:

> *Dispositions involve 'attitude or comportment' toward the world, generated through a set of practices which can be seen to be interconnected in a general way…. dispositions are not descriptions of events or practices; they are the mechanisms that engender those events or practices. In short, dispositions capture not only to what one knows but how he or she knows it; and not only the skills one has acquired, but how those skills are leveraged.*

Arguably, Gresalfi & Cobb (2006,329) say that 'this does not suggest a disregard of the content that students might encounter, rather renewed attention to the interaction between particular content and the nature of learners' mathematical engagement as a critical aspect of what students come to know and who they come to be.' Drawing on Ames & Archer, (cited in Gresalfi, 2009, p.329) they demonstrated that when the classroom is organized to emphasize relative ability, students are likely to engage in behaviours that will yield favourable judgments or avoid unfavourable judgments of their competence. 'If the classroom instead emphasizes and rewards effort, improvement, and participation, students will be more likely to believe that effort leads to success, to pursue challenging tasks, and to try harder in the face of failure,' (Ames, 1992, pp.262-263).

Several suggestions of how dispositions can be developed are proposed in the literature. Gresalfi (2009) argues that if classrooms emphasize the rewarding of effort, improvement, and participation, (above performance) learners will be more likely to believe that effort leads to success, to pursue challenging tasks, and to try harder in the face of failure. It is noted that 'if students' participation in their mathematics class is focused on getting correct answers and avoiding getting caught "not knowing", (Varenne & McDermont, 1998) they are likely to engage with the study of mathematics in limited ways,' (Gresalfi, 2009, p.329).

Kilpatrick, Swaffold, & Findell's (2001) definition of productive dispositions below resonate with the statement above (regarding "effort") in that believing that steady effort in learning mathematics pays off. 'The tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics.'

Similarly, Carr & Claxton (2002, p.14) argue that:

> *One of the key learning dispositions must surely be the inclination to take on learning (at least some) challenges where the outcome is uncertain, to persist with learning despite temporary confusion or frustration and to recover from setbacks or failures and rededicate oneself to the learning task.*

I have noted that if learners' approach is based on a quest to improve and deliberate effort to engage with content, they may be more likely to feel comfortable even in making mistakes and would be enabled to modify their thinking skills. It should be noted that key in developing dispositions is the importance of classroom practices in shaping students' engagement with specific content and what they will ultimately know and be able to do. Gresalfi (2009, p.331) shares an analysis that examines the ways in which classroom practices shape individual participation at two levels:

> (*a) As a moment by moment process through which students are presented opportunities to participate in particular ways (Greeno and Gresalfi, 2008; and*
>
> *(b) Over time, as expectations for behaviour become more stable aspects of the classroom culture (Holland et al.,., 1998; Wortham, 2004).*
>
> *At the moment-by-moment level, this interaction can be seen most easily in talk, as students and the teacher speak to one another about academic content, about themselves, and about their current work (van Langenhove & Harre, 1999).*

Gresalfi (2009, p.331) notes that when looking over longer time periods, one sees students start to be treated as certain kinds of people through the emergent participant framework of a classroom that shapes 'the ways in which students are expected, obligated, and entitled to participate with content and with others in the classroom.'

Since dispositions are thus connected with the practices promoted within a learning community, dispositions will evolve as the community practices evolve. According to Gresalfi (2009):

Dispositions shift gradually moment-by-moment over time (especially when learners are presented with more opportunities to participate in meticulous ways and over time. The potential to perform becomes enhanced and more stable towards characteristics of the classroom culture. At the moment-by-moment level, this interaction can be seen most easily in learner talk and how the learner might be disposed to act. For example, as learners and the teacher speak to one another about academic content, about themselves and about their current work. Over long time periods, learners start to be viewed as certain kind of people within the framework of their participation in the classroom that shapes deliberately the ways in which learners participate and engage with content and with others in the classroom.

Gresalfi & Cobb (2006, p.329) put it plainly that ‘learning is a process of developing dispositions, ways of beings in the world that involve ideas about, perspectives on, and engagement with information that can be seen both in moments of interaction and in more enduring patterns over time.’

Notably, dispositions are not simply qualities of individuals, and may not be made possible by classroom practices alone. ‘While classroom practice seems to make it more likely that learners’ dispositions will develop in positive ways Gresalfi (2009) declares that:

Learners build up dispositions by engaging mathematics in relation to classroom mathematical practice, and that it is the practice that offers the prospects of improving understanding. For example, classrooms that make possible for learners while engaged with content to share their mistakes, listen to and offer suggestions about others’ work and the actual content with which learners were engaging. Being able to listen and consider other points of view or other methods for solving problems also supports opportunities to better understand the substance. Learners need to be encouraged to think about proof or rationale behind why certain decisions were meaningful. This is a long time process that can happen from the beginning to the end of the school year.

Simultaneously teachers need to enquire into why some learners develop a passive, disengaged relationship with mathematics i.e. (the presence or absence of required or not required dispositions). It is argued that dispositions are not rigid but rather shift over the course of the school year through the learners’ engagement and teacher interventions conjointly shape productive dispositions for learners’ rich opportunities to learn.

As explained above, mathematical dispositions in particular, can only develop in relation to opportunities to work on mathematical content. Gresalfi (2009) explains that 'learners are able to exercise authority for mathematical meaning-making; they are expected, obligated, and entitled to explain.' The act of explaining and justifying their ideas helps students to become attuned to the opportunities to make connections between ideas (Web, 1982). This helps student to organize their understanding around the concepts. Thus, collaborative practices are seen as important to productive dispositions and conceptual understanding (Gresalfi, 2009).

Gresalfi's (2009, p. 363 - 364) view and that of other contemporary researchers specifically on the question the of dispositions development:

> *Make no absolute claims of how dispositions for learners maybe developed. She strongly suggests that 'more research is essential to expand into more comprehensive observations and understanding on the nature of learners' dispositions towards engaging mathematics.*

Her view is that:

> *Future work should vigilantly scrutinize the nature of learners' mathematical activity and whether and how this activity is supported through different curricular designs and classroom organization. For example, when constraints affect dispositions negatively, when learners are given differential access to opportunities to learn or the ways in which membership in a learning community might create conflict in engaging particular dispositions.* (Gresalfi, 2009, p. 364)

Similarly, we are cautioned to 'take into account the background of learners and that understanding learners' participation require looking beyond what an individual learner is doing to consider how that performance is made meaningful in context of the classroom,' Gresalfi, 2009, p. 365).

3.5 Reviewing Local and International instruments for researching dispositions

Searching for instruments which gather information about learner mathematical dispositions with young learners I note that they tend to involve ticking or circling pre-given options. Mathematics attitudinal research of the seventies and eighties focused on the use of scales and the Fennema-Sherman Mathematics Attitude Scales (FSMAS) published by Fennema and Sherman (1976) became widely used in the seventies, eighties and nineties (Mulhern & Rae, 1998). Attitudinal items such as ‘I see mathematics as a subject that I will rarely use in daily life as an adult’ (see Mulhern & Ray, 1998, p.302) which must be completed on a scale of 1-7 however did not seem appropriate for young learners who are unlikely to be used to working with such instruments. The Chair project team thus searched for instruments more appropriate for young learners and piloted these. For example they piloted instruments which involved circling pictures and locating themselves on a learning tree (see Graven, Hewana & Stott, 2013).

Since these instruments provided little data on learner dispositions a new open-ended instrument was designed and following some post piloting additions of questions was finalized as given in *Figure* 1 in Chapter 1 above.

The instrument was purposefully open ended but allowed for key elements of a ‘productive disposition’ to emerge. Thus we asked learners, for example, open ended complete the sentence items such as, ‘Maths is …’ in order to see whether they see mathematics as a meaningful activity; we asked them to indicate where they saw themselves on a scale of one to nine learners to see how they see themselves as a mathematics learner, and we asked them to describe a ‘strong’ mathematics student (with complete the sentence ‘Mpho is…’) in order to see whether they saw strength in mathematics as an innate ability, as teacher dependent or dependent on ‘steady effort’ and work. Learners were asked to respond to situations of ‘not knowing an answer’ in order to access how they say they would act in such situations. The instrument’s referral to others (even while learners often followed descriptions of Sam or Mpho with “I am…’) aimed at enabling a ‘safe’ and less personal space where learners could articulate their views. The names Mpho and Sam were deliberately chosen to enable the interpretation of both male and female genders. Additionally the complete the sentence items relate to being scared of and loving mathematics respectively. The final question on this instrument was added to provide data about what learners *do* if they don’t know an answer in class. In this respect the question is different from the other questions in that it is the only question that aims to get at learner dispositions in terms of learner stated actions (Graven, Hewana & Stott, 2013).

The instrument was piloted with six learners in the club that I am conducting my research in. The data across the learners indicated that none of the learners drew on their own resources for suggesting a way forward when they did not know an answer thus the responses indicated either ‘ask your teacher’ (5/6) or ‘ask a friend’ (1/6) (Graven, Hewana, Stott, 2013). While several limitations are acknowledged as to the value of such an instrument (Graven, Hewana & Stott, 2013), particularly when used as a written instrument administered to whole classes of learners, the instrument still yielded themes of learner dispositions and particularly fore-grounded the absence of several aspects of productive disposition such as resilience.

Thus, given that the piloting process indicated rich data emerging from the use of this instrument as an interview I decided to use this instrument to gather data over time on my four case study learners in the club. However this only provided data on what learners say not how they act. Lahire's (2003) notion that beliefs do not automatically produce action nor do they define a habit to act meant that it was critically important for me to find an instrument that could support me in gathering observational data of learner dispositions when actively involved in mathematics. At this point Carr and Claxton's (2002) work became particularly useful for my observational part of my study.

3.6 Three dimensions for observing learning dispositions

To help explore the notion of productive disposition is to populate Carr and Claxton's (2002, p. 30) learning disposition grid with three dimensions and an axis of dimensions of strength labelled sophistication and robustness. Concomitantly, one of the considerations in designing methods for tracking and assessing the development of these dispositions must be the extent to which the 'testing' situation itself affords or invites the expression of the dispositions in question. However they leave it open for teachers and researchers to fill in the indicators (based on research) for this grid. 'We have favoured the ones which seem to us to be at a suitably intermediate level of generality; relatively independent of each other; commonly afforded by educational setting; and Useful from the point of view of exploring the assessment question'. These are the dispositions Carr and Claxton (2002, p. 13-14) refer to below as: (i) Resilience; (ii) Playfulness; and (iii) Reciprocity. The following discussion focuses on each of these dispositions as debated in the literature consulted.

3.6.1 Resilience

Arguably one of the key learning dispositions is the inclination to take on learning challenges where the outcome is uncertain, to persist with learning despite temporary confusion or frustration and to recover from setbacks or failure and rededicate oneself to the learning task. Nicholls (1984, pp. 328-346) suggest that:

> *people who believe that experiencing difficulty is a reflection of a generally or innately low level of 'ability' tend to select less challenging learning situations and to become*

defensive much more quickly in the face of frustration than those who believe that through effort it is possible for them to develop their learning muscle.

Dweck, (1991) and others have identified resilience as a central characteristic of those with ‘learning’ (Dweck, 1991), ‘mastery’ (Ames, 1992) or ‘task-involvement’ (Nicholls, 1984) goals, as opposed to ‘performance’ or ‘ego involvement’ goals. Kagan (1994) has also shown marked differences in the resilience of children of little more than a year old, for example, which cannot be satisfactorily accounted for on the basis of heredity, while Smiley & Dweck (1994) have shown that many four year olds are sacrificing valuable learning opportunities in order to ‘look good’ [i.e. they give an expression as if they know when they don’t – they will put up a hand and answer incomprehensibly]. The opposite disposition to reliance [we] (Carr & Claxton, 2002, p. 14) might call ‘brittleness’:

A tendency to get upset at the first sign of difficulty and to shift from ‘learning mode’ into a defensive, self-protective stance. The key indicators of resilience might be taken to be: sticking with the difficult learning task; having a relatively high tolerance for frustration without getting upset; being able to recover from setbacks or disappointment relatively quickly.

In our after school maths club sessions the SANC project strives to see that all participants in the Chair schools progress to a level where we can observe their capacity of logic thinking, reflecting, mathematizing and justifying their responses. We encourage and try to develop ability to formulate, represent, and solve mathematical problems, comprehension of mathematical concepts, operations, and relations, and skills in carrying out procedures flexibly, accurately, efficiently and appropriately.

I should stress that it is not the focus in the maths clubs to look for the right answers instead facilitator seek to improving learners’ sense making in maths and we expect that they become more maths engagers who are unruffled by making mistakes instead learn to review their thinking. This is supported by Gresalfi and Cobb, (2006, p.8) their observation is that dispositions capture not only to what one knows but how he/she knows it; and not only the skills one has acquired, but how those skills are leveraged.

3.6.2 Playfulness

Drawing on Langer’s notion of playfulness, (cited in Carr & Claxton, 2002, p.14)

> *being playful in the present context means being ready, willing and able to perceive or construct variations on learning situations and thus to be more creative in interpreting and reacting to problems. In their current conceptualization they identify three types of playfulness, which they refer to as mindfulness, imagination, and experimentation. They state that Mindfulness is a kind of perceptual openness which relies upon inclination to notice the unfamiliar or to read the situation in different ways.*

Contrary to mindfulness, is mindlessness (Langer & Piper, (1987) Langer & Piper explain that 'It is the inclination to see only in terms of familiar categories and details that are incidental to the process of categorisation or inconvenient to it. Mindlessness is marked by a rigid use of information during which the individual is not aware of its potential novel aspects, whereas, mindfulness is characterised by active distinction-making and differentiation' (Langer & Piper, 1987, p.280). Similarly Carr and Claxton (2002) refer to experimentation as the ability to play with or explore physical material and condition so as to discover their latent properties and possibilities. Often just 'messing about', without a clear goal or purpose, reveals new affordances and thus makes both new means and new goals possible [What one might want to do emerge from an open-minded exploration of what one can do]. 'The opposite of being practically playful in this way we might call being *conventional*, or suffering from what Maier famously called *functional fixedness*, i.e. 'seeing only familiar uses for objects and being unable to shift categories when it might be used to do so' (Carr & Claxton 2002, p.15).

Lieberman (1977, p.4) in her study of playfulness identifies the disposition in terms of 'physical, social and cognitive spontaneity, a sense of humour and a kind of joyful, exuberance or even mischievous attitude, a glint in the eye'. Since Carr & Claxton's (2002) work was in an Early Childhood Education context the notion of playfulness was more appropriate than resourcefulness. However at Grade 4 level it would seem that the resourcefulness aspect of playfulness is critical and thus from here on I will refer to resourcefulness for the dimension of playfulness.

3.6.3 Reciprocity

On their third illustrative learning disposition, Carr & Claxton (2002, p. 15-16) assert '[we] call 'reciprocity', and this term embraces a number of more specific variants. The most valuable learning resources, especially for the young, are of course, other people.' Carr and Claxton (2002, p. 15) suggest that:

> *Those who lack the awareness to articulate their own learning processes and problems, the ability to communicate these to others or the inclination or the courage to do so are inevitably handicapped as learners. Bronfenbrenner, 1979, p.192 make a claim that 'reciprocity' to us has both expressive and receptive and verbal and non-verbal dimensions. We assume that effective learners need the confidence and inclination to give opinions and contribute ideas through any or several of a range of communicative and expressive means.*

Thus, work needs to be done for such an instrument to become operational. Bronfenbrenner describes 'educational competence', for example, in terms of disposition 'to think, to persist in tasks, to give opinions and contribute ideas and to work collaboratively.' On the other hand, Goleman (1996, p. 193) lists what he describes as 'the seven key ingredients for the capacity to know how to learn.' This comprises disposition-like terms such as 'confidence, curiosity, intentionality, self-control, relatedness, communication and cooperation.'

Carr & Claxton (2002, p.15) supported by others argue that not all dispositions are equally relevant to learning power.

> *The inclination to be bossy, for example, is probably less crucial to learning in general than the tendency to persist with learning in the face of confusion or frustration. In part, the way the learners respond depend on the practices and intentions of people who maybe framing learners' environment and on the opportunities to deploy a particular disposition and thus discover its value. For instance, some environments 'afford' and encourage the deployment of playfulness or persistence, for example; others do not. Learning to learn has been shown to flourish in the context of 'reciprocal and responsive' relationship,* (Carr & Claxton, 1998, p. 2); *with others and this requires a willingness and an ability, on both sides for 'joint attention'* (Moore & Dunham, 1995; Smith, 1999), *participation* (Rogoff, 1990, 1997; Kantor et al., 1992) *and taking account of the opinion and needs of others.*

Thus Carr & Claxton, (2002) argue that different classroom practices create different opportunities for students to learn to work together, construct knowledge, and construct perceptions of themselves as meaning makers. They say that 'the opposite side of reciprocity is a kind of 'epistemic solipsism' in which the existence of others, both as resources and as learning partners with need and goals of their own, is ignored,(p.16).

Carr & Claxton’s (2002) work draws on Early Childhood Education as its context and thus talks of learning dispositions in general. However Kilpatrick, Swaffold & Findell’s (2001) definition of a productive disposition is mathematics specific. There are some overlaps in their work but also each provides aspects which the other overlooks. In the next section I draw on the broader Chair project work of bringing these together in order to find a way of using them both to research learner evolving dispositions across various contexts.

3.7 Bringing together Kilpatrick et al.’s 2001 indicators of *Productive Disposition* with Carr & Claxton’s (2002) three dimensions of ‘Resilience, Playfulness and Reciprocity’

Within the broader Chair project work on dispositions we have collaboratively worked towards combining the work of Carr and Claxton (2002) with the notion of productive dispositions and designed rubrics and observational grids that pull these together for the purposes of analysis. These combined instruments will be discussed in the methodology chapter that follows, however here I explain their similarities and differences as developed by our Chair team in working discussions.

In Table 2 below I map resourcefulness and resilience onto Kilpatrick et al.’s (2001) definition:

Table 2: *Cross mapping dispositional indicators within definitions*

Kilpatrick et al.'s (2001) indicators of a productive disposition	**Carr & Claxton's (2002) 3 dimensions of disposition**
Tendency to see sense in maths	Links to 'resourcefulness' – conceptual/explorative understanding
Perceive it as both useful and worthwhile	not connected – no equivalent in Carr and Claxton's three dimensions
Believe steady effort pays off	Links to resilience
See oneself as effective and doer of maths	Links to some extent to resourcefulness however the notion of self-efficacy is not directly addressed in Carr and Claxton
No indication of willingness to engage with others as an indicator of a productive disposition	Reciprocity – willingness to engage with others

Later when analysing data additional indicators have been added to the above table.

From the above 'reciprocity' (the third dimension of Carr and Claxton) is notably absent from Kilpatrick et al.'s (2001) definition. Conversely there is no link to the notion of seeing mathematics as useful and worthwhile in Carr & Claxton's 3 dimensions- maybe because their suggested grid is not subject specific however a positive attitude towards an area of learning could be a fourth dimension.

Resourcefulness links directly with sense making, conceptual understanding, adaptive reasoning, strategy (strategic competence etc.) and independence of learning in seeing that one can figure it out drawing on one's own thinking.

While actively seeking help might be considered resourceful it is not placed here as it goes against this sense of resourcefulness in terms of one's own ability. Additionally 'enjoyment or passion' - enthusiasm/creativity both are missing (Leonie 2010, Graven & Schafer, forthcoming). For the purposes of this research I have included this aspect as a dimension of strength to resilience, playfulness and reciprocity (when indicators are present). This differs from Carr & Claxton's (2002) dimensions of strength as robustness and sophistication. However since these emerged as more visible in the data I have opted rather for this. (Discussed in the data analysis chapter below) [That is if indicators of passion and enthusiasm such as jumping up, dancing when sharing 'aha moments' and indicators of excitement are present then this strengthens the indicator].

3.8 Concluding remarks

Relating to the limitations cited above, this study suggests Carr & Claxton's (2002) learning disposition matrix framework to investigate and access learner's mathematical productive dispositions. They proposed an oral interview administered instrument and leave the criteria for indicators in the grid completely open for mathematics teachers to fill and find maths indicators task based and relevant for the grid Carr & Claxton (2002) offer an example of a composite assessment format within a matrix framework (see *figure.* 1) for the evaluation of the potential of activities or situations. They explain that:

> *There are two axes on the matrix: dispositions (resilience, playfulness and reciprocity, our present example of learning dispositions) and dimensions of dimension of strength (sophistication and robustness). The teacher collects exemplars of positions that can be along a five point scale, from 1, 'the disposition is absent', to 5, the appearance of dispositions which are so robust and sophisticated, they have become such as a pervasive part of person's 'being' as a learner, that the learner in effect functions as a role model of that disposition for others.* [They stress that] *'indicators and exemplars are not the same thing, although indicators can be treated as exemplars rather than as a prescriptive scheme. (*Carr & Claxton 2002, p. 29).

Developing this instrument proposed by Carr & Claxton (2002, p. 30) for assessing and accessing dispositions of learners further and populating such a grid is a challenge for teachers, especially, when it has to be based on research. Indeed, this is what fascinates me in this study and hope to contribute towards.

Chapter 4

Methodology

4.1 Introduction

In the previous chapter, I talked about researching dispositions and identifying a gap in research literature, the evolving productive dispositions, the relationship between dispositions and the practices of the learning community and among others the need for designing an instrument for assessing and accessing dispositions for observation. In this chapter, I present my research approach and the various methods used to gather data. In doing so, I have drawn, among others, on Cohen, Manion and Morrison (2005, p.79) regarding the ability of revealing reality they suggest that one has 'to present and represent reality – to give a sense of 'being there', and an in-depths, detailed data from wide data source and to catch the complexity and situatedness of behaviour.' Additionally, Hammersley (cited in Cohen et al., 2005, p. 107) declare that 'our accounts will only be representations of that reality rather than reproductions of it.'

4.2 Research Approach and Orientation

Maxwell (1992, p.235) argues that 'whenever you have a choice about when and where to observe, whom to talk to, or what information sources to focus on, you are faced with a sampling decision. Even a single case study involves a choice of this case rather than others, as well as requiring sampling decisions within the case itself.' Miles and Huberman (1994, pp. 27–34) and LeCompte and Preissle (1993, pp. 56–85) provide valuable discussions of particular sampling issues used in this study.

The theoretical framing of this enquiry points to a qualitative interpretive study with occasional quantification. This study sets out to illustrate the extent to which a phenomenon might recur in the data. Merriam (1998) notes several characteristics common to all forms of qualitative research. These include: the researcher is the primary instrument for data collection and analysis; it usually involves fieldwork; it primarily employs an inductive research strategy; typically research findings are in the form of themes, categories, typologies, concepts, tentative hypotheses and theory, and as importantly, the research product is richly descriptive. She adds that the design is flexible and emergent and that sample selection is usually non-random, purposeful and small. Each of the above is a characteristic that apply to my research study.

Within this qualitative approach I chose this case study approach because such an approach would provide an in-depth rich detailed data that would enable me: to portray [and using] Cohen, Manion & Morrison's 2005, p79) notions of 'thick description' so that:

> *The quality of a piece of research not only stands or falls by the appropriateness of methodology and instrumentation but also by the suitability of the sampling strategy that has been adopted (see also Morrison, 1993: 112-17). Questions of sampling arise directly out of the issue of defining the population on which the researcher will focus on.*

4.3 Piloting

According to Maxwell, (1992):

> *Pilot studies serve some of the same functions as prior research, but they can be focused more precisely on your own concerns and theories. You can design pilot studies specifically to test your ideas or methods and explore their implications, or to inductively develop grounded theory. One particular use that pilot studies have in qualitative research is to generate an understanding of the concepts and theories held by the people you are studying—what I have called "interpretation"* (Maxwell, 1992, P.227).

As a Masters fellow working within the SA Numeracy Chair projects, I had the opportunity to pilot how I might gather observational data. I video recorded a club session run by a mentor and had the opportunity to watch the video several times in order to consider logistical arrangements for gathering data as well as tentative indicators for populating the Carr and Claxton (2002) disposition grid. From this, I realised that three categories proposed in the grid are useful for gathering dispositional data. I also realised that it is difficult to gather good transcribable data in large clubs or classroom situations. Therefore, two video cameras would at most be able to gather quality data from six students (each camera positioned to record participation of three learners). The maths clubs consist of between six to twelve learners and so I selected a club with six learners for my study. Additionally as discussed above I administered the Chair Productive disposition instrument to whole classes across Chair project schools. As indicated in the rationale, through this process I realised that the written productive disposition instrument is limited and I thus adapt it in this study as an individually administered interview.

4.4 Selecting the cases (sampling)

As explained in the context of this study in Chapter 1, the South African Numeracy Chair at Rhodes is one of the two national chairs focussing on numeracy in the primary schools, because of the recognition that numeracy interventions need to begin much earlier in schooling. The Rhodes Chair projects established a research program that partnered with numeracy teachers (ranging from grade 0 to grade 6) in 12 local schools in the broader Grahamstown area to work towards the improvement of numeracy teaching and learning. In addition the project established after school mathematics clubs in several schools. As explained in Chapter 1, a central aim of the maths clubs is to develop learner sense making, shifting learner dispositions from being passive learners to becoming active participators. At the time of writing this thesis the Chair had established 7 after-school mathematics clubs in the broader Grahamstown area, ranging in size from 6 to 12 students each.

Our sample is located in one of these after school clubs in Grahamstown in the Eastern Cape in the Makana Municipality. Our club maths sessions were conducted here weekly after school and last for 1 hour. The medium of instruction at the schools is Afrikaans for some and English for others as learners in this club are from 3 different schools. The club runs at a non-profit after school care centre. This is the smallest maths club in the whole project with six participants of 3 boys and 3 girls. For convenience purposes I chose to focus on the most regular club attendees who come to this centre on a daily basis after school for their meals and unlike others who leave school for home. My focus was on these 3 learners (all 10 years old i.e. Saki a boy, Jade and Nandi 2 girls).

To enable transcription of club sessions, I selected this smallest maths club to constitute my empirical field. Thus the learners in the club were thus an opportunity sample as they were in Grade 4 attending the club rather than a selection of learners.

4.5 Learner stories

I have drawn on Carr & Claxton (2002), Sfard and Prusak (2005,) and Heyd-Metzuyanim & Sfard's (2012) notions of learner stories both for the gathering of data on learner dispositions portfolios (LDP) and in the data analysis that follows.

Carr and Claxton (2002) explain that 'Learning stories' were originally developed as an assessment tool for use in the New Zealand early childhood education. They describe learner stories as follows:

> *Learning stories are structured observations in everyday or 'authentic' settings, designed to provide a cumulative series of qualitative snapshots or written vignettes of individual children displaying one or more of the target learning dispositions. (Claxton & Carr, 2002, p.22)*

Drawing on Carr & Claxton, (2002) their approach was to translate the different learning dispositions on their list into 'observable actions', such as 'taking an interest', 'being involved', 'persisting with difficulty', 'expressing and idea or a feeling' and 'taking responsibility or another point of view.'

> *Practitioners collect 'critical incidents' that highlight one or more of these dispositions and a series of learning stories over time, for a particular child, can be put together and scanned for what Carr has called 'emerging learning narratives' what we might call, in the present context, 'developmental trajectories' of learning dispositions.* (Claxton & Carr, 2002, p.22)

They add that: 'learning stories, unlike experimental challenges, can retain the richness, complexity, and interdependence of events and actions in the real classroom' (Salomon, 1991, p.16)'

Sfard and Prusak (2005, 16) distinguish between first person and second person stories. In this study I rely on both first & second person stories. Heyd-Metzuyanim and Sfard (2012, p. 2) introduced a new set of conceptual tools for studying identifying talk, in mathematical learning situations, namely two concurrent processes: mathematizing (talking about mathematical objects) and subjectifying (talk about the participants of the discourse). These can be done by both learners and teachers/researchers. Heyd-Metzuyanim (2013, pp.51-52 & 128-145) stress that 'teacher-learner talk' is vital and should be deliberately focused on to build and shape the learner's self-confidence and identity. Thus mentor-learner talk will be a key focus of my club observations and analysis of transcripts.

4.6 Data Collection Tools

The data collection tools that will together inform the learner stories include:

1. Individual interviews with learners [at the start and at the end of the term]

2. Video recordings of learners participating in club sessions [all club sessions in the first term- approximately 8 sessions]
3. Researcher field notes and Reflective Journal
4. Interview with club mentor on the learner dispositions [towards the start and at the end of the term].

Additionally, I recorded 'qualitative snapshots or written vignettes' (Carr & Claxton, 2002. p. 22) of key dispositions or critical incidents from each club session. The reflective journals allowed me to record the insights into the nature of emergent productive dispositions within the clubs.

Each of the above data collection tools are discussed below:

1. Individual interviews with three club members

Interviews with three club members were conducted at the beginning of the period of the study (May 2012) and in (November 2012) and again in (May 2013). [A final interview in November 2013 but that one falls outside the study]. These interviews used the Productive Disposition Chair Instrument. The first interviews were administered with the facilitator reading out the questions and the students wrote out their responses. But the subsequent interviews were administered as an interview only with the facilitator writing down the responses. The change in the method was because it was found that asking the student to write down answers took a long time, and writing answers was an unnecessary challenge given the objective of the study.

2. Video recordings of learners participating in club sessions [all club sessions in the first term- approximately 8 sessions]

I made use of video recordings (two video cameras positioned to capture participation of 3 learners each) to gather data of learner participation in club sessions. These were transcribed for analysis. Inter alia material for 'critical incidents' are sourced from these videos as also from other sources.

3. Researcher field notes and Reflective Journal

I recorded 'qualitative snapshots or written vignettes' (Carr & Claxton, 2002. p. 22) of key dispositions or critical incidents following each club session. The reflective journals allowed me to record the insights into the nature of emergent productive disposition within the clubs.

Field notes were used to record specific events and observable data related to the nature of learner participation.

4. Interview with club mentors on the learner dispositions.

These interviews aimed to capture the more impressionistic judgements made by those who had experience of learners over a period of time (Carr & Claxton, 2002, p. 23-24). Thus, I interviewed the mentor to gather her insights on individual learner stories and their learning dispositions.

5. The Wright et al., (2006) Instrument

a) Prior to the commencement of this study the team at the Chair administered The Wright et al., Instrument to test mathematics fluency of 614 Grade 3 and Grade 4 students in all 12 of the Chair's participating schools in the Grahamstown area. The results of which were analysed by the team at the Chair. This assisted in the planning of the subsequent set of programs based in part on insights into strengths and weaknesses.

b) The completed Wright et al., (2006) Instruments responses of the children in the study sample were extracted and used as background for the study sample and in its analysis. Furthermore the Wright et al., (2006) Instrument was administered a number of times to the club sample during the study.

4.7 Validity

Maxwell (1992) views validity as the key issue in debate over the legitimacy of qualitative research. Cohen, Manion & Morrison (2005, p. 105) declare that:

> *Validity is an important key to effective research……. Whilst earlier versions of validity were based on the view that it was essentially a demonstration that a particular instrument in fact measures what it purports to measure. More recently validity has taken many forms. For example, in qualitative data validity might be addressed through the honesty, depth, richness and scope of the data achieved, the participants approached, the extent of triangulation and the disinterestedness or objectivity of the researcher.*

This research will employ multiple strategies, collecting rich data over an extended period of time to ensure and enhance validity and reliability of the data.

- Long-term involvement (1 year) and continuous gathering of data over this period.

- Intensive interviews using carefully designed instruments will enable me to collect 'rich' data, data that are detailed and varied enough that they provide a full and revealing picture of what is going on.
- Detailed observation of many examples (8 video maths club sessions involving the same 3 participants over 6 months)

According to Becker, (1970, p. 51) *'Rich data'*, both long-term involvement and intensive interviews allowed me to collect "rich" data, data that are detailed and varied enough that they provide a full and revealing picture of what is going on as explained in chapter 4. In interview studies, such data generally require verbatim transcripts of the interviews, not just notes on what you felt was significant. For observation, I used Becker's notion of rich data as the product of detailed, descriptive note-taking (or videotaping and transcribing) of the specific, concrete events that I observed.' Drawing on Becker (1970, p. 50), in this study, such data will respond to the dangers of observer bias. On the other hand, McMillan and Schumacher (2001, p.407) state, that 'validity in qualitative research is the degree to which the interpretation and concept have mutual meaning between the participants and the researchers.' Responded validation, according to Bryman, Lincoln & Guba (cited in Maxwell, 1992, p.224) 'are "member-checks" which involve getting systematic feedback on data and conclusions from the people studies.' While this is an important way of ruling out the possibilities of misinterpreting the meaning of what participants say and do this will not be appropriate for the young learners in the club to do member-checks. However I requested that the club mentor checks my transcripts of club sessions and engages with my analysis and that she checks the transcript and analysis of the interviews that I conducted with her.
I used the triangulation [the so called 'common method'] to ensure agreement between different sources and methods of information. Thus I collected information from a diverse range of individuals and settings, using a variety of methods to seek corroboration of the information gathered. I have compared and cross-checked my analysis from my video recorded and transcribed observations, transcribed interviews, reflective journals and field notes, including transcribed mentor interviews. This strategy reduces the risk of systematic biases due to a specific method and allows a better assessment of the generality of the explanations that one develops.

It is argued that reliability generally refers to the extent to which research findings can be replicated. However, Merriam's (1998) view is that reliability is problematic in the social sciences simply because human behaviour is never static (p.205). The argument is presented that the notion of reliability is rooted in quantitative and positivist research traditions and that in some studies reliability has been interpreted to refer to the degree of consistency with which different observers assign the same category to data (Hammersley, 1992, 50-1). However, Adler in Graven (2002) argues that since categories are a discovery it is unreasonable to expect others to discover the same category as the researcher and thus she argues, reliabilities should establish to which extent these already discovered categories are recognisable to others.

In this respect I have drawn on my supervisor and research colleagues to look at the same data according to those categories and to see whether the categories and indicators within them are recognisable to others in the data. As suggested by Cohen, Manion and Morrison above (2005) I will strive to minimize invalidity and maximise validity.

4.8 Ethics

Hitchcock and Hughes, cited in Cohen, Manion and Morrison (2005, p. 56) in terms of ethics declare that,

> *On other occasions it may be better for the teachers to develop a pilot study and uncover some of the problems in advance of the research proper. If it appears that the research is going to come into conflict with aspects of the school policy, management styles, or individual personalities, it is better to confront the issues head on, consult relevant parties, and make rearrangements in the research design where possible.*

The SA Numeracy Chair (Rhodes University) has already been granted permission by the Eastern Cape Department of Education to conduct research into selected after school maths clubs in the Grahamstown district. This club took place in an afterschool centre that cares for learners from three schools in the Grahamstown area. As such permission was obtained from the directors at the centre and letters were sent to parents explaining the research and asking for their signed permission for their learners to participate. It was made clear to learners and parents that participation was entirely voluntary and that learners could withdraw at any time. Data was kept under lock and key and children's names have been changed and pseudonyms given. Furthermore, where photographs of the learners have been used in this reporting, faces have been blurred, so as to ensure learner anonymity.

Additionally I ensured that my presence in the club was not intrusive and kept the camera in the corner. The learners in the club were particularly lively and aside from some initial smiling or face pulling at the camera didn't seem to notice it as the sessions rolled on. Learners in the club were friendly and would chat openly at the start of sessions which allowed for a good comfortable relationship to develop between myself and the learners. Interviews were conducted by the club facilitator so as to maintain continuity and I videoed and transcribed these.

4.9 Limitations

The limitations to this study might be that some of the explanations and interview responses were in Afrikaans and isiXhosa (the learners' vernacular) and while I speak these languages there is a risk that some information might get lost through the process of translation. Cautiousness was applied in the process and my supervisor and research colleagues were drawn on to check translations. The second limitation is that, as with all case studies of research, it is not possible to generalize the findings across all after school maths clubs.

Many qualitative researchers struggle with the notion of generalizability. Some argue that generalizability is not central to qualitative research because it is inappropriate (Adler, 1996). Consequently, some South African educators argue that rather than looking for generalizability in research one should focus instead on its generativity (Adler, 1996). That is, to what extent does the language of description and the themes, which emerge from the study, generate further research questions and provide explanatory models. In this respect the generativity of this study needs to be considered in relation to the extent to which the themes, issues illuminated and language of description used might inform and stimulate debate in exploring learner mathematical dispositions further.

4.10 Method of Data Analysis

Data analysis is a process that involves the coding, categories, concepts mapping and themes generated. A basic principle of qualitative research is that data analysis should be conducted simultaneously with data collection (Coffey & Atkinson, 1996). This allowed me to progressively focus my interviews and the observations enabled me to assess my emerging findings. By means of Merriam's (1998) notion, I conducted simultaneous data collection and analysis for generating categories and building theories. By doing so I was able 'to uphold focus, be aware of logical patterns and themes correlated to my frameworks and data collection technique allowed flexible modifications of any surfacing themes.'

In analysing my data from the interviews recurring themes in learner responses were captured. In analysing observations of learner dispositions in relation to how learners responded to task based questions and how learners participate in the clubs I used a populated version of Carr and Claxton's (2002, p.30) disposition grid. This enabled me to generate data from three key sources such as: what learners say, what the mentor says and what learners do and I was then able to analyse across these sources for consistencies and discrepancies. I discussed these analytical tools in chapter 3 above.

Chapter 5

Analysing learner dispositions over time

Contextual Background of learners

I begin this chapter by providing a brief background of the sample of learners including their mathematical fluency levels. All three learners were participants in one of the after school maths clubs run by the SANC Project in the broader Grahamstown area. The learners attend local schools. Learners were intentionally selected to have a range of numeracy levels at the start of their participation in the project and from both genders.

Part 1: Mathematical Proficiency Levels

At the start of the project **Saki,** a 10 year old boy was particularly weak at numeracy and very dependent on fingers and one to one counting even for small additions. Saki came from a school class where the medium of instruction was Afrikaans (his home language). **Jade** a 10 year-old girl was at the start of the program quite weak in basic numeracy skills and also reliant on using her fingers for counting, although with greater speed than Saki. She was however able to not use fingers for some smaller numbers or bonds to ten. **Nandi** also 10 years old was the strongest learner in the club at the beginning of the program and she showed ability to add and subtract ten from numbers without the need for fingers. From the Wright et al.'s (2006) test of maths proficiency administered to Nandi in May 2012, she was fluent in both English and Afrikaans when talking about numbers, counted back in 10's and used pattern strategies to for example, separating piles by colour, and saw patterns of 10. When asked to subtract 15 from 42 she adopted a strategy of drawing 42 small circles on the page and then crossing out 15 (See Appendix B for her working out). This showed an understanding of the concept of subtraction objects even while her working required concrete representation indicating that she had not yet fully abstracted the concept. Saki and Jade, were seldom absent from the club while Nandi was occasionally absent. Attendance depended on whether they were at the after school Centre on that day or not.

A vast range of data (including: timed fluency assessments, the Wright et al.'s (2006) instrument involving one to one interviews, and basic operations assessments) was collected by the club facilitator on these learners between May 2012 and May 2013.

Reviewing this data indicates similar levels of proficiency across instruments and similar progress over time for the three learners across instruments. For this reason I have chosen to focus my background of learners' mathematical proficiency levels on the data gathered in the timed fluency assessments as these are most simply summarized and easily communicated. The 'timed fluency tests' are given (See Appendix B) and have been reported on by club facilitators (see Stott & Graven, 2013). They assess a limited range of what Askew et al. (2006) refers to as 'basic number facts': adding and subtracting numbers below 10; doubling numbers and adding and subtracting 10 to numbers between 0-1000. Learners were given one minute to complete as many sums as possible. Each grid had several possible sums (See Appendix B) that learners had to answer in a minute.

Table 3 below gives a summary of learner fluency and progress over time as indicated by these assessments:

Table 3 *Summary of learner proficiency scores.*

Learner	Questions	Number of sums answered correctly in Feb 2012	Number of sums answered correctly in Mar 2013	Number Possible sums
Saki	+ and - (1 + 1 minute)	0	1	48 + 48
	Doubling 1 minute	2	2	17
	+ 10 and – 10 (1 + 1 Minute)	0	4	20 + 20
Saki's Total in 5 minutes		2	7	153
Jade	+ and _	3	15	48 + 48
	Doubling	5	2[1]	17
	+ 10 and – 10	2	6	20 + 20
Jade's Total in 5 minutes		10	23	153
Nandi	+ and -	15	37	48 + 48
	Doubling	11	11	17
	+ 10 and – 10	3	13	20+20
Nandi's Total in 5 minutes		29	61	153
Total for all 3 learners		41	91	

[1] While Jade's score on the doubling goes down here it was due to her displaying stress when writing the timed test and so the facilitator paused and chatted to her about the purpose of the test and explained that it was not a competition with the other learners but rather to see whether she had improved at all on her earlier scores. However this meant that Jade did not use her full minute for this doubling item.

From this table we can see the number of sums answered correctly more than doubled (from 41 to 91) for the 3 learners together.

From these scores the relative proficiency of the three learners, as indicated by the facilitator and which influenced the choice of learners, is evident. Thus Saki is by far the weakest indicating constantly poor skills. Although there is some improvement for Saki over time this improvement still indicates a dependence on concrete counting which slows him down and enables him to only answer a few questions in the given minute. Jade has limited proficiency although this improves various aspects and she is able to answer more questions as her methods are not always dependent on concrete counting. Nandi shows some proficiency from beginning particularly in her ability to add and subtract ten as she did not depend on counting up or down but noted patterns for answering this and was thus able to answer many more.

Part 2: Exploring Learning Dispositions communicated via the Productive Disposition Instruments interviews

Introduction:

In this part I summarize and discuss the responses of the learners to the productive disposition instrument (PD Instrument) discussed above administered in May 2012 (as an orally administered but written response questionnaire and again in 2013 (as an interview). Thus in May 2012 learners wrote their responses, in 2013 we wrote down the responses from the children to the oral questions put to them. (See Appendix C for an example of: a May 2012 learner written response and a May 2013 facilitator notes of learner responses to her interview questions of the PD instrument.

The Three Interviews

The tables below lists the four indicators present in Kilpatrick et al.'s (2001) definition of a productive disposition (viz. effective learner and doer of mathematics; seeing mathematics as useful and worthwhile; sense making; steady effort) and in some cases matched or supplemented with two of Carr & Claxton's three dimensions of a learning disposition (viz. resilience; reciprocity). Plus I have added four new categories that make more explicit certain disposition elements.

I incorporated Carr & Claxton's (2002) concept of 'playfulness' under the slightly broader category of resourcefulness which they saw as a disposition where a learner takes chances, risks even if she/he does not know the answer, tries new things; thinking of the box. This is because this kind of exploring goes beyond the circumstances suggested by play.

These new aspects include learners' affective relationship to mathematics, learners 'compliance' with expected norms and learners ability to describe it. Learners provided utterances which indicated their relationship to mathematics, and their willingness to participate in relation to 'compliant norms' (e.g. listen to teacher, ask teacher if don't know) and their ability to explain *what maths is* and these responses seemed to be more positive and richer one year later. It also seemed reasonable to expect that a positive like or love of mathematics and an ability to describe it would be indicative of a more positive disposition to the subject than a dislike and inability to describe any related activities (e.g. simply say maths is: 'maths')

Learner responses to the five items on the instruments: (i.e.)

- Maths is….
- Effective scale (Range 1-9)
- Describe an effective learner – Mpho is…
- Do you love maths or are you scared of maths?
- What do you do if you don't know an answer in a maths class?

are recorded in the tables below against indicators that learner responses related to. Thus learner responses to items relate to different dispositional aspects depending on his/her responses.

5.3.1 Summary stories of disposition questionnaire and interview

Here below are three summary tables of Saki, Jade and Nandi's responses and how they relate to several dispositions indicators. Translations into English are given in brackets.

Note: The learners spelling errors have been maintained in the typing of learners written responses.

Legend for literature that indicators relate to: Kilpatrick (2001) = (K); Carr & Claxton (2002) =(C&C); Own Categories = (O); Heyd-Metzuyanim (2013) = (H)

Table 4: *Summary of Saki's learning disposition.*

Indicator	*Questionnaire instrument item*	May 2012	May 2013
Effective learner and doer of mathematics (K)	*Scale 1-9 (Q2)*	9	9
seeing mathematics as useful and worthwhile (K)	*Maths is: (Q1)*	Die beste (the best)	goed om te leer (good to learn) want dit help (because it helps) it makes you clever
sense making (K) resourcefulness (O) (which includes what Carr & Claxton call playfulness (C&C)	*Maths is: (Q1)*		
	What do you do if you don't know the answer in maths class? (Q6)	Ek vra die juffvrou om te help (I ask the teacher to help)	vra die juffrou, (ask the teacher) tel op my hande (count on my hands) , tel op die tel-kaart (count on the counting card)
steady effort (K) resilience (C&C)	*Describe an effective learner of mathematics (Q4)*		
	What do you do if you don't know the answer in maths class? (Q6)	Ek vra die juffvrou om te help (I ask the teacher to help)	tel op my hande (count on my hands) , tel op die telkaart (count on the counting card)
reciprocity (C&C)	*No question*		
compliant behavior (O)	*Describe an effective learner of mathematics (Q4)*		luister na die juvrou (listens to the teacher) hy doen goed want hy wen want hy luister (he does well because he wins because he listens).
	What do you do if you don't know the answer in maths class? (Q6)	Ek vra die juffvrou om te help (I ask the teacher to help)	vra die juffrou, (ask the teacher) tel op my hande (count on my hands) , tel op die telkaart (count on the counting card)
Enjoyment /affective relationship (with maths) (O)	*Do you love maths or are you scared of maths? (Q5)*	ek hou wiskunde (I like maths)	lief want dis goed en lekker om die tel.it te doen, hou om te tel (love it because its good and nice to count and do it and I like to count)
Language repertoire/able to describe mathematical activities (O) mathematizing (H)	*Maths is: (Q1):*		tel; minus,as gelyke (count, minus and equals)

Table 5: *Summary of Jade's learning disposition.*

Indicator	*Questionnaire instrument item*	May-12	May-13
Effective learner and doer of mathematics (K)	*Scale 1-9 (Q2)*	2	9
seeing mathematics as useful and worthwhile (K)	*Maths is: (Q1)*		
sense making (K) resourcefulness (O) (which includes what Carr & Claxton call playfulness (C&C)	*Maths is (Q1)*		
	What do you do if you don't know the answer in maths class? (Q6)		in maths club I will try to figure it out and I will take a paper
steady effort (K) resilience (C&C)	*Describe an effective learner of mathematics (Q4)*		listens a lot can remember what teacher told working everything and show teacher and fix mistakes
	What do you do if you don't know the answer in maths class? (Q6)	ask the teacher	in maths club I will try to figure it out and I will take a paper and in class I will ask my friend to explain
reciprocity (C&C)	*No question*		In class my friend explains and I get a piece of paper
compliant behavior (O)	*Describe an effective learner of mathematics (Q4)*		listens a lot can remember what teacher told working everything and show teacher and fix mistakes
	What do you do if you don't know the answer in maths class? (Q6)	ask the teacher	Then I'm getting scared for the teacher [referring to her classroom teacher] says you didn't listen
enjoyment affective relationship (with maths) (O)	*Do you love maths or are you scared of maths? (Q5)*	I don't like mathematics.	love because nice to do it and we learn more than we do at school.
Language repertoire/able to describe mathematical activities (O) mathematizing (H)	*Maths is (Q1):*	'phonics'	Learning a lot of sums and you have to listen because the next day teacher comes and tell you did not listen concentrate. You learning lots of fun maths maths games, card to play, time tables, ÷ sums.

Table 6: *Summary of Nandi's learning disposition.*

Indicator	Questionnaire instrument item	May-12	May-13
Effective learner and doer of mathematics (K)	*Scale 1-9 (Q2)*	5	8
seeing mathematics as useful and worthwhile (K)	*Maths is: (Q1)*	Ind of times	we are learning maths, sometimes we do + and x and -. I don't know! [the latter meaning that there is in fact a longer list to tell or say]
sense making (K) resourcefulness (O) (which includes what Carr & Claxton call playfulness)	*Maths is (Q1)*		
	What do you do if you don't know the answer in maths class? (Q6)		
steady effort (K) resilience (C&)	*Describe an effective learner of mathematics (Q4)*		Sometimes other children can't do it and they get some things wrong, I get everything right because he's paying attention and he's listening, he's reading before his writing.
	What do you do if you don't know the answer in maths class? (Q6)	You put up your hand	Put up my hand and tell the teacher I'm not understanding. If teacher busy, I will ask the person next to me [but in the videoed club sessions she did not ask]
	Do you love maths or are you scared of maths? (Q5)	Scared	I love it because it is nice to do some are easy things and some are not but I will do it finish
Reciprocity (C&C)	*No specific question*		If teacher busy, I will ask the person next to me [but in the video's club lessons she did not ask]
compliant behavior (O)	*Describe an effective learner of mathematics (Q4)*		because he's understanding and because he's listening paying attention.
	What do you do if you don't know the answer in maths class? (Q6)	You put up your hand	put up my hand and tell the teacher I'm not understanding. If teacher busy, I will ask the person next to me

Indicator	*Questionnaire instrument item*	May-12	May-13
enjoyment / affective relationship (with maths) (O)	*Do you love maths or are you scared of maths? (Q5)*	Scared	I love it because it is nice to do some are easy things and some are not but I will do it finish
Language repertoire/able to describe mathematical activities (O) mathematizing (H)	*Maths is: (Q1)*	Ind of Times	we are learning maths, sometimes we do + and x and - I don't know

The tables above match the interview responses of the three participant children against the Carr and Claxton (2002) & Kilpatrick et al.'s (2001) disposition categories and the additional categories we have added. Where there is no interview comment there was no example in these interviews that seemed related to that category. The number of gaps suggests some limitations of the instrument itself, which are explored elsewhere in this thesis as also in Graven, Hewana & Stott (2013). The interviews were focused on gathering the children's own expressed views about themselves in the context of mathematics (as opposed to views of observed behaviours).

In the next section I limit immediate analysis of the 3 tables above to evidence of some *change* in the children's view of themselves over time to two aspects. Firstly as 'effective learners and doers of mathematics' and secondly I go on to examine their use and change in the repertoire of language to describe mathematics and to describe their strategies to deal with the doing of mathematics over time.

- In the category of 'Effective learner and doer of mathematics' we see Saki ranked himself as a 9, indicating a strong maths learner, in May 2012 and again as a 9 in May 2013. He is thus consistent in placing himself as an effective doer of mathematics from one year to the next. But based on the fluency tests, and observations he overrating his relative performance to others both times.

  This persistent view of "himself" of course needs explaining. An answer is suggested by his views about mathematics. Firstly he has a very positive view of learning maths. He writes in May 2012 'it is the best' and says in May 2013 it is 'good to learn' 'it makes you clever' and 'I love it because it's good and nice to count and do it, and I like to count.' Secondly, and importantly he has a comprehension of maths that is very limited viz, just counting and doing the tasks given without regard to the correctness of the answers, and his commitment to coming to the club session and doing the homework tasks and class tasks. The mere doing of these appears to confirm for him that he is a successful doer of maths.

- By contrast both Jade and Nandi had a more modest and also more realistic view of their relative performance as "Effective learner and doer of mathematics' at the start of the project in May 2012 (a 2 and 5 respectively). Both of them then raised their own ranking of themselves by a large amount (to an 8 &9) a year later in May 2013.

Jade ranked herself as very low (at 2) in May 2012. At that date Jade's maths performance as shown in tests was also low, so in that sense she was being realistic in ranking herself as low. She also had no language at the time to describe what maths is, even to the extent of mysteriously describing it as 'phonics.' She wrote she did not like maths. A year later we see a very different way of reporting. Now she ranks herself as a 9, which is slightly higher than what Nandi, who scores higher in test results, had ranked herself. Jade's maths performance as shown in tests had in fact improved, so she had performance grounds to raise her ranking. Jade now in 2013 has a richer and more confident description of what maths is, viz. it is: 'Learning a lot of sums and you have to listen because the next day the teacher comes and tell you did not listen, concentrate! You learning lots of fun maths, maths games, cards to play, time tables, division sums.' But perhaps more important as evidence of her new view of herself as a 'maths doer' is the rich array of action strategies she now turns to and can describe when she is unsure of an answer. These are discussed below.

- Nandi ranked herself as 5 or a middle performer or doer of maths in May 2012. At the time it appeared that she may have underrated herself as she scored much higher than the rest of the club learners in the test. But given that there was still much room for her to improve, which she did over the year, this initial ranking, seemed appropriate and was probably appropriate to her placing in relation to her school class. After one year (May 2013) she ranked herself as an 8. In her interview remarks at the time she saw herself as being top of the class: 'Sometimes other children can't do it and they get some things wrong, I get everything right….'; but the self ranking of 8 signaled that there was in her mind still room for personal improvement. Nandi said she was 'scared' of maths when asked about this in 2012 but this changed to a confident and positive response a year later in May 2013; i.e. 'I love it because its nice to do maths; some easy things and some are not, but I will do it finish.'

From the analysis of the tables above, I now turn to focus on learners' use and repertoire of language to describe mathematics and to describe their strategies to deal with the doing of mathematics. It is proposed that advances in their sophistication in this use of language and descriptors of strategies would possibly reflect to a degree their understanding of mathematics:

a) Because a sign of understanding is to be able to describe mathematics processes, strategies, objects etc. Heyd-Metzuyanim and Sfard (2012, p. 2) talk about 'mathematizing', viz. the talking about maths, maths objects, and maths processes. That is, the ability to describe what you have done. This facility with the language of maths is one indication of a child understands of mathematics.

b) The language descriptions can also reflect the repertoire of tools or strategies to do maths at a point in time and over time. And so reflect the acquisition (or not) of a greater set of strategies the child is willing to use to tackle maths obstacles and challenges and thus a more advanced resilience.

- Saki's ability to talk about maths and the maths strategies he may use was restricted at the start of the program. In May 2013 his written responses to our oral questions using the PD instrument, he only described mathematics as 'the best.' A year later this had not advanced much in terms of elaborating on this. Here now in an oral interview with the facilitator he describes mathematics as: 'good to learn, because it helps' and 'it makes you clever.' Although revealing about the value he places on doing maths, these are all personal relations to maths and not features of the subject itself. But nonetheless by May 2013 he could list at least some math activities and operations, viz "count, minus and equals.' In the arena of how he describes strategies he might use in doing maths he started off at the beginning of the program by saying in response to the interview question: 'What would you do if you did not know the answer in maths class?' by saying 'I ask the teacher to help.' A year later had added two strategies, viz 'ask the teacher', 'count on my hands', and 'count on the counting card.'

- Jade (as I will discuss later from observational data) became the most talkative and outgoing of the three children. But at the beginning of the program in May 2012 she was unable to describe mathematics in any coherent way (her written response was ‘phonics’). She was unsure and lacking confidence in herself in maths and she seemed aware of her problem with maths. While not reflected in the table above this difficulty in expressing herself and in describing maths was also manifest in the early maths classes. But a year later we see a very different response style in her confidence and facility in communicating on a range of fronts. Now in her oral answers during the PD instrument interview, she describes maths and its operations as: time tables, You learning lots of fun maths, maths games, division sums, cards to play, and you have to listen a lot, can remember what the teacher told you because the next day the teacher comes and tell you did not listen, concentrate. Equally in the regular class exchanges she showed this change in her command and use of language and mathematizing. When it comes to her descriptions and repertoire of the strategies she might use if she did not know the answer in maths class? At the beginning of the program she hesitantly said ‘Ask the teacher.’ But she is perhaps most striking in the richness and range of answer for this question a year later. Now she says: ‘in maths club I will try to figure it out and I will take a paper’, ‘and in class I will ask my friend to explain’, and she describes a successful maths learner as ‘listens a lot can remember teacher told working everything and show teacher and fix mistakes.’

- Nandi’s overall characteristic of quietness and not generally volunteering comments or answers unless directly asked was in sharp contrast to the very social and proactive communications that emerged in Jade in the club sessions. At the beginning of the program in May 2012 Nandi, like Jade, was unable to describe mathematics in any coherent way, described it as ‘ind of times’. But a year later in response to our oral question of ‘Maths is?’ (This time we wrote down the responses) she says briefly: ‘We are learning maths, sometimes we do addition, ... and multiplication, …and subtraction…. I don't know! [The latter meaning that there is in fact a longer list to tell or say].’ When it comes to her descriptions and repertoire of the strategies she might use if she did not know the answer in maths class she increased these over time and also the language and confidence she shows in discussing her responses to the challenges of maths. In 2012 all she said was just ‘Put up my hand.’ But a year later (May 2013) her response was: ‘Put up my hand and tell the teacher I'm not understanding. If teacher busy, I will ask the person next to me.’ ‘Sometimes other children can't do it and they get some things wrong, I get everything right because he's paying attention and he's listening, he's reading before he’s writing.’ ‘…..some are easy things and some are not but I will do it finish.’

Nandi expresses her identification as someone who gets things right but shifts in her explanation to because ‘he does…’ possibly because she is relating this back to her earlier description of Sam who is a ‘top’ student. Thus she is mixing her description of herself and that of Sam possibly because like Sam she has identified herself as a 9 on the spectrum (like Sam).

In the next section I discuss the learner stories based on video recorded and observed data of participation in clubs. I include the data of the dispositional maths stories above. In this way I compile stories for each learner across data sources.

5.4 Part 3: Three learner stories emerging from across the data sources

All club sessions from May 2012 to May 2013 were video recorded and transcribed. However detailed analysis of all the transcripts is beyond the scope of this thesis. Instead transcripts were read and sections were coded for where aspects of learner dispositions in terms of the indicators given in the tables above were evident for the three case study learners. For each learner, critical incidents within all club sessions were also examined to further illuminate possible disposition patterns.

Then, in line with my chosen methodology of using learner stories as one of the main methods of characterizing dispositions and analysis (Carr & Claxton, 2002; Sfard & Prusak, 2005; Heyd-Metzuyanim & Sfard, 2012) I developed and present 3 learner stories compiled in large part from:

1) The Wright et al (2006) interview assessment Instrument results for each learner
2) Analysis of all the videos of the club sessions with these three learners plus illustrative critical incidents in these sessions of each learner.
3) The Productive Disposition Instrument interviews of the three learners (the above stories are included here where relevant)

Presented below are the three learner stories that emerged from this analysis:

5.4.1 Saki's Story

Saki began the club in May 2012 with extremely weak mathematics skills and a complete dependence on the concrete and a failure to see patterns. We are yet to see evidence of him sense - making as a key aspect of his mathematical working in club sessions and throughout the data collection process no data collected showed evidence of this aspect of a productive disposition for Saki.

In the timed procedural fluency assessment (i.e. the doing of operations (See Table 7 for data and Appendix B for the instruments): add and subtract numbers up to 10; doubling e.g. 5,13,15,16 etc., and add & subtract 10 to a number Saki showed some improvement in scores over the year. Thus in the first timed test in 2012 Saki managed only 2 out of the 153 possible sums (only 1.3%) while in 2013 he managed 7 out of the 153 sums (i.e. almost 4.5%). While his doubling score remained constant his addition and subtraction up to 10 and of 10 to a number improved.

In the Wright et al.'s (2006) instrument interview conducted by the facilitator in May 2012 (see Appendix D for an example of a filled in interview schedule), he lost track when counting backwards and could not read 1025, and he had no idea of a ½ or a ¼. With regard to his dependence on the concrete, he also adhered to 1-to-1 counting as indicated in Wright et al. (2006) interviews. While he attended all club sessions and also worked to answering questions, most of all in the homework books (showing the most resilience and steady effort among the three in respect of the homework), it has been hard to shift him forward to conceptual thinking and seeing patterns rather than 1 to 1 concrete finger counting. For example: saying to him 10 + 2; 10 + 3; 10 + 4 and pushing him to see the pattern (of say just adding one more in each case) rather than looking at and counting on his fingers. His attention struggled to focus on seeing the pattern. Thus he would count on his fingers starting at 1. More recently (May 2013) the facilitator noted more progress with seeing patterns although he still struggles to see and use the abstract patterns (personal interaction).

The recorded club sessions showed Saki as confident in his homework book-work which he showed the facilitator at the start of sessions. There is evidence that his reasoning to support this view of himself as being strong at maths, is that he sees the mere doing of maths as making him clever, thus for example in the interviews he says in response to why he likes maths? , "because it will make me clever" coupled with his pattern of 'steady effort' in doing quantities of homework well above the class average. He sees his ongoing participation in the club and ability to do the concrete way as what being good at maths is. He does not envisage what is needed in order to see mathematics as *sensible, useful*, and *doable* (elements of productive disposition). Though in regard to doable, he exhibits a strong measure of steady effort in his homework book and in class.

Saki had advanced since May 2012 in the degree to which he could articulate in words his opinions and feeling about mathematics. Thus in May 2012 in responding to questions posed in the SANC Productive Disposition Instrument interviews: (e.g. What is maths? Tell me about Mpho in the classroom? Tell me about Sam in the classroom? Etc.) Saki could only provide limited explanations often only one-word answers, but by mid-2013 he has elaborated more on each question, using examples of maths objects in his explanations. (See Table 4). For example, Saki response to Maths is….. in May 2012 all he says is: "(*Die beste!)* It is the best!" By May 2013 responding to the same question he says: "(*goed om the leer want did help*)…..is good to learn because it helps… (*om goed in die class is wil leer*) ….it is good to learn in the class……..(*ons doen wiskunde tel, plus, minus, as gelye, skryf nommers*)…..we learn maths [to] count, to add, to minus, divide, write numbers. … (klub lekker want jy tel jou same)…...the club is nice because you count your sums." (SANC Productive Disposition Instrument, May 2013 – Saki)

In the club sessions he chose to remain quiet (even when probed and encouraged) possibly to cover himself from embarrassing himself in providing wrong answers unless he is helped and pushed to think and answer. He appears very shy and answers very quietly – even winning the Bingo game (a maths activity) he beamed but would not shout out 'Bingo' as a norm even with prompting (and tickling from the facilitator. He is yet to see sense making as a key aspect of maths and the facilitator is still working towards this. Of interest the i-pads worked well to allow his progress as this did not require group participation or discussion/ keeping up with other learners and reduced distraction. Similarly the club facilitator found in her last session that making him and others close their eyes when she demonstrated for example the pattern of 'the 10 times table' or 'the pattern of the 11 times table' seemed to work well to enable Saki's focus. Thus the removal of the social noise that seemed to affect Saki helped his focus on patterns.

Below I provide two narrative vignettes of Saki based on two transcribed extracts of critical incidents related to Saki's participation in maths club sessions. This vignette illuminates his shyness even when he has won mathematically:

Vignettes of Saki

Vignette 1: Saki's shyness

In the extract below taken from a club session on the 16th April 2013 the class is playing a BINGO game. Each child has a card with rows and columns of 3 clock times in words or clock faces. Mellony, the facilitator, calls out a time from her master set of cards and the learners must then look to see if they have that time as one of the times given in their 4 by 4 table 'Bingo' sheet. As with the game Bingo learners each have different sheets with different times and learners win if they complete a full row and then shout Bingo.

Table 7: *Excerpt indicating Saki's shyness during Bingo time game.*

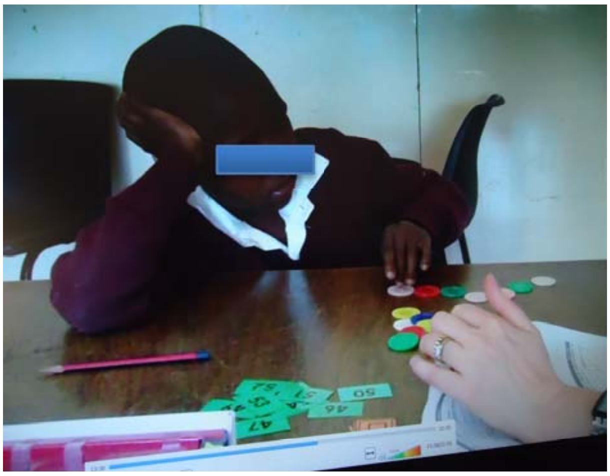
38:24 Mellony	Who has got …quarter …to 7?	
Nandi	Nhaa!!!	
Jade	I've got	Then mark it. She said …but knew she had not… marking over an earlier answer…
Mellony	Quarter to 7!	Speaking each word slowly and deliberately…
Mellony	You've have got quarter to 5. You've have got quarter past 7. Look here. What's this time?	Pointing to a Jade's card…
	Seven o'clock. Seven o'clock! Teacher has called out 7 o'clock!	
Jade	Quarter to 7…. shu	
Mellony 39:00	Who has got half past 12?	
	Why don't you shout SAKI? Why don't you shout Saki?	He first smiles at the facilitator showing his

	Come on Saki, what must you shout? SAKI.	pleasure at winning but then hides his head shyly in his arms over the table….
	What… must YOU shout? Shout it. BINGO!!!! Well DONE Sa…ki!!! Well done!	….he hides his head behind one arm,,, and scribbles on his sheet not looking up an obviously pleased with himself…. But still says nothing Mellony begins Tickling him.
Mellony	Hey Benjamin WELL done MY BOY!! Ok…. Rub out!! Did you like that?	Shaking his arm gently.
The rest of the class (but not Saki) sing out…. Mellony		Clapping her hands. And all the class then clap their hands for him.

The above showed Saki's social shyness even while he showed he was pleased at winning. He participated by doing what is required but his willingness to reciprocate verbally with others in mathematical interactions seems limited by shyness. This shyness seems to affect this dispositional aspect identified by Carr & Claxton (2002).

Vignette 2: Saki's inattention to patterns – May 2012

The photo below shows Saki participating in May 2012 in the Wright et al (2006) interview with the facilitator (Mellony) on the opposite side of the table.



In the extract given in Table 8 below Mellony (the facilitator) is busy conducting part of the Wright et al (2006) interview with Saki who is sitting opposite her. Now she goes onto the next task. She scrabbles round in a box on the table for some green numbered cards that are numbered from 46 to 55.

Table 8: *Extract of Saki's inattention to patterns*

11:38 Mellony			She finds them and takes off the elastic band and places them in random order in front of Saki
Mellony	Nou…ek gaan vir jou hierdie karte gee.	Now…. I'm going to give you these cards.	She says softly again….
11:45 Mellony	Ummmmm… hiedie….kan jy vir my hierdie karte in volg order sit asseblief? In volg order vir my…	Mmmmm … this… can you please place these cards in order? In order for me..	

11:50 Mellony 13:07 (he takes a mere 2 minutes and 17 sec) Mellony	 Baie mooi! So dit gaan so, ne? … ……....Baie mooi. Ok!!....mooi….ok	 Very good! So it goes like this, eh?.... …….. Very good. Ok!!!....good….ok	Relaxed he leans his head on his one hand and with his other arm and free hand ….. he begins, without hesitation, to move them about with his index finger placing them in into order with some confidence… He first makes a row running from 50 to 55…. Then moves the remaining into a row above from 46 to 49. Viz. 46 47 48 49 50 51 52 53 54 55 Mellony pointing runs her finger along the top line and then back to the lower line … as she explains how it runs…. Just to reinforce the link. Mellony writes a note on the interview schedule.
Mellony			Mellony now goes to the next task. She gets out some coloured plastic disks and places them on the table in front of him…

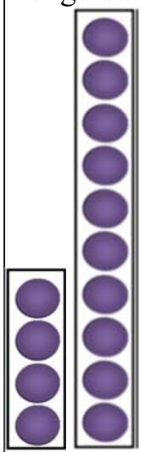
Mellony	….PLAAS diertien tellers uit vir my. Kan jy diertien tellers tel vir my? Baie goed!	….Lay out thirteen counters for me. Can you count thirteen for me? Very good!	Saki still with his head leaning on his one arm on the table, with his free hand with his index finger moves the disks and counts out 13 in a snake.
	Kan jy vir my agtien tellers uitplaas? Agtien… Baie goed! Ok ….. Dankie! ***************	Can you lay out eighteen counters for me? Eighteen… Very good! Ok….. Thank you! *********	Mellony does not disturb his snake of 13, but now adds some more disks to the small surplus on the table for his use. Saki taking from the new pile of disks counts off ten with his finger moving them into a row of ten disks, and then he continues to count the 11, 12, 13, 14, 15, 16, 17, 18 from his original snake….. then he fairly firmly pushed the rest away. Mellony collects all the disks and moves to the next task.

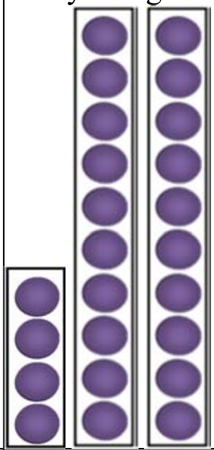
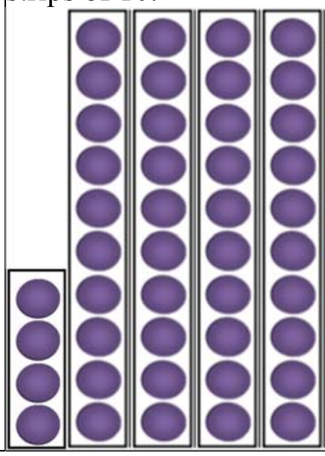
In table 9 below we see the continuation of the Wright et al (2006) interview with Saki. The first two turns involve Mellony asking Saki to place out a certain number of counters. He places these out one by one counting each one in both cases.

Thereafter he is asked to say the number of dots in front of him. For this, dot strips are placed on the table and Saki is asked each time to say how many. The first dot strip has 4 dots and all subsequent dot strips added to it have ten dots. The transcript is relatively long due to the one to one counting of each dot all the way up to the final question of 74 dots but this is important to not that even given the painstakingly slow process of counting in this way Saki persists with this method failing to use the groups of ten and pattern of adding ten each time to speed things up.

Table 9: *Second excerpt of Saki's inattention to patterns*

Turn	Speaker	What is said (Afrikaans)	English translation	
1	Mellony	….PLAAS diertien tellers uit vir my. Kan jy diertien tellers tel vir my? Baie goed!	….Lay out thirteen counters for me. Can you count thirteen for me? Very good!	Mellony now goes to the next task. She gets out some coloured plastic disks and places them on the table in front of him… Saki still with his head leaning on his one arm on the table, with his free hand with his index finger moves the disks and counts out 13 in a snake one by one.
2	Mellony	Kan jy vir my agtien tellers uitplaas? Agtien…	Can you lay out eighteen counters for me? Eighteen…	Mellony does not disturb his snake of 13, but now adds some more disks to the small surplus on the table for his use.
3		Baie goed! Ok ….. Dankie! **************	Very good! Ok….. Thank you! *********	Saki taking from the new pile of disks counts off ten with his finger moving them into a row of ten disks, and then he continues to count the 11, 12, 13, 14, 15, 16, 17, 18 from his original snake….. then he fairly firmly pushed the rest away.

4		(14:18) Ok….Hoeveel? Hoeveel kolletjies sien jy?	 Ok… how many? How many dots do you see?	Mellony collects all the disks and moves to the next task. With a quick movement Mellony picks up some plastic strips. They have coloured circles on them. She first places a short strip with 4 circles running down it. 
5	Saki	(**silently**) een, twee, drie, (**sofltly aloud**) Vier.	(**silently**) one, two, three, (**softly aloud**) Four.	Still leaning on his one arm Saki points with his index finger onto each circle counting in his head in ones. Then says the answer very softly without looking up….
6	Mellony	Ok Nou ….. hoeveel koletjies al te same is daar?	Ok now…. How many dots all together are there?	Mellony writes a note and quickly adds a new strip of 10 alongside the strip of 4. 
7	Saki	(**Silently**)…..een, twee, drie, vier, vyf, ses, seve, agt, nege, (**aloud**) Tien.	(**Silently**)… one, two, three, four, five, six, seven, eight, nine, (**aloud**) Ten.	Saki pointing onto each of the circles down the 10 strip counts silently. He then stops…..
8	Mellony	Al twee same?	All together?	Mellony pointing to the two strips to indicate how many altogether on both strips

9	Saki	(**Silently**)….een, twee, drie, vier, vyf, ses, seve, agt, nege, tien, elf, twaalf, diertien. (Aloud) Viertien.	(**silently**)… one, two, three, four, five, six, seven, eight, nine, ten eleven, twelve, thirteen, (Aloud) Fourteen.	Saki starts counting again with his finger at one at the top of the 10 strip and then continues counting the additional 4. He then says the answer very softly without looking up….
10	Mellony	Ok ….baie goed! En now? Hoeveel?	Ok…. Very good! And now? How many?	Mellony adds another 10 strip making sure that they are all nicely alongside each other…. 
11	Saki	**(Silently)** een, twee, dirie, vier, vyf, seve, agt, nege, tien, elf, twaalf, diertien, viertien, vyftien, sestien, seventien, agtien, nientien, twintig, een en twintig, twee en twintig, drie en twintig, **(Aloud in a whisper)** Vier en twintig.	**(Silently)** one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen, seventeen, eighteen, nineteen, twenty, twenty one, twenty two, twenty three, **(Aloud in a whisper)** Twenty four.	Saki starts counting silently to himself with his finger from one, pointing to each one as he goes down the first strip of 10, then the second strip of 10 and then the remaining 4. Then gives the answer in a whisper.
12		Baie goed! En NOU hoeveel?	Very good! And NOW how many?	Mellony now adds two more strips of 10. 

13	Saki	(15:14) (**Now softly counting out load all the numbers)** een, twee, dirie, vier, vyf, seve, agt, nege, tien, elf, twaalf, diertien, viertien, vyftien, sestien, seventien, agtien, nientien, twintig, een en twintig, twee en twintig, drie en twintig, viwer en twintig, vyf en twintig, ses en twintig, seve en twintig, ag en twintig, nege en twintig, diertig, een- en diertig, twee en diertig, drie en diertig, viier en diertig, vyf en diertig, ses en diertiig, ses en diertig, ag en diertig, nege en diertig, viertig, een en viertig, twee en viertig, drie en viertig…(**Louder)** Vier en viertig. (15:43)	(**Now counting softly out loud all the numbers**) one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen, seventeen, eighteen, nineteen, twenty, twenty one, twenty two, twenty three, twenty four, twenty five, twenty six, twenty seven, twenty eight, twenty nine, thirty, thirty one, thirty two, thirty three, thirty four, thirty five, thirty six, thirty seven, thirty eight, thirty nine, forty, forty one, forty two, forty three, **(Louder)** Forty four.	Saki starts counting **this time softly out loud** from one while pointing with his finger to each circle as he goes down each of the strips until he gets to the last circle at 44.
14	Mellony	Ok so hoeveel? (M & S) **(Both together)** **---**Vier en viertig.	Ok so how many? (M&S) (**Both together**) --- Forty four.	
15	Mellony	En NOU hoeveel? Kan jy ‘n vinniger manier kan jy dit uit werk?	And NOW how many? Can you do it a quicker way you can work this out?	Now Mellony adds 3 more strips of 10 to make the total number of dots up to 74.

16	Saki	(15:55) **(Now a bit louder than the last time he counts out all the numbers from 1 to 74)** een, twee, dirie, vier, vyf, seve, agt, nege, tien, elf, twaalf, diertien, viertien, vyftien, sestien, seventien, agtien, nientien, twintig, een en twintig, twee en twintig, drie en twintig, viwer en twintig, vyf en twintig, ses en twintig, seve en twintig, ag en twintig, nege en twintig, diertig, een- en diertig, twee en diertig, drie en diertig, viier en diertig, vyf en diertig, ses en diertiig, ses en diertig, ag en diertig, nege en diertig, viertig, een en viertig, twee en viertig, drie en viertig, vier en viertig, vyf en viertig, ses en viertig, seven en viertig, agt en viertig, nege en viertig, vyftig, een en vyftig, twee en vyftig, drie en vyftig, vier en vyftig, vyf en vyftig, ses en vyftig, seve en vyftig, agt en vyftig, nege en vyftig, sestig, een en sestig, twee en sestig, drie en sestig, vier en sestig, vyf en sestig, ses en sestig, seve en sestig, agt en sestig, nege en sestig, seventig, een en seventig, twee en seventig, drie en seventig, vier en seventig. (16:55) (This last count took 2 minutes)	**(Now a bit louder than the last time he counts out all the numbers from 1 to 74)** one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen, seventeen, eighteen, nineteen, twenty, twenty one, twenty two, twenty three, twenty four, twenty five, twenty six, twenty seven, twenty eight, twenty nine, thirty, thirty one, thirty two, thirty three, thirty four, thirty five, thirty six, thirty seven, thirty eight, thirty nine, forty, forty one, forty two, forty three, forty four, forty five, forty six, forty seven, forty eight, forty nine, fifty, fifty one, fifty two, fifty three, fifty four, fifty five, fifty six, fifty seven, fifty eight, fifty nine, sixty, sixty one, sixty two sixty three, sixty four, sixty five, sixty six, sixty seven, sixty eight, sixty nine, seventy, seventy one, seventy two, seventy three, seventy four.	Saki again starts counting out loud (but a bit louder this time) from one while pointing with his finger to each circle as he goes down each of the strips until he gets to the last at circle at 74.

17	Mellony	Baie goed! Dis correk. Dink jy nie daars 'n korter manier? Hoeveel is daar?	Very good! That's correct. Do you think there's a shorter way? How many are there?	Mellony tidies up the strips a bit…. Mellony points her finger at each end of the first strip she asks how many there are.
18	Saki	Tien	Ten	
19	Mellony	So? Tien…	So? Ten…	
20		Twintig Dertig Viertig Vyftig Sestig Seventig (**slight pause**) ….Tag…tig	Twenty Thirty Forty Fifty Sixty Seventy (**slight pause**) …Eigh…ty	Mellony leads through each strip of 10…. Pointing and separating and moving each strip slightly to his right as he counts them up aloud ….. ….. but then, when Mellony points to the last strip (which is only 4 dots) with a slight pause he says 'tagtig'
21	Mellony	Ah Ah. Dit is nie tien nie. …..Seventig PLUS?	Ah ahh… That is not ten! …. Seventy PLUS?	Mellony separates the 4 strip a little with her finger and shakes the strip backwards and forwards a bit, as if asking a question with it.
22	Saki	………………Vier ?	………Four..?	He pauses for a moment and then says 'vier'
23	Mellony	Ja seventig PLUS vier. …. Hoeveel is dit, seventig PLUS vier?	Yes seventy PLUS four…. How many is that, seventy PLUS four?	Mellony then sweeps her hand over the 70 strips and then points to the 4 strip.
24	Saki	Seventig en vier (**softly**)	Seventy and four (**softly**)	

25	Mellony	Baie goed!………Vier en seventig NE?…..Vier en seventig. DAAR is seventig … en hier is vier! … Dan kry jy vier en seventig. Sien jy dis bietjie vinniger? … (clicking her fingers a couple of times.…He nods slightly) Tien, twintig, dertig, viertig…. Was dit vinniger? (he nods slightly) Ja Ok!!	Very good! ….Seventy four, Hey? ….Seventy four. THERE is seventy… and here is four!.... Then you get seventy four. Do you see it's a little faster!? ….. (clicking her fingers a couple of times…. He nods slightly) Ten, twenty, thirty, forty…. Was it faster? (he nods slightly) Yes OK!	

In the transcript above we note that Saki continues and consistently uses one-to-one counting even when the resource laid in front of him is clearly grouped in tens. In each case he begins counting from one all over again treating each question as a new isolated question that does not follow on from the previous counting he did. This relates to his avoidance of noting the patterns (add ten each time 4; 14; 24; 34 etc…) or sense making that would allow more efficient strategies to emerge from drawing on his answers to the previous questions or on his noting that a full dot strip has ten dots. It is unclear his reasons for this and whether it is an inability to see the patterns or instead a dependence and 'faith' in the accuracy of the one to one counting method.

5.4.2 Jade's Story

When Jade started in the club in May 2012 she had generally low mathematical fluency but her fluency had improved somewhat by May of 2013. Her basic proficiency is average in the club group. Thus in the timed procedural fluency assessment (i.e. the doing of operations (See Table 7 for data and Appendix B for the instruments): add and subtract numbers up to 10; doubling e.g. 5,13,15,16 etc., and add & subtract 10 to a number Jade showed some improvement in scores over the year. Thus in the first timed tests in 2012 Jade managed only 10 out of the 153 possible sums (only 6.5%) while in 2013 she managed 23 out of the 153 sums (i.e. 15%). While her doubling score is lower in 2013 this is as a result of her stress during this test thus she stopped after the first few seconds when the facilitator drew her aside as explained earlier in Table 7. Her addition and subtraction scores however improve more than three times over the year.

In the Wright et al.'s (2006) instrument interview conducted by the facilitator in May 2012 (see Appendix D for an example of a filled in interview schedule), Jade at first had difficulty in seeing patterns and she preferred to jump to answers without thinking or used concrete ways as her method goal rather than using sense making. But she improved in seeing patterns in mathematics and began to make sense if pushed. The Wright et al.'s (2006) instrument interview test showed number of difficulties. For example with numeral identification, she thought of a quarter (¼) as "a half and 4", and showed no understanding of fraction at that stage. She was confused with number lines, for example she could not figure out what number comes half way between 10 and 20 and just guessed. When counting over a 100 she left out numbers. She used fingers to count and she often counted in 1's, but did now and then count in 2's. She also tended to lose concentration when dealing with larger numbers.

As indicated in (Table 5) in May 2012 at the start of the club when the written Productive Disposition Instrument was used Jade positioned herself on only a (2) on the spectrum of learners, i.e. as one of the weakest at math's in her class. Thus Jade appropriately recognized herself as not performing very well in mathematics at the time.

In May 2013 when interviewed again using the SANC Productive Disposition Instrument she was much more fluent in describing what maths is. In 2012 she could only write it was 'phonics' but by 2013 she described it a bit more fully such as: 'learning a lot of sums, and you have to listen because the next day she comes and tells you did not concentrate… learning lots of fun maths games, cards to play, times table, sums and multiples'. But even more notable in 2013 she positioned herself at the top of the performance spectrum [on a (9) or strongest in maths in his class], which is a dramatic change from the 2 she positioned at one, here she now said she loves maths 'love it because its nice to do it... and we learn more than we do at school.' Also she is willing for a challenge, speaking of the club she says: [it has] 'harder maths activities, nice maths, we have fun.'
Some of the reasons for this change would be: she had gained confidence; she had direct feedback of her good performance; she could now see herself as being above some others in her maths class as report results showed above average performance; she now took on challenges as exciting; and when she gets it right she celebrates and dances around; and she wants to strongly compete against

others to answer first, especially with Nandi a strong mathematics student. Further her mother has added an additional motivation to her drive when her mother, according to Jade says: 'you are becoming good at mathematics, you will be able to get to university at Rhodes.'

From videos analysis of sessions and as indicated earlier Jade is able to see patterns in mathematics and make sense if pushed. She prefers however to jump to answers or use concrete ways as her main goal rather than sense making. This seems to be to keep up and be ahead of and stand out from others especially Nandi who she seems to compete with. She appears to want to win and please the facilitator far more than figuring out the problems. She gets frustrated if her answer is challenged by another learner. According to the club facilitator she is delightfully social and gets excited by problems. She does better at sense making when it is one on one with the facilitator or only two learners as she becomes easily distracted by the larger group and her will to compete or be first to answer tends to shift her into guessing mode and away from thinking. Sometimes Jade would contribute negatively by criticizing Saki or others' work and would not listen to their ideas or jump to intercept indicating sometimes a difficulty with reciprocity in Carr and Claxton's ((2002) terms.

Jade's resilience was initially low in the face of a problem that she perceived as showing the others in the group that she was not doing so well. For example, her stress and almost tears in 2012 in the timed basic operations and doubling where she only obtained 2 out 23. But by 2013 her resilience had become stronger in that there is evidence across sessions that she pushes more to get an answer right. she also other resilience strategies to deal with hurdles, such as asking the facilitator 'can you please explain to me again?', and she even began to consult peers at times for help, indicating greater reciprocity in terms of willingness to engage with others in co-learning rather than merely seeing classmates as competition. Her competiveness however remained present over, even while in later sessions it seemed enable rather than defeat her resilience.

In terms of steady effort she displays an eagerness to get involved with tasks and to get them right and get the approval for this from the facilitator. Observations of sessions show Jade consistently engaging with the tasks given with occasional distractions from other learners particularly in earlier sessions. She does not however display much steady effort in terms of her homework book. The influence of a different setting may be the main explanation for Jade being less committed in her effort in doing homework at home on her own, as it is a different setting as compared to club where the students learn and interact with each other.

Below I provide a narrative vignettes of Jade based on a transcribed extract of a critical incident related to her participation in maths club sessions. This vignette illuminates Jade's competitive nature and the way in which her social awareness of others and how she may be perceived by them influences the nature of her participation. In Table 9 below an extract from a session using i-pads is given.

Vignette – Jade turns to guessing

The picture below shows Jade standing and participating in the i-pad game with fellow club learners sitting next to her. Throughout the activity Jade stood and danced when moving up a level.

In order to understand the transcript I must first explain the i-pad game learners are playing. Each learner is given an i-pad with a pre-loaded game called 'pop maths' to play maths. This game involves fast thinking as one has to calculate by figuring out which 2 sets of bubbles match. Some bubbles have sums while other bubbles have numbers. E.g. 2+ 3; 6-2; 5; 10; 4; 9+1. Each time learners touch a correct pair of bubbles the bubbles 'pop' (i.e. disappear) and make a popping sound as they do so. If a learner touches a wrong pair of bubbles, e.g. 2+3 and 4 then the game makes a 'squirt' sound indicating an error has been made. It is possible to move up a level without solving the sums and just tapping randomly at the bubbles resulting in squirt sounds until correct pairs are randomly touched. Mellony explained that they should not do this and they must try to work the bubbles out and that if she hear squirt squirt it would indicate that they were cheating.

An example of a screen shot showing the bubbles and a learner's hand touching a pair of bubbles with two fingers in the game is shown below:

Table 10 *Vignette – Jade turns to guessing.*

Mellony 6:24 6:28	Ja yes, yes. You see! It's much quicker to count on. Hey. Now these are subtractions. Ooh, some of you have multiplication already. Ai, now you are guessing Jade.	Speaking to Saki – Mellony is encouraging Saki to count on to calculate addition sums in the bubbles rather than counting all Mellony notes Nandi on multiplication which occurs round level 10 Jade is tapping the iPad rapidly. Clicks her fingers. But now there is a squirt, squirt sound
6:32 Jade	I'm not guessing I am on level 13.	
6:35 Mellony	Ja, I don't want to hear squirt, squirt because that means you are guessing hey!	Jade is doing well to be on level 13 but having noticed Nandi is ahead started guessing round level 12. She is still tapping enthusiastically but seemingly randomly.

Nandi	I'm on level 14.	Nandi looks at Jasmine momentarily and claps her hands together
Jade	My, my, my	Tapping the pad and talking to herself
Mellony	Ja, what's here? What's 11 less 2? Count down, 11, 10, 9. Ja, count down. Count down from 11. Right good. Good, good, well done.	Speaking to Saki. …. Saki has slowed down and doesn't seem enthusiastic. He looks like he is struggling. He does it and she affirms him.
Jade	Pop! 13 now!!! Pop, pop, pop.	(Referring to getting to level 13!) Jade hits her iPad with intensity. Squirt, squirt sounds…..
Mellony	Hey you are guessing. You're GUESSING Jade!	Mellony notes the squirt sounds coming from Jade's i-pad which indicates she keeps getting them wrong as a result of her randomly tapping at the bubbles at speed now that the levels are harder and thus the sums in the bubbles need much more time to calcualte.
Mellony	Stop the guessing!	Mellony sweeps her hand over Jade's i-pad to physically stop her from tapping randomly and to get her to take note of her instruction and the mathematical aspect of the activity
Mellony	Well done.	Speaking to Saki.
Mellony	What is 3 and 9 Jade?	Mellony had restarted Jasmine so that she began at Level 1 again and to encourage her to pay attention to the sums in the bubbles she asks her what the answer to one of the bubbles on her screen is.

Jade	Thirteen	Answers immediately
Mellony	No what is 3 plus 9? 3 plus 9, think!	Putting up her fingers and begins to count on from 9.
7:43 – 7:45 Jade & Mellony together	9, 10, 11, 12.	Jade looks at Mellony.
7:57 Nandi	I'm on level 17, level 17 teacher.	
7:57 – 8:23 Mellony 8:22	Think, think, think. What is 13 and 8? 34 minus 17? Good. Well done.	Jade is intensely tapping. Mellony takes Jade's hand to stop her tapping and encourage her to think …Jade then proceeds to count on 8 from 13. Jade counts openly on her fingers. Then taps the answer. Jade taps in the answer. Jade is loving this game, hands in the air. Standing and dancing.
8:24 Jade	Moet nie guess nie Ruan.	Not looking at Ruan. While dancing and snapping her fingers.
8:25 – 9:00 Mellony	When I hear quirk, squirk, squirk I know that you are guessing.	Mellony talking to Jade. Jade is frowning and looking a bit unhappy.

In the excerpt above we note that Jade repeatedly reverts to guessing in order to stay ‘up to speed’ with others particularly paying attention to Nandi and the levels she was on. Mellony needs to constantly pull her back to doing the mathematical sums required by the game. We note here both an absence of resilience when sums get harder as well as a social awareness and competitiveness that interferes with her mathematical thinking. While she complies with Mellony’s request each time she reverts to guessing whenever Mellony’s attention is diverted to other students.

5.4.3 Nandi’s Story

Nandi is the strongest of the group at the club in terms of numeracy fluency assessments. She picks up on patterns very quickly and, while competitive, is not as easily distracted by others in the group.

In the timed procedural fluency assessment (i.e. the doing of operations (See Table 7 for data and Appendix B for the instruments): add and subtract numbers up to 10; doubling e.g. 5,13,15,16 etc., and add & subtract 10 to a number Nandi showed some improvement in scores over the year. Thus in the first timed test in 2012 Nandi managed only 29 out of the 153 possible sums (only 18.9%) while in 2013 she managed 61 out of the 153 sums (i.e. 39.8%). While her doubling score remained constant (11 out of 17 both times) her addition and subtraction up to 10 and of 10 to a number improved almost threefold.

In the Wright et al.’s (2006) instrument interview conducted by the facilitator in May 2012 (see Appendix D for an example of a filled in interview schedule), she was fluent in both English and Afrikaans when talking about numbers, counted back in 10’s and used pattern strategies to for example; separating piles by colour, and saw patterns of 10. When asked to subtract 15 from 42 she adopted a strategy of drawing 42 small circles on the page and then crossing out 15. This showed an understanding of the concept of subtracting objects even while her working required concrete representation indicating that she had not yet fully abstracted the concept. In May 2013 again doing a timed fluency test she not surprisingly still had high scores.

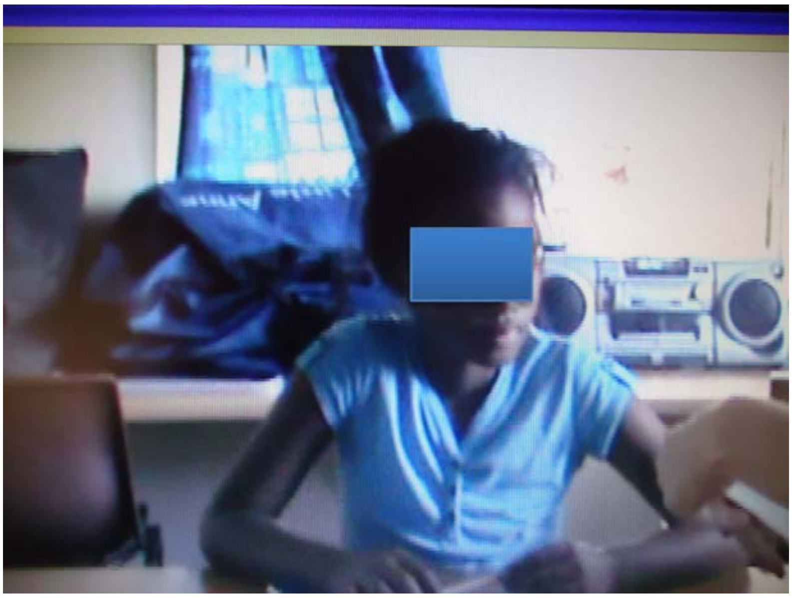
As indicated in (Table 6) the May 2012 instrument administered by the SANC team across schools she then positioned herself at (5). That is, as average or in the middle of her class. But in 2013 she positioned herself on a (8). That is, as one of the strongest in maths in her class, which is up from the (5) she ranked herself at a year earlier. Nandi was seemingly aware of her improvement over time although perhaps in the May 2012 instrument she positioned herself in relation to her school class where her position would be appropriately described as average while within the maths club she is the strongest and so her response later could be as a result of her answering this instrument in relation to her experiences of her strong numeracy relative to other club learners.

In the same instrument of May 2012 Nandi wrote for Maths is… 'maths is ind of times', which we did not understand what she meant. In answering do you love maths or are scared of maths, she just wrote 'scared.' And to what you do if you do not know the answer in maths class, she wrote: 'you put up your hand.' But when the club facilitator interviewed her in May 2013 using the same instrument, she says maths is: '…learning maths, sometimes we are doing addition, multiplication and minus. ….Sometimes other children can't do it and they get something wrong, I get everything right.' Now when asked do you love maths or are you scared of maths, she says, 'I love it because it is nice to do maths, because some easy things and some are not but I will do it finish.' And to the question what you do when you don't know the answer in a maths class, she said, 'put up my hand, tell the teacher 'I'm not understanding.' If teacher busy I will ask the person next to me and if she is busy, yhoo I will ask Mellony (club facilitator). When she says no I will try and try and do it.'

Describing the main characteristics of Nandi's engagement with maths, we observed that Nandi picks up on patterns quickly and while competitive is not as easily distracted by others in the group. She has had to be pushed to think conceptually as she tends to want to answer immediately or wants the 'rule' of what to do rather than to figure it out herself. Thus for example, even though (as will be seen in the transcription below) she was first to solve for the circle in the number puzzle as 5, when she was trying to solve the rest of the puzzle, which was harder and not immediately evident to her, she repeatedly asked the facilitator what to do, even though she had not yet tried. Thus she seemed to rely more on her quickness to see things but seemed often unwilling to think for herself and showed low levels of independent steady effort or resilience in the face of problems that were unfamiliar or challenging for her. Similarly she did very little work in her homework books. This absence of steady effort and resilience likely hampered her progress. She is able to use different strategies to solutions and showed progress to abstract thinking by not relying on counting by fingers instead draws on her own resources. In most times she solves problems quicker than others and can explain the process.

The following transcription was used by the club facilitator and Chair to communicate in the Annual Chair's Community of Practice forum slide show presentation importance of the developing in learners a productive disposition (See SANCP, 2013). Specifically resilience and steady effort are fore-grounded as absent (she was quick to get to the circle) in this transcript. It clearly indicates that despite Nandi's strength in being able to figure things out she seems to default to pushing the facilitator to tell her what must be done before trying herself. The problem is shown in the top left hand corner and asks learners to solve for the shapes given that the middle rows add to 25 and 20 respectively and the fourth column adds to 26.

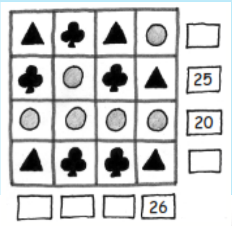
The picture below shows Nandi participating in the Wright et al (2006) interview in 2012.



Below I provide a narrative vignettes of Nandi based on a transcribed extract of a critical incident related to her participation in maths club sessions. This vignette illuminates her resistance to drawing on her own resources when a problem becomes slightly more challenging even while her quick response to part of the problem indicates strong capability to solve the rest.

Vignette 1: ***Nandi wants teacher's instructions.***

Table 11 Excerpt of *Nandi wants teacher's instructions.*



Transcript

Mellony 20:28	So how are you going to figure out the club?	Nandi walks to a desk away from the group to work on it.
Nandi and Mellony 21:16 – 21:42		Nandi shows Mellony her answer of 3 for the triangle and Mellony engages her in why it doesn't work because the column will then give a total of 16 not 26.
Nand 21:42	don't understand.	Nandi mumbles this as she walks away from Mellony.
Mello 21:44	isn't that you don't understand you need to keep trying. ...	A lot of children are wanting Mellony's attention.
Nand 22:18	eacher teacher - I don't understand! 34 secs later	Complaining in an emphatic tone that she doesn't understand. Nandi stands and looks confused.
Mellony 22:20	No, it is not that you don't understand it is that you have to think. You do understand, because you found the circle. But, it's not so easy to find the ub, and the triangle, you have to think. You have to problem solve. So top thinking you don't understand and think.	
Nand 22:32	hoo	She turns her head away seemingly unimpressed by the instruction
Mellony 22:33	You have to problem solve. So stop thinking you don't understand and think.	
22:33 – 23:35	63 secs later	Mellony works with other learners individually. Nandi sitting looking at her problem solving sheet and doing some counting with her fingers against her cheek
Nandi 23:36	Teacher, teacher, teacher, teacher.	Nandi comes running from her side of the table to show Mellony what she has got. She is so excited.
Nand 23:38	found it. It is	Nandi gives her card to Mellony and points to her answer
Mellony 23:50	Shh. Ahhhh! Very good!!! Now who told me they didn't understand? And all she had to do was think.	Nandi goes out of the cameras site but you can hear her excitement.

The above transcript is taken from SANCP (2013) 13th presentation slide for Graven's presentation to the August 2013 Community of Practice Forum. Nandi's resistance to thinking for herself is particularly visible in this short almost a minute excerpt. She repeatedly returns to the facilitator and moans loudly when sent away and yet her excitement at finding herself in the end is visible as indicated by her jumping up and running to show her answer. Perhaps this incident may shift her towards a more independent learning disposition but longer-term research of Nandi's participation in clubs and classrooms would be needed to see shifted.

It is significant that in this study the unit if analysis is the student utterances and dispositional behaviours and not the facilitator or the mediation strategies of the facilitator. Also it is important to note that in this study I have not looked at the 'facilitator' per se or her approaches.

This said I do describe some general features (from the literature and the Chair's goals as for these clubs of the club purposes and intended approaches in the earlier chapters.) These are general and do not necessarily reflect the granular features of what a particular facilitator is doing in these sessions. I have of course provided examples of this facilitation in vignettes presented but these strategies or mediatory questions are not the unit of analysis.

Chapter 6:

Findings and discussion

6.1 The Goals of the research project

The goal of this study was to investigate 3 grade 4 learners' (evolving) mathematical learning dispositions while participating in an after school mathematics club and through this to suggest possible elaborations/adaptations for current definitions and instruments available for assessing young learner dispositions.

Research Questions:

To achieve the above goal, I endeavoured to answer the following questions:

1) What is the nature of the 3 learners' mathematical learning dispositions?
2) How might these dispositions evolve within the context of their participation in a weekly after school mathematics club over time?
3) What adaptations/elaborations of existing dispositional instruments are required to access and assess learner dispositions?
4) What are the implications of the research for adapting/extending Kilpatrick, Swafford and Findell's (2001) definition of productive disposition?

In the sections that follow I answer these question based on the data and learner stories presented in chapter 5. Section 6.2 addresses the first two questions where section 6.3 will focus on the latter two questions (thus the methodological contribution of the study).

6.2. The nature of evolving dispositions (Research Questions 1 and 2)

Analytic/propositional statements about the children's dispositions

Below I provide a series of analytic statements that emerge from my position in relation to the stories I have compiled of these three learners in the data and data analysis sections above. The learner stories were represented by their statements and explanations (written or oral) and their observed actions and responses in several club sessions to a wide range of mathematical tasks and activities. With only three children in the sample I cannot make claims at this stage about the dispositions of all children in the math's clubs or in the population at large.

Keeping the above qualifiers in mind, the following are some propositional or analytic statements about the children's dispositions that emerge from our interpretation of the data of this study. These statements all have in my view a reasonable level of support from the data even though to varying degrees.

Analytic Statement 1:

It emerges that two children can make big strides forward in their maths fluency but end up with a different profile or package of dispositions.

For example: We saw that Jade and Nandi both improved their math fluency by quite a lot as indicated by the tests but their profile of dispositions and whole character were clearly different.

Analytic Statement 2:

A disposition is not fixed: each day is different in terms of evolving dispositions. Dispositions go back and forth in that certain indicators can be stronger today and weaker tomorrow; it changes over time and grows and transforms.

For example: resilience in say Nandi was rather susceptible to whether she was tired or not. In both Jade and Nandi we saw an evolution in their confidence in themselves and in doing maths.

Analytic Statement 3:

A recurring manifestation of a disposition can lead to a greater confidence in believing that disposition is habitual (in a particular context) in responding in a particular way. Dispositions are enduring habits of mind that helps learners to respond to their experiences in a particular way. They are different from capabilities and abilities, they are a different kind of learning.

For example: The same evolution over the year in the confidence of Jade and Nandi in themselves and in doing maths reached a point where one might even conclude that in this context at least it was imbedded.

Analytic Statement 4:

The children were not as active or skilled as we had expected or would have liked in terms of reciprocity or participating with others on maths items in the after school maths club sessions.

In the original conception of the club a participationist rather than an acquisitionist approach to learning, which aims to have the children talk to each other about mathematics, sharing ideas, and communicating a lot with each other was proposed. But we recognized from the start that this would only develop with time. Over the year of the learners being together they did not seem to meet the facilitator's original, expectations in terms of communicating, sharing, and talking to each other. We should note that Jade was quite quick to want to be very active in sharing her feelings and views but these efforts were largely rejected by the others.

This lower than expected outcome for the club as a whole was perhaps disappointing for the facilitator, but provides cause for reflection. And raises such questions as: Were assumptions of the speed of this developing wrong? Did we take too much for granted that (reciprocity) would develop on its own?

Analytic Statement 5:

We see the children vary in their solution of maths tasks (e.g. routine, problem solving) where they may show a particular type of disposition, e.g. resilience. Resilience is about a learner or a student taking on in this case, a maths problem and sticking with it and not giving up, even when the learner doesn't know the answer. In other words resilience is connected to continuing to strive for a solution.

For example: we see Saki showed notable steady effort/resilience in doing his homework in his workbook well beyond the rest of the class, while Jade and Nandi both showed a notable absence of steady effort on their homework, doing very little of it. But Jade and Nandi showed a growing disposition of steady effort/resilience in maths problem solving in club session while Saki shared less of this.

Analytic Statement 6:

Two of the three children each acquired a wide repertoire of strategies for dealing with maths over the year with the program.

For example: Jade moved from a single strategy of ‘ask the teacher’ when faced with something she could not immediately do, to a much more active set of approaches with a positive view of herself: she asked the teacher, or person next to her, or discussed options. She said ‘if they are busy I’ll figure it out’ and she said she would experiment with game challenges.

6.3. Methodological insights from the study (Research question 2and 3)

The goal of this study was not to uncover some general truths about mathematical dispositions of the three children or children in general, but rather to enlighten us as researchers into methodological issues in investigating mathematical dispositions of young children. To find ways to observe and see manifestations of these dispositions; and signs of change in such; and possibilities for understanding and analyzing them; and to discover the strengths and weaknesses of the tools we are using and possibilities for the next steps forward.

The following are some of the methodological insights that emerge from the research experience and the data from the study:

6.3.1 Kilpatrick et al. (2001) disposition categories

The data generated by this study illuminated that Kilpatrick et al.’s (2001) productive disposition criteria (viz. sense making in mathematics, seeing mathematics as useful and worthwhile, believing they are effective learners and maths doers, believing that steady effort in learning mathematics pays off) were insufficient to fully tell the story of what we observed in the three children. Thus I have added those indicators of Carr & Claxton (2001) (viz.

resilience (adding this to steady effort), playfulness (adding it to sense making), and reciprocity which gave a richer and fuller picture.

However the data also pointed to three additional aspects (viz. resourcefulness (adding it to sense-making/playfulness), compliant behavior, enjoyment/affective relationship with maths) Further during the process of analysis data pointed to another new category (viz. language repertoire being able to describe mathematical activities/operations or what Heyd-Metzuyanim (2013) calls mathematizing as a criterion that points towards a shifting aspect of learners' mathematical dispositions.

6.3.1.1 Adding terms to sense-making

Kilpatrick's sense-making, includes makes sense of maths, making connections and seeing patterns, and seeing value in mathematics and seeing it as a tool that you can use in your daily life. Carr & Claxton's (2002) idea of playfulness refers to trying out new methods, dealing with a problem in an unusual way, and enthusiasm about challenges. I have added resourcefulness, by which we include creativeness, drawing from your own resources and thinking out of the box.

I felt that sense-making, playfulness, and resourcefulness, while very closely related, could each draw attention to and capture additional elements that could be observed. Yet they should still be grouped together.

6.3.1.2 Compliant behavior

Compliant behavior was not mentioned anywhere in the literature yet we observed examples of it and felt that it was sufficiently important observed behavior to make it a category of its own. Compliant behavior comes in a number of forms, such as wanting to please the teacher, which is something one may wish to interrupt as it relates to passive learning. For example, a learner would strive to remember exactly what the teacher said to answer a question or solve a problem. Another example is when a learner tries to be helpful by offereing to carry the teacher's bag, thus trying to please the teacher.

6.3.1.3 Changes in language repertoire

While examining the children's answers to certain interview questions at the beginning of the study, in the middle of the study and at the end of the period it was striking to observe in some of the children the changes and expansion of their language repertoire in describing mathematic activities, operations or solution strategies they might use. It could be that their use of language is a sign of an evolving mastery of elements of mathematics but could also be at the affective level of changes in confidence and attitudes towards mathematics. So for example the three children could only say one or two words to describe maths at the beginning of the year but this expanded significantly by a year later.

The literature on dispositions did not mention or speak to the use of language until very recently, which we have called 'language repertoire.' Heyd-Metzuyanim (2013) speaks of mathematizing, which relates to learners being able to describe what they do and how they do it. They called it 'learner-teacher talk relationship.' She viewed this as an additional tool for assessing dispositions. Further she argued that when the learner talks about maths objects and processes they change their teacher's views about them – their ways of being as perceived by the teacher and themselves.

6.3.1.4 Enjoyment/affective relationship with maths

Across the three learner stories I noted an increased enjoyment of participating mathematically both in what they said in the productive disposition interviews and by what was observed in sessions. I thus added this category to the Kilpatrick et al (2001) and Carr and Claxton (2002) indicators because I observed that expressions of enjoyment of maths was a frequent feature in our maths clubs and also students sometimes compared this experience with that of their formal classrooms.

6.3.2 Modifying the PD interviewing questions and approach

Limitations in the design of the PD instrument design were uncovered but we still see it as a work in progress. In designing the PD interview instrument the intent was to get the children's feelings about maths, and about themselves doing maths. And this was administered at first as an interview with oral questions from the interviewer but written responses by the child on the form.

We discovered in a pilot that while we had the intention to capture their view of doing maths from the discussion of the doing by the two imaginary children on the scale. We felt that this needed to be enhanced and triangulated with a more direct question of what they would do: and so added the question: 'What would you do if you don't know and answer to a maths question in class?”. This turned out to be very fruitful and they talked directly about themselves doing maths.

A further modification was in the way the interview was administered. We found that while the children could write answers, these were limited and time consuming. The limits to their answers could have been in part caused by the challenge for them in writing. So in subsequent administrations we directed oral questions to the children and then elicited oral answers and the interviewer herself wrote down their answers.

6.3.3 A vignette of an observed disposition moment is useful

While we (myself and my supervisor/facilitator) frequently reviewed all the videos of all the lessons in the analysis stage the question still remained could one identify and present specific examples of dispositions in action or transitions or tension of a disposition? Could one cleary identify a specific manifestation of a disposition and say there it is? I feel the value of this approach in contributing a lens and tool for drawing meaning from what was happening.

6.3.4 What have we learnt in how we chose to see a child’s disposition?

In summary this study has drawn attention to how we see a child’s mathematics dispositions is in part by seeing:

1. What strategies they use when responding to maths tasks and challenges.
2. We see a child’s resilience by interpreting what they say they will do or what we see them do in certain tasks. Some are routine tasks and some challenging maths problems but all are to be understood in a certain context.

6.4 Implications of the study

The study has pointed to the notion that dispositions need to be given more opportunities in mathematics activities in order to develop them. Furthermore the development of a child is strongly influenced by the teacher who frames and encourages how this is done. While this was small case-study research which has been based on the facilitator’s and the researcher’s story of learner stories it has illuminated for myself as a teacher several insights that I will take with me into my future work with learners. I discuss these briefly below. Additionally the study has pointed to the usefulness for researchers in combining and extending dispositional frameworks.

6.5 My process of learning

For my own teaching, this research experience of closely observing learner participation, has lead me to focus on the importance of working with learner attitudes and dispositions towards the subject and the way in which they participate. Thus I would actively pay attention to not only *what* they do mathematically but *how* they do it and how their conceptual understanding is linked with the way they participate. I have increasingly through this process become aware that the strands of procedural fluency, conceptual understanding and productive disposition are, as Kilpatrick et al (2001) have stated, complexly intertwined and all are needed to work together for progress to occur. So for example Saki's progress in mathematical proficiency was held back by his poor conceptual understanding and low levels of procedural fluency even while he had quite a productive disposiotion in terms of resilience and attitude towards the subject. His absence of sense-making – the aspect of Kilpatrick et al's (2001) defintion of productive disposition - is thus essential for progress and this sense making clearly links to conceptual understanding as this is defined in sense making terms. In contrast Nandi who showed the strongest of the three learners in terms of procedural fluency and conceptual understanding was hampered by her low levels of resilience, steady effort and perseverence in the face of more difficult or challenging problems. These three case study learners, while not generalisable, have provided me with powerful illuminatory vignettes which carry the theroetical insights of this study forward for me into my future teaching and work in mathematics education.

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APPENDICES

Appendix A

Matrix of raw data

School	Teache	No. of learner	No. answer	"Maths is …" Categories														
				Hard/ difficult	Easy	Counting	Numbers	sums or + - x ÷	Cool	Good/	The best/ best thing/	Thinking/ you think	Reading	Tests	Other	Incomplete	Incomprehensible	Illegible
A	A1	36																
A	A2	45																
A	A3	33																
B	B1	35																
C	C1	38																
D	D1	42																
E	E1	41																
E	E2	30																
F	F1	21																
G	G1	36																
G	G2	35																
G	G3	30																
H	H1	3																
I	I1	41																
I	I2	31																
J	J1	39																
J	J2	40																
J	J3	38																
Totals		**614**	**386**	**17**	**29**	**39**	**13**	**80**	**15**	**122**	**10**	**1**	**2**	**4**	**54**	**174**	**30**	**25**
% out of 614			**63%**													***28%***	***5%***	***4%***
% of total No. answered				**4.4%**	**7.5 %**	**10.1 %**	**3.4 %**	**20.7 %**	**3.9 %**	**31.6 %**	**2.6 %**	**0.3%**	**0.5 %**	**1.0 %**	**14.0 %**	**N/A**		

Appendix B

Test type	Description	Time allocation	Test out of …[2]
1. **Add and subtract to 10**	***Number range up to 10*** Use the numbers in the shaded header rows and shaded columns to add / subtract e.g. 2 + 3 = 5 and 10 – 2 = 8	1 minute for add 1 minute for subtract	48 48
2. **Doubling**	Double the shaded number e.g. double 4 is 8, double 2 is 4	1 minute	17
3. **Add / subtract 10**	Add 10 to / subtract 10 from the shaded number. e.g. 5 + 10 = 15, 12 – 10 = 2	1 minute	20 20

[2] Note: the sample sum in each test is not scored

Add and subtract to 10

Do as many of the addition sums as you can in 1 minute.

Then, when your teacher tells you to, do as many of the subtraction sums as you can in 1 minute. One sum has been done for you.

Name						Date					
Add +	2	4	1	0	3	Minus	10	8	7	9	6
3	5					2	8				
5						4					
4						5					
6						3					
7						6					
Score out of 48				Number completed				Number correct			

Doubles Double each shaded number. One sum has been done for you.

Name						Date					
5		4		2	4	6		7		8	
15		11		12		13		17		14	
16		18		22		25		24		34	
Score out of 17				Number completed				Number correct			

Add and subtract 10 - Add or subtract 10 to each shaded number. Do as many as you can in 1 minute. One sum has been done for you.

Name						Date					
Add 10		5	15	4		Minus 10		10		12	2
2		9		14		19		25		65	
36		42		99		98		108		205	
102		410		600		327		512		700	
Score out of 20				Number completed				Number correct			

Appendix C

MATHS IS ..... (complete the sentence) Phonics

Mpho is the weakest maths student in the class

Put a circle around yourself

Sam is the strongest maths student in the class

Tell me about Mpho in the Maths class: is whik

Tell me about Sam in the Maths class: I LOVE Sam Sam is good in Maths

Mpho is scared of maths because ___ (complete the sentence) LOVE Mathemtics

Sam loves maths because ___ (complete the sentence) He is good in Maths

Do you love maths or are you scared of maths? I don't like maths

What do you do if you don't know an answer in maths class? I ask teacher

Other:

10 jaar.

0533 Name: [redacted] Date: 30/05/2013 Club: St MDCC George Dickson (PD-ENGLISH)

SA NUMERACY CHAIR

MATHS IS ..... (complete the sentence) goed om te leer want dit help, om goed in die klas is; wil leer; leer die wiskunde; tel; plus, minus, jaag gelyke skryf nommers; club lekker want jy tel jou syme

Mpho is the weakest maths student in the class

Put a circle around yourself want ek skryf die nommers. want Sam is slim hy is goed in wiskunde

Sam is the strongest maths student in the class

13=4

Tell me about Mpho in the Maths class: hy goed in die klas hy skryf nie luister nie na juffrou.	Tell me about Sam in the Maths class: slim luister na die juffrou hy doen goed want hy ken sy werk want hy luister
Mpho is scared of maths because ___ (complete the sentence) wil nie leer nie want hy is nie goed nie.	Sam loves maths because ___ (complete the sentence) hy leer 'n klomp goed in wiskunde hy like dit
Do you love maths or are you scared of maths? lief want dis goed lekker om dit te doen hou om te tel	What do you do if you don't know an answer in maths class? vra die juffrou tel op my hande tel op die telkaart tel

Other: leer wiskunde baie want ons leer goed, wil om dat dit slim in die klas nommers tel en skryf

Appendix D

School: ... Mary's Primary

MP

SOUTH AFRICAN NUMERACY CHAIR

INDIVIDUAL INTERVIEW for MATHEMATICAL PROFICIENCY

GRADE 3 - AFRIKAANS

SA Numeracy Chair — Rhodes University, Where leaders learn

LEARNER & INTERVIEW INFORMATION		40 minutes	Date	17 FEB 2012
Surname	[redacted]	First name	Nosiphiwe	
Club	[redacted]	Gender	Male ☐ Female ☒	Age 9
Mentor	[redacted]	Interviewer	Debbie	

Instructions in **[bold brackets]**, what you say to the learner in *italics*

PART ONE – Qs 1 to 11

Numeral identification, FNWS, BNWS, Counting by 10s & 100s, Place Value

Task 1: Numeral Identification — W/CU

[Use number cards to show each number to learner. Tick if correctly identified]

Sê vir my wat noem jy hierdie getalle

6		11		20		99		101		208		300		1025		½		¼	
	✓		✓		✓		✓		✗		✓		✓		✗		✗		

Comments:

Task 2: Number Representations — A2/CU

[White card. Show 1 number line at a time] *Hier is 'n getallelyn. Sê vir my na watter getal die pyltjie wys.*

	Wrongly positioned?	Correct
(a) 15	11	✗
(b) Approx. 90	✗	✗

Comments:

No idea of no line halfway between 10 & 20

Task 3: Forward counting number word sequences — W/CU

[Ask orally] *Begin in ene tel vanaf ____ ek sal sê wanneer jy moet stop.*

	Skipped numbers	Last no counted correctly
(a) 1 to 32	✗	✓ 32
(b) 48 to 61	✗	✓
(c) 93 to 112	10 hundred	109

Comments:

quite confident in English & Afrikaans.

Task 4: Backward counting number word sequences — W/PF

[Ask orally] Example: *Tel terug vaaf 3. . .drie, twee, een.*

Tel nou terug in ene vanaf ___ gaan aan totdat ek sê stop.

	Skipped numbers	Last no counted correctly
(a) 10	✗	0
(b) 23 to 16	22	[illegible]
(c) 72 to 67	72, 62, 52	

Comments:
a) used fingers   b) fingers / switched between Eng/Af.   c) counted back in 10's.

Task 5: Number word before — W/PF

[Use green number cards for each number] Example: *Watter getal kom net voor 2? Sê nou watter getal kom net voor___*

Note each answer

(a) 9	8	*(b) 11*	10
(c) 20	19	*(d) 30*	29
(e) 50	49	*(f) 100*	99

Comments

Task 6: Number word after — W/PF

[Use green number cards for each number] Example: *Watter getal kom net na 1? Sê nou watter getal kom net na___*

Note each answer

(a) 4	5	*(b) 19*	20
(c) 25	26	*(d) 32*	33
(e) 70	71	*(f) 99*	100.

Comments
bigger numbers in English.

Task 7: Sequencing numerals — W/PF

[Show the green number cards face up in random order, asking the learner to identify each number as you put it out. Then say] *Kan jy hierdie kaartjies in volg orde sit? Begin by die kleinste getal.*

	Note sequence learner laid cards out	Sequence correct
(a) Cards from 0 to 10	all correct.	✓
(b) Cards from 46 to 55	46 48 ... 47-50. at end	

Comments:
Strategy - lay all out 1st & then order.

Task 8: Perceptual counting — W/PF

[Ask learner to place out counters for a & b. Note how learner counts these and the number counted]

	Counts in 1s?	Counts in multiple? Say which?
(a) Plaas 13 tellers uit vir my	✓	
(b) Plaas 18 tellers uit vir my	✓	

Comments:
by colour.   2 separate piles

Task 9: Counting with incrementing tens — W/AR&CU

[Use pink strip cards. Show strip (a) then add others for steps b to e. Ask] *Hoeveel kolletjies is daar altesaam?*

	Note Given Answer & How Answered	Correct?
(a) The 'four dot' strip		✓
(b) Add a 'ten dot' strip to the right	counted the strip.	14
(c) Add another 10 to make 24	added 10.	24
(d) Add another 20 to make 44	counted 1 strip	44
(e) Add another 30 to make74		

Comments:

(counted in 10's @ d & e)

Task 10: Adding / subtracting with tens — A2&3/PF

[Ask orally]

	Note Given Answer	Correct
(a) Voeg 10 by 92	10+92 said fingers. 102	✓
(b) Voeg 10 by 294 *(twee honderd vier en 'neentig')*	fingers from 294 303	X.
(c) Neem 10 weg vanaf 50	no fingers immed. 40	✓
(d) Neem 10 weg vanaf 700 (sewe honderd)	600	X

Comments:

Immediate, no hesitation

Task 11: Adding with incrementing hundreds — A2&3/PF

[Ask orally]

	Note Given Answer	Correct
(a) Voeg 'n 100 by 9	fingers ✓	109 ✓
(b) Voeg 'n 100 by 932 *(negehonderd twee en dertig)*	X.	
(c) Neem 'n 100 weg van 400	300	✓.
(d) Neem 'n 100 weg van 634	635	X

Comments:

b) "Can I do it like plus" used pencil & paper. - horizontal sum. didn't get answer.

END OF PART ONE

PART TWO – Qs 12 to 16

Early Arithmetic Strategies, Combining & Partitioning

Task 12: Horizontal sentences – Early Arithmetic Strategies W/AR

[Use blue sentence cards] *Sê vir my hoe sal jy die antwoord uitwerk vir die volgende:*

	Note Given Responses & How Answered	Correct
(a) 16 + 10 = ☐ *(b) So wat is 16 + 9?*	fingers 26 Immediate. 25	✓ ✓
(c) 42 + 23 = ☐ *If correct ask, het jy 'n ander manier of metode hoe jy dit uitwerk?*	63	
(d) 43 – 15 = ☐ *Repeat the question above*	28.	

Comments: very clearly. c) drawing circles for 42+23. counted on from 42
b) explained. - took one away.
d) used previous 42 circles, added 1. Crossed out 15, counted circles

Task 13: Number Stories– Early Arithmetic Strategies A2&3/SC

[Ask orally] *Ek gaan 'n paar woord somme uit lees. Antwoord die vraag aan die einde van die som.*

	Note Given Responses & How Answered	Correct
a) Daar is 12 mense op 'n bus en vyf klim af. Hoeveel mense is daar nou op die bus?	7	✓
b) Daar is 22 mense op 'n bus. 13 van hulle is kinders. Hoeveel volwassenis (groot mense) is daar?	36	
c) Daar was 18 mense op 'n bus. 8 mense klip op en 3 klim af. Hoeveel mense is daar nou op die bus?	23.	

Comments: Very good @ repeating story back
a) circles. very quick. b) 22+13 she said, 2 guess then counted. c) lines this time.

Task 14: Number Stories– Early Arithmetic Strategies A2/SC

[Use pale yellow card with sums] *Ek gaan nog 'n woord som lees. Hier is 'n paar somme. Sê vir my watter* ***som*** *sal jy gebruik om die vraag te beantwoord. Ek soek nie die antwoord nie.*

	Given Answer	Correct
(a) Daar is 43 kinders in die klas. 28 van hulle is seuns. Hoe gaan jy uitwerk hoeveel dogters daar is?	43+28	

Comments:

Task 15: Non-count-by-ones – Early Arithmetic Strategies W/AR

[Use the orange calculation cards. Note how learner arrives at answers]

	Note Given Answers & How Answered	Correct?
(a) Wat is 9 + 3	13	X
(b) Kan jy dieselfde metode gebruik om die somme uit te werk 9 + 4	~~Counted on~~ added 1 to previos 14	X
(c) en 9 + 5	added. 15	X
(d) Wat is 7 – 5	quick as a flash 2	✓
(e) Kan jy dieselfde metode gebruik om die somme uit te werk 27 – 5	circles. 22	✓
(f) en 47 – 5		X.

Comments:
e) circles.

Task 16: Number combinations W/PF

[Ask orally]

	Note answers
Ek sal 'n getal sê. Wat moet by kom om 5 te maak? *(a) 4* *(b) 0* *(c) 3*	1 5 very quick 2.
(d) Gee vir my twee getalle wat die getal 10 maak	5+5 quick
(e) Gee vir my nog twee getalle wat die getal 10 maak	6+4.
(f) Ek het 7, hoeveel het ek nodig om 10 vol te maak?	3 ✓ quick

Comments:

END OF PART TWO

PART THREE – Qs 17 to 24

Subitising, Multiplication and Division

Task 17: Visible items arranged in arrays – Subitising W/AR

[Use red dot cards. Show 1 at a time. Note how the learner counts & the given answer]

Sê vir my hoeveel kolletjies is daar altesame.

	Given answer	Counts in 1s/ multiples?		Which multiple?
(a) Show the 10 × 2 array of dots	20.	1s ✓	multiples ✓ 10	20
(b) Show the 5 × 3 array of dots		1s	multiples ✓ 3.	
(c) Turn (b) through 90 degrees		Recounts?	Instant answer?	

Comments:
a) counted 1st ten,) then in 10's b) 15 counted in 3's. c) 15 the same.

Task 18: Visible items arranged in arrays – Subitising A2/AR

[Show the cake cards 1 at a time. Note how the learner counts & the given answer]

Daar is 5 koekies in elke houer. Ek gaan vir jou 'n prentjie wys van wat die kinders gekoop het. Jy moet mooi daarna kyk en vir my sê hoeveel koekies het elkeen gekoop.

	Given answer	Counts in 1s / multiples?		Which mult. ?
(a) Natasha	6	1s	multiples	
(b) Rajesh	53.	1s	multiples	

Comments:

Task 19: Visible items arranged in arrays- Subitising A2/AR

[Show the apple cards 1 at a time. Note how the learner counts & the given answer]

Daar is 10 appels in 'n sak. Ek gaan vir jou 'n prentjie wys van wat die kinders gekoop het. Jy moet mooi daarna kyk en vir my sê hoeveel appels het elkeen gekoop.

	Given answer	Counts in 1s / multiples?		Which multiple?
(a) Dawn	20	1s	multiples	
(b) Gary	43.	1s	multiples	

Comments:

Task 20: Equal grouping of visible items – Subitising and Multiplication W/CU

[Use orange circle cards. Place down four circles with three counters on each. Show the difference between circle and counter. Note how the learner counts & the given answer]

	Given answer	Counts in 1s / multiples?		Which multiple?
(a) *Hoeveel sirkels is daar?*	4	1s ✓	multiples	
(b) *Hoeveel tellers is daar in elke sirkel?*	3	1s	multiples	
(c) *Hoeveel tellers is daar altesaam?*	12.	1s	multiples ✓ 3	

Comments:

Task 21: Equal grouping of visible items – Partition Division W/PF

[Place out a pile of 15 counters. Note how the learner counts & the given answer]

	Given answer	Works in 1s / ~~multiples~~?		Which multiple?
(a) Hoeveel tellers is daar?	15	1s	(multiples) 3's	2's
(b) Deel dit gelyk op tussen 3 kinders.		1s	multiples	
(c) Hoeveel kry elke kind?	5	1s	multiples	2's.

Comments:
a 3's then 2's.

Task 22: Equal grouping of visible items – Partition Division with Redistribution W/PF

[Place out a pile of 24 counters. Note how the learner counts & the given answer]

	Given answer	Works in 1s / multiples?		Which multiple?
(a) Hoeveel tellers is daar?	24	1s	(multiples)	2's
(b) Deel dit gelyk op tussen drie kinders.		1s	multiples	
(c) Hoeveel kry elke kind?	8	1s	multiples	
(d) Deel dit nou gelyk op tussen vier kinders.	6..			

Comments:
b) 2 or 3 @ a time.

Task 23: A2/PF

[Ask orally]

	Given answer	Correct
(a) Drie groepe van drie maak? (of drie maal drie is gelyk aan?)	6	
(b) Vier groepe van vyf maak? (of vier maal vyf is gelyk aan?)	20	
(c) Wat is tien groepe van vier?	40.	
(d) Wat is tien groepe van sewentig (70)?	170 ~~[illegible]~~	X

Comments: a) immediate answer.
b) drawing ○ ○ ○ ○ counted in 5's after 1st one 5, 10, 15, 20.
c) wanted to use counters, then drew – counted in 1s.

Task 24: A2/CU

[Show white marbles card] *Jane en Peter speel met albasters. Hier is 'n prentjie van die albasters.*

	Given answer	Correct
(a) Jane wen die helfte van die albasters. Hoeveel albasters wen sy?	4	✓
(b) Peter wen 'n kwart van die albasters. Hoeveel albasters wen hy?	2	✓

Comments:

END OF PART THREE

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90011597

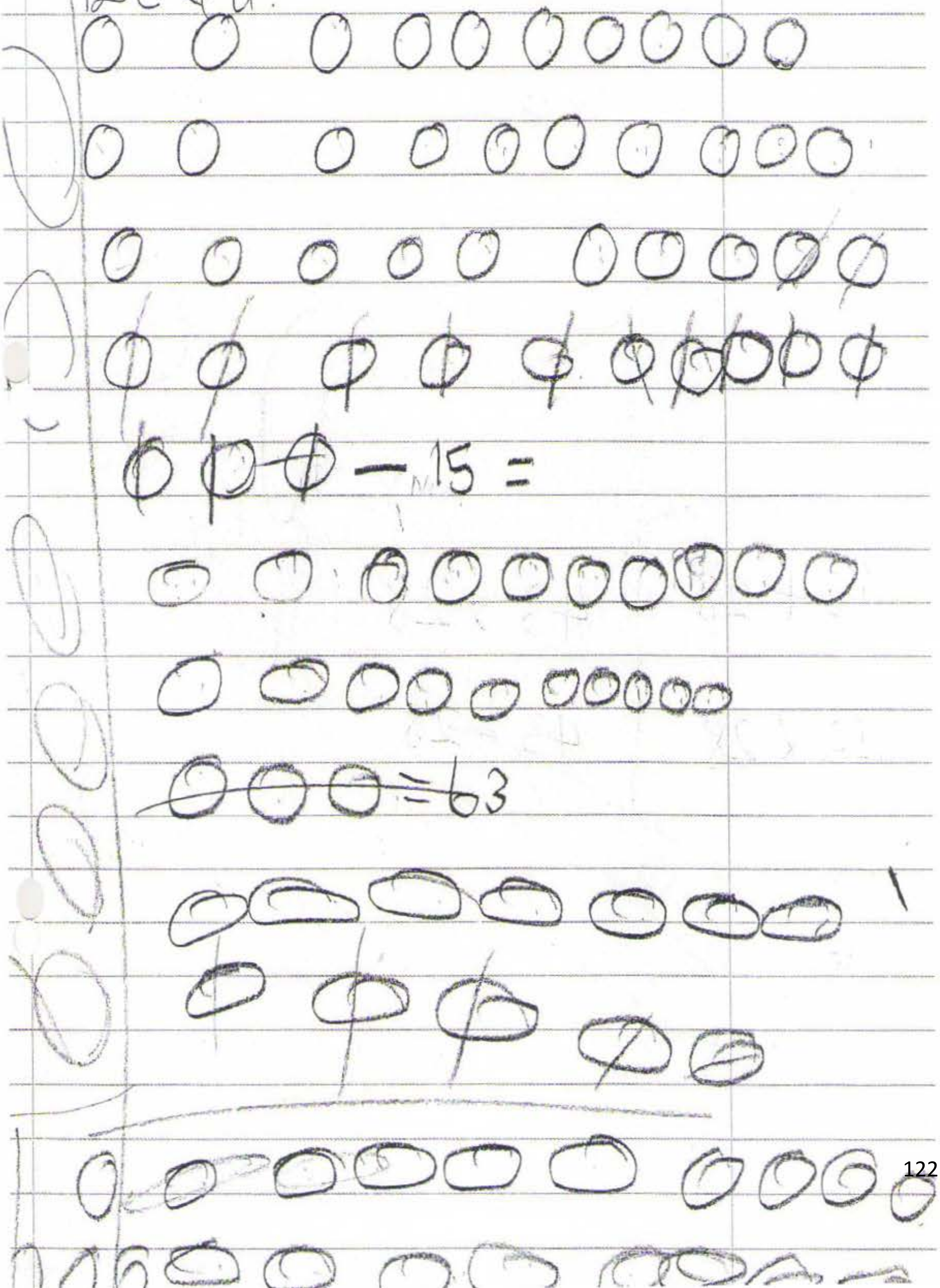
WERKOPDRAGSKRYFBLOK – ASSIGNMENT WRITING PAD
Skryf – Write

Dosent se Kommentaar
Tutorial Comments

[redacted] 48 93

923 932 + 100 =

12c & d.



Tik - Type

Dosent se Kommentaar
Tutorial Comments

2a1

3

43 + 28	43 ÷ 28
43 × 28	43 − 28

15a b:

9 + 3 = 13

9 + 4 = 14

23b.