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# USING FORMATIVE ASSESSMENT TASKS DIAGNOSTICALLY IN THE NUMERACY LEARNING PROGRAMME IN FOUNDATION PHASE CLASSROOMS




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**A research project by coursework and research report submitted to the Wits School of Education, Faculty of Humanities, University of the Witwatersrand in fulfilment of the requirements for the degree of Master of Education**

**Johannesburg, 30 August 2013**

## Abstract

The idea of formative assessment being used in teachers' instructional practice as a means to promote learning has evoked a number of research studies. In this study, I continue to examine the idea of formative assessment, but with, what is for me, a far deeper question in mind: "How can formative assessment practices be used to diagnose the quality of learning and understanding, and inform teaching instruction so as to improve learning?" In particular, this study investigates how Foundation Phase teachers use formative assessment tasks to diagnose learner difficulties, and to improve their methods of instruction in Number in the Numeracy Learning Programme.

This study is a small scale case study that used a qualitative approach. I used semi-structured interviews and non-participant observations to interpret and assign meanings to the practices of three Grade Two teachers that participated in the study, as they worked diagnostically with formative assessment in Number. The data was collected from four different phases: an interview with the teachers, prior to the formative assessment task they administered; observation of the teachers whilst they administered the formative assessment task; a second interview with the teachers, after the formative assessment task, the focus of which was the teachers' making a diagnosis of learning; and lastly, an observation of the follow-up lesson that was done by the teachers based on the diagnosis of learners' difficulties.

The findings were analysed in four categories, viz. 'Content Knowledge,' 'Instructional Practice,' 'Practices of Evaluation' and 'Socialisation.' Black and Wiliams' (2006) description of the activity theory of formative assessment was used as a broad framework to situate the discussion of the findings. The main finding of the study indicates that using formative assessment to diagnose difficulties learners are experiencing in Number and to improve the instructional practice is part of a carefully planned, 'scaffolded' cycle of events for each of the three teachers studied.

On the basis of what has been learned about this cycle six central claims are made: Firstly, the "learning analysis" (Black and Wiliams, 2006, p.95) that takes place throughout the 'scaffolded'[1] events involves careful planning by the teachers and does not only occur at one particular point. It occurs in each phase of the 'scaffolded' process and is an integrated part of the diagnostic assessment that takes place in the four phases. Secondly, there is a strong correlation between what the teachers understand as the relationship between formative assessment and diagnostic assessment, and the ways in which the teachers interact with the learners as they work with a 'scaffolded' process of formative assessment to diagnose the learners' difficulties in the learning of number. Thirdly, the decisions that the teachers make about the methods or strategies that they use during instruction is most often related to a particular purpose in the 'scaffolded' process. Fourthly, the


[1] 'Scaffolded' in this report refers to the carefully structured and planned cycle of events that occur as the teachers use formative assessment diagnostically in their teaching.

methods and strategies that the teachers use are not worked with in isolation. The methods are interrelated according to the purpose for which they are intended, as the teachers work with the different types and forms of mathematical knowledge, and as they use formative assessment to support the diagnosis of learning needs and improve instruction. Fifthly, while the teachers use particular methods or strategies in their teaching practice with varying frequencies, this is not an indication of some teachers being more inclined to use one method over another. The number of times that the method or strategy is used in the teachers' classroom practice is also determined by the purpose to which it is related in the 'scaffolded' cycle of diagnosing the difficulties the learners are experiencing in Number. Lastly, the views that the teachers have of learning and on the teaching of mathematics are demonstrated in the role/s that the teachers take as they proceed through the phases of the 'scaffolded' process of working with formative assessment diagnostically, in the methods and strategies that the teachers use and in the types and forms of mathematical knowledge with which they work.

## Declaration

This is to certify that the research report entitled “USING FORMATIVE ASSESSMENT TASKS DIAGNOSTICALLY IN THE NUMERACY LEARNING PROGRAMME IN FOUNDATION PHASE CLASSROOMS”, submitted by Lucinda Meyer as a research project by coursework and research report submitted to the Wits School of Education, Faculty of Humanities, University of the Witwatersrand in fulfilment of the requirements for the degree of Master of Education, is a bona fide record of research work carried out by me under the supervision of Professor Yael Shalem. The contents of this research report, in full or in part, have not been submitted to any other University for the award of any degree.

Lucinda Meyer

Date: 30 August 2013 Signature

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## Dedication

This study is dedicated to the late Hannlie Murray, who so willingly shared her research on the teaching of Mathematics in the Foundation Phase in South Africa with me and inspired me to pursue this topic.

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**Using formative assessment tasks diagnostically in the Numeracy Learning Programme in Foundation Phase classrooms**

## Chapter One

## Introduction

### 1.1. Context

> If students are to learn desired outcomes in a reasonably effective manner, then the teacher's fundamental task is to get students to engage in learning tasks that are likely to result in their achieving those outcomes…It is helpful to remember that what the student does is actually more important in determining what is learned than what the teacher does. (Shuell, 1986, p.429, as cited in Biggs 2003, p.1)

Perhaps it can be argued that the complexity of the role of the teacher in the learning process is not captured by Shuell (1986), but the idea that is foregrounded is that teaching can be thought of, metaphorically speaking, as the electric current between the switch and the bulb, or the catalyst through which learning is ignited. Therefore, learning cannot be simplistically viewed as a result of what the teacher does, but rather the meaning that is created by the learner as a result of both the teaching and learning experience.

This view of learning creates much debate and is one in which I frequently find myself engaged with colleagues at the school where I teach. It always provokes questions such as, "What is the learning outcome that we are working towards achieving?" "What are the constructs that are required to achieve the learning outcome?" "How will we tell whether the learner has achieved the desired outcome?" I argue that behind these questions is a far deeper one: *"How can assessment practice be used to diagnose the quality of learning and understanding, and inform teaching instruction so as to improve learning?"* It is my view that the teachers' ability to diagnose whilst assessing needs to be carefully investigated.

I argue that addressing the question of using assessment practices diagnostically[2] is crucial in a South African context, where there is an enduring concern to improve the quality of teaching and learning. The most recent assessment guidelines for the Foundation Phase[3] refer to teachers using assessment practices to make instructional decisions. In this, the ability to use assessment practices diagnostically

[2] 'Diagnostically' in the context of this research does not refer to clinical diagnosis, but refers to practices in which teachers evaluate and reflect on the teaching and learning experience and make instructional decisions based on these.

[3] Foundation Phase, in a South African context, refers to young learners in the first three grades of school.

is considered to be a fundamental aspect of the teaching and learning experience. This is captured in the following statements from the National Protocol for Assessment:

> Assessment is necessary to make the decisions that influence a learner's progress. It should therefore be viewed as a fundamental practice that happens naturally in the teaching and learning process. This means that learners in Grades R-3 should be assessed continuously to monitor their progress and make daily instructional decisions. (National Department of Education, 2007, p.1)

> [Informal assessment] should be used to provide feedback to the learners and teachers, close the gaps in learners' knowledge and skills and improve teaching. (Department of Basic Education, 2011, p.4)

Therefore, the challenge teachers in the country face is two-fold: Firstly, it is centred on the complex notion of how to observe and interpret learning which cannot be viewed physically and can, therefore, only be interpreted through assessment (Killen, 2003). Secondly, they face the challenge of determining how to use the information diagnostically, once the interpretation has been made, to make instructional decisions and structure the learning experience (Shepard, 2000; Gipps, 2004).

Current literature suggests formative assessment as the type of assessment practice that allows for diagnostic thinking. Black (2003, p.2) defines formative assessment as "a process, one in which information about learning is *evoked* and then *used* to modify the teaching and learning activities in which teachers and students are engaged." Formative assessment, therefore, provides a lens through which teachers can think reflectively, and consequently diagnostically, about the teaching and learning experience: "Reflectively," in that the teacher analyses the learner's performance in relation to his/her teaching and the learner's previous knowledge, and "diagnostically," in that the teacher has to make pedagogical decisions as to what the nature of the learner's weakness is, and how to go about addressing it.

### 1.2. Aim of study

The purpose of this study is to investigate how Foundation Phase teachers use formative assessment tasks to diagnose learner difficulties, and to improve their methods of instruction in the Numeracy[4] Learning Programme.

[4] Numeracy refers to the subject, mathematics, in the Foundation Phase. At the outset of the study the terminology used in the South African context was Numeracy in place of mathematics.

More specifically, this study focuses on teachers' use of formative assessment tasks to diagnose learner difficulties, and to improve their methods of instruction in the area of 'Number'[5] in the Numeracy Learning Programme.

The research is guided by the following questions:

### 1.3. Main research question

What process of formative assessment do Grade Two teachers use to diagnose and address learner difficulties in the concept of number, and to improve their methods of instruction?

### 1.4. Sub-questions

1. What aspects of formative assessment promote the practice of diagnosis in the teaching and learning experience?

2. What do the teachers understand as the relationship between formative assessment and diagnostic assessment?

3. How do the teachers use diagnostic assessment to interpret the learners' difficulties and attend to/improve their teaching?

### 1.5. Rationale and Significance

The reasons for the particular study are based on the following:

Firstly, as a previous University lecturer, both in a pre-service course in the area of Numeracy in the Foundation Phase and in a post graduate course in the area of Teaching and Assessment, I am particularly interested in studying how these areas (Numeracy, Teaching and Assessment) work in relation to one another. My interest in the relationship between Teaching and Assessment was first sparked by my personal experience as a Foundation Phase teacher. I recall the Head of Department telling me that assessment was something that was reliant upon instinct, or as she put it, "Going with your gut." I found myself feeling uncomfortable with this thought, because the assessment practice was not aligned to anything- it felt mystical. As a result, I have grappled throughout my teaching career to understand assessment practices and their relation to teaching and learning in my classroom. Subsequently, I have found that my teaching colleagues express experiencing a similar challenge in

[5] 'Number' in this study will focus on young learners' development of number concept. This includes the development of concepts such as numerosity, counting, number relationships, number patterns, place value, using known number facts and derived number facts, and performing the four main operations on numbers.

their classrooms. The relationship between assessment practices and teaching and learning in Numeracy are always expressed as a particular area of anxiety in the Foundation Phase. In order to understand the ways in which teachers are reasoning about the assessment of their learners in relation to what and how they teach, and more broadly in relation to the curriculum, this study explores the relationship between teaching, learning and assessment in Numeracy, and specifically in the area of Number in the Foundation Phase. In Biggs' (2003) terms, the questions of this study fall broadly into the research area of the alignment between Curriculum, Teaching and Learning and Assessment.

Secondly, based on South Africa's poor performance in systemic evaluations JET (Joint Education Trust), 2000); Grade Three Numeracy Challenge, 2006; (ANA (Annual National Assessments) 2011) and on international evaluations, such as TIMSS (Third International Mathematics and Science Study, 2003) and ICAS (International Competitions and Assessments for Schools, 2006), it is evident that while we know that the performance of learners in the Foundation Phase in Numeracy in South Africa is low, there is little knowledge of that with which learners struggle, little analysis of learners' errors and misconceptions, and almost no analysis of the ways in which *teachers try to diagnose and address these in their teaching*. Therefore, this study, hopes to gain insight into Foundation Phase teachers' understanding of formative assessment and its use diagnostically in the teaching and learning experience of Number in the Numeracy Learning Programme. Furthermore, it hopes to understand better the considerations, decisions and plans that teachers make when they use their assessment decisions to improve their teaching of Number in the Foundation Phase.

The remaining chapters of the research are structured in the following way:

Chapter Two situates the research study in relation to current literature on theories of learning, mathematics (Numeracy) teaching and the notion of formative assessment as a means to diagnose learners' learning.

Chapter Three describes the Four Phases of the research design and the methodology that was used for the study.

Chapter Four is a presentation and analysis of findings. The presentation and analysis of findings captures the "pedagogical moves" (see pp.32-36) that the teachers use as they work diagnostically with formative assessment. I discuss the findings using four main categories, namely: Content Knowledge, Instructional Practice, Practices of Evaluation and Socialisation.

Chapter Five discusses the pedagogical moves of the teachers by using Black and Williams (2006) activity theory of formative assessment as a broad framework to answer the three sub-questions. The findings in relation to the literature reviewed in Chapter Two are also discussed in this Chapter.

Chapter Six concludes the research by looking at the implications for teaching and learning when using formative assessment tasks diagnostically in the teaching of Number. It also discusses the limitations of this study.

## Chapter Two

## Literature Review

## Introduction

Changing assessment approaches in “an attempt to improve the [quality] of teaching and learning” (Vandeyar, 2005, p.464) has been emphasised in many instructional reform efforts (Sato et al, 2005). An important aspect of these changes in assessment has been the use of formative assessment in teaching and learning practices. I argue that the ways in which teachers use formative assessment diagnostically in their instruction is what needs to be examined more closely.

The literature review is presented by going from a wide-angle lens (an overview of the field) of teaching, learning and assessment, to a telephoto lens (focused view) on the diagnostic use of formative assessment in the teaching and learning of mathematics. The following structural organisation is used:

Conceptions and ideas of formative assessment, and how these relate to a reform mathematics curriculum, begins the discussion. This is followed by a review on local studies in South Africa on the teaching of Numeracy in the Foundation Phase, particularly in view of the new curriculum. International and local studies that focus on the conceptual difficulties learners in the Foundation Phase experience in studying Number are further considered, as are ways in which the teaching of Number can be improved in the Foundation Phase. The review is concluded with a discussion on how studies on formative assessment can help us to think about the diagnostic assessment of Numeracy in the Foundation Phase.

### 2.1. Shifts in conceptions of teaching and learning and assessment

In the framing of this research, it is important to consider the relationship of formative assessment to learning theories, as approaches to assessment cannot be thought of as something that occur in a vacuum devoid of epistemological views on the acquisition of knowledge (Argyris, 1976; Ramsden, 1992 as cited in Biggs, 1996). The notion of assessing for the quality of student learning, as opposed simply to the quantitative measurement of student learning in education, comes from a “major paradigm shift in thinking about learning and teaching” (Hargreaves, Earl and Schmidt, 2002, p.70). This is a shift away from what might be referred to as traditional theories of learning (Gipps and Cumming, 2004) to constructivist theories of learning (Shepard, 2000).

The traditional approaches to learning are largely linked to hereditarian theories of individual differences and to behaviourist learning theories (Gipps, 2004). The underlying principles of these theories view learning as an accumulation of atomised bits of information, where each objective must

be taught explicitly. Learning is further seen to occur in a “hierarchical, sequenced order” and the motivation for learning is thought of as something that is “external and based on the positive reinforcement of [specific] steps” (Shepard, 2000, p.94). Assessment practices linked to these theories of learning are based on what Gipps and Cumming (2004) refer to as a ‘*scientific*’ model of certainty and *objectivity*. In other words, they are based on the theory that certain skills or abilities are ‘out there,’ and these need only to be captured in test content that can be measured accurately or objectively (Gipps and Cumming, 2004). These objective tests are seen as ways of evaluating the learners’ abilities to recall facts and apply them in a sequenced, hierarchical and routine manner (Gipps and Cumming, 2004). In this view, assessment is primarily seen as a way of checking that the information that has been transmitted by the teacher is received. Therefore, learning is seen in quantitative terms (Cole, 1990 as cited in Biggs, 1996).

However, the constructivist theory of learning is centrally built on the notion that learning is an “active process of mental construction and sense making” (Shepard, 2000, p.6). Knowledge, as part of constructivism, is not thought of as something that is ‘out there,’ static and ready to be discovered, nor is it seen as something that is transmitted and received passively by the learner (Gipps and Cumming, 2004).

The sources of meaning for the “active process of mental construction and sense making” within the constructivist learning theory are approached from two schools of thought (Newmann, Marks and Gamoran, 1996). Some stress social sources of meaning (Vygotsky, 1996), while others stress individual sources of meaning (Piaget as cited in Ginsburg, 1985). Those that stress social sources of meaning emphasise that the new learning acquired by the individual is shaped by assumptions, motives, prior knowledge (Biggs, 1996), the “social context of values” and the “environment in which the information is first communicated” (Newmann et al, 1996, p.285). They argue that “learning activities are never considered separately from the context in which they take place” (Sfard, 1998, p.6). Those that stress individual sources of meaning believe that an essential aspect of intelligent thought involves the learner having the ability to process, interpret, negotiate (Newmann et al, 1996) and “self-monitor learning and thinking” (Shepard, 2000, p.6).

For the purposes of this study, learning, as part of a constructivist theory, is approached from the orientation that learning depends on the individual learner’s cognitive development, but the main focus for learning is on the “nature of the social interaction that surrounds the presentation of information and its later expression by the student” (Newmann et al, 1996, p.285). In this study, “social interaction” is investigated solely in relation to the practice of formative assessment, specifically in relation to teachers’ assessments of tasks.

What is apparent as part of this learning theory is that the making of meaning for individuals involves using “complex and diverse processes” (Gipps and Cumming 2004, p.2) of meaning-making. Biggs

(1996) and Newmann et al (1996) argue that crucial to these meaning-making experiences is that they are authentic (Biggs, 1996). Newmann et al (1996) describe authentic experiences or "authentic construction" (p.286) as involving application, interpretation and manipulation of information, and not simply retrieval or reproduction of information. Work produced by learners should not be "intellectually shallow" (Newmann et al, 1996, p.281). Learners need to be active and intentional participants (Cowie, 2005). The constructivist idea of learning has brought attention to the importance of activity in teaching (learners actively engaging in the learning experience through activity-based teaching) and the need for authenticity of this activity. However, what can be proposed is that to ensure "authentic construction" of activity in the learning and teaching experience, the teacher needs to develop diagnostic skills so that the activity can be used as a means to interpret the learning and improve the instruction.

Constructivism, unlike behaviourists, see cognitive performance as something that depends on the ways learners make meaning of what they learn and on the learning environment that the teacher creates, hence the notion that "all [learners] can learn" (Shepard, 2000, p.7). Learning is seen in qualitative terms (Cole, 1990, as cited in Biggs, 1996). Constructivists pay attention to the quality of teachers' engagement with learners' thinking. On this view, the most essential aspects are that learners need to be taught how to be actively involved in evaluating their work and teachers need to reflect on the learning process demonstrated in the learners' performance (Biggs, 1996 and Cowie, 2005). Assessment practice is an integrated part of instruction and needs to be used as a means to evaluate the teaching, as well as the learners' learning. Therefore, assessment practices should encourage a deep approach to learning, which allows the learner to engage with the learning activity meaningfully, rather than a superficial approach which arises from "an intention to get the [activity] out of the way with minimum trouble" (Biggs, 1999, p.4). Expectations are made explicit to the learners and assessment is used formatively as a means to support the learners' learning (Shepard, 2000). To this extent, I support Shepard's (2000) and James' (2006) view that teachers need to comprehend the relationship between assessment for learning and instructional practice. Teachers need to have an "insight into pedagogic strategies and approaches that support learners' learning" (Hodgen and Marshall, 2005, p.153) and which relate to the promotion of assessment for learning.

While this is true, in relation to this study, I propose that we are challenged to think about two key elements more deeply. If teachers are to use assessment as an integrated part of their instruction, they need firstly to understand the ways in which they can use their teaching to diagnose learning. Secondly, there needs to be an understanding of the insights that the teachers may gain about their learners' learning through the activities or tasks given, and thus, by implication, about their approach to teaching as well.

## 2.2. International shifts in the conceptions of teaching and assessment in Numeracy

School mathematics has not remained uninfluenced by these changes in the conceptions of teaching and learning. In her extensive work on teacher knowledge Ball (1993) emphasises the notion of learners actively constructing mathematical ideas and the value of authenticity of assessment tasks in mathematics teaching. In the move towards reform mathematics curriculum, Skemp (1989) discusses how important it is that learners' mathematical understanding is not based on the memorisation of rules, but rather that mathematics is taught in an exploratory, relational way. The conceptual knowledge or understanding that is created by the learner is "constructed anew by every learner in his own mind" (Skemp, 1989, p.203).

In the teaching and learning of mathematics, learners are increasingly required to "...experiment, and make arguments, [...] frame and solve problems" (Ball, 1993, p.373) and "...understand the significance of what they are doing" (Nunes and Bryant, p.5). Therefore, what have been referred to as reform initiatives have aimed at making the learning experience more participatory and discussion-based (Street, Baker and Tomlin, 2005, viii). In order to create this learning experience, the teacher needs to be knowledgeable about, and responsive to, the learners' own methods and ideas in Numeracy (Street et al, 2005). Thus, the type of teacher envisioned in a reform mathematics curriculum is one whose activities are guided by "deep disciplinary understandings" (Ball, 1993, p.373). An argument is made by Ball, Hill and Bass (2005) that these "deep disciplinary understandings" are more than just "knowing the subject" (p.20). They argue that the teaching of mathematics involves mathematical reasoning as much as it does pedagogical thinking (Ball et al, 2005). Teachers' mathematical reasoning and pedagogical thinking are interrelated and cannot be easily separated. To teach mathematical reasoning, the teacher requires more than knowing the answer. The teacher has to think from the learner's perspective and needs "to consider what it takes to understand a mathematical idea for someone seeing it for the first time" (Ball et al, 2005, p.21). It is from this perspective that Ball et al (2005) argue that "mathematical knowledge for teaching" consists of "two key elements: "common knowledge" of mathematics that any well-educated adult should have, and mathematical knowledge that is "specialised" to the work of teaching and that only teachers need to know" (p.22). "Specialised" mathematical knowledge includes not only the specialised content knowledge of mathematics that teachers need to have, but specifically incorporates what Shulman (1996) terms "pedagogical content knowledge" (p.9) and what Ball et al (2005) refer to as pedagogical thinking, or the practice of teaching mathematics. Ball, Thames and Phelps (2008) explain that pedagogical thinking comprises "everything that teachers must do to support the learning of their [learners] (p.395)." This requires that teachers are able to "make mathematical sense of students' work and [choose] powerful ways of representing the subject so that it is understandable to the [learner]" (Ball et al, 2008, p.404).

Boaler (2001) refers to the methods and strategies that teachers use in "making sense of [learners'] work" and in making decisions on ways in which to represent the mathematical content in the instructional practice, so that it makes sense to the learners, as: "teacher moves" (p.6), or what I refer to in this study as "pedagogical moves." In the following, I discuss a few examples taken from literature on reform mathematics and draw implications for the idea of diagnosis as an integral part of the teacher's "deep disciplinary understandings" and "pedagogical thinking."

Cobb, Yackel and Wheatley (1991) undertook an action research project to evaluate whether Grade Two learners, who were being taught using a reform curriculum (and more specifically a curriculum that was compatible with a socio-constructivist theory of knowledge), performed better than learners who were not involved and not taught using a reform curriculum. The findings indicate that the learners involved in the reform curriculum performed better. The research found that the "teachers initiate[ed] and guide[ed] both individual [learner's] construction of knowledge and the classroom community's negotiation of mathematical meanings and practices" (Cobb et al, 1991, p.24). In relation to my research question, I propose that in order for the teachers to have guided their learners that way, they would not only have needed "deep disciplinary understandings" and an understanding of the relationship of these to a reform curriculum, but they would also have had to use diagnostic assessment continuously. Teachers' diagnosis is required for working through differences between the ways learners are constructing mathematical concepts and the ways in which these are held by a mathematical expert.

Ball (1993), Hodgen and Marshall (2005) and Good (2008) show that teachers who engage authentically in reform curriculum not only have the "deep disciplinary understandings," but are able to respond in a meaningful manner in their teaching approaches to the previous knowledge and social experiences learners bring with them (Good, 2008). Good argues that "helping [learners] to make sense of the math they "do" is potentially a powerful strategy for increasing [learners'] understanding and the ability to apply mathematics" (p.12). Teachers get learners to discuss their solutions to mathematical problems (Ball, 1993) and alter their teaching strategies according to what they believe will have the most effect on learner achievement (Ball, 1993; Hodgen and Marshall 2005; Good, 2008). In the study done by Good (2008), appropriate teacher expectations for learners' learning and pacing are also highlighted as relevant to a reform curriculum and are discussed as having an impact on learner achievement. In order to ensure that they have appropriate expectations for learners' learning, Ball (1993) argues that teachers need to grapple with what is the 'right' choice. The teacher needs to make the 'right' choice as to what a worthwhile activity or strategy is, taking into consideration the present mathematical level of the learners and how to get them to transcend this level (Ball, 1993). Lampert's (2001) argument in her studies, which look at the teaching of mathematics, is comparable to that of Ball's (1993). She similarly claims that "the fundamental structure of activity in the practice of teaching involves a teacher doing something with students around something to be learned" (p.1). Learners' learning in the classroom requires the teacher to be

convinced that the instruction strategy will allow the learners to be involved in a process that will bring each learner to a deeper understanding of mathematics (Lampert, 2001). To engage the learner in the learning process, the teacher needs to make the 'right' choice with the instruction strategy.

Therefore, the teacher working with the kind of mathematical pedagogy as described in the studies by Cobb et al (1991), Ball (1993), Lampert (2001), Hodgen and Marshall (2005) and Good (2008) would need to make diagnostic assessments. In a reform curriculum, specifically in a mathematics curriculum, the type of teacher required seems to be: one who is able to use assessment practices to diagnose learners' responses to specific activities or tasks, in order to understand what concepts or parts of concepts learners are missing, and what mistakes learners make as a result of this. This kind of approach to assessment yields information that the teacher can use to gain specific insight into what the learner does or does not understand in mathematics and why. The teacher also uses this information to improve his/her methods of instruction. This ability to make diagnostic assessments from assessment practices is perhaps best captured in the words of Ball (1993, p.374): "The things that children wonder about, think, and invent are deep and tough. Learning to hear them, I think, is at the heart of being a teacher."

### 2.3. Conceptions of teaching and assessment in Numeracy in South Africa

In keeping with international trends, South Africa has moved towards a reform mathematics curriculum. In view of the weak performance of learners on national and international evaluations, it is interesting to review how this reform curriculum has been translated in Numeracy teaching in the Foundation Phase. Such a review provides an insight into the role that diagnostic assessment is seen to play in teaching and learning, and particularly in assessment practices as part of this new curriculum.

What is striking is that my quest to gather literature on teaching, learning and specifically assessment as part of the new Numeracy curriculum in the Foundation Phase in South Africa, revealed that there seems to be little research, let alone current research, to be reviewed. Current emphasis seems to be placed on systemic assessments that are focused on testing learners' mathematics achievement levels, for example, through Annual National Assessments (ANA) or the Southern and East African Consortium for Monitoring Educational Quality (SACMEQ). Research work that has been done (Murray, Human and Olivier, 1998) is based on a problem-centred learning approach (compatible with a constructivist view of learning and therefore, a reform mathematics curriculum) and not specifically on the new curriculum[6]. Therefore, the primary purpose of the studies reviewed in this section is to provide some context around primary school (where possible, specifically Foundation Phase) reform mathematics in South Africa.

[6] The new curriculum being referred to in this study is The Revised National Curriculum Statement that was gazetted in (2002)

As early as 1986, more than 10 years prior to the official introduction of the new curriculum in South Africa, Nick James reported in his study that he conducted in primary schools, both locally and internationally, that the focus of most mathematics teachers was on the answers to problems and whether they were wrong or right. James (1986) argues that what is necessary in approaching mathematics teaching is to understand the underlying process (thinking) that learners use to solve problems. James claims that the essence of learners' conceptual understanding of mathematics is to be found in the analysis of their thinking. The feedback that teachers gain about the learners' thinking, by analysing the process undertaken to solve problems, is crucial in gathering insights into the learner's conceptual understanding.

James' study provides evidence that in South Africa, prior to the introduction of the new curriculum, there were the beginnings of a shift towards the importance of considering learners' thinking in understanding their mathematical constructions. There was a move towards teachers making the 'right choice' (Ball, 1993) in relation to their learners' mathematical understandings and the teaching strategy that they used. This choice was to be decided upon by teachers analysing the thinking process their learners used to solve problems. The strength in James' argument lies in the idea that the analysis of learners' thinking in solving problems is central to the teaching and learning of mathematics. However, whether the response is right or wrong cannot be thought of as secondary to the process, but rather that the analysis of the process of learners' thinking is what leads to an understanding of the answer given. The analysis of the process becomes central in guiding "… both individual students' construction of knowledge and the classroom community's negotiation of mathematical meanings and practices" (Cobb et al, 1991, p.24). I suggest that diagnostic assessment can be thought of as a conceptual tool that can be used to bridge the 'gap' between understanding the learner's thinking process and the answer given when solving problems.

Murray (2000), after a number of studies (1991; 1993; 1998) on a problem-centred learning approach in the teaching of primary school mathematics in South Africa, some of which involved the Foundation Phase, describes what she considers important in assessing learners' mathematical reasoning. She argues that learners' mathematical learning consists of a combination of learners' personal and social constructions. These constructions:

> are constrained by the quality of previous constructions, by the beliefs of the student about the nature of mathematics and what type of behaviour is required from [them], and by the types of tasks and learning culture to which [they] are exposed. (Murray, 2000, p.1)

Murray's argument concurs with that of Nick James. In 1989, Murray, Human and Olivier started an experimental project for the implementation of a problem-centred learning approach for the teaching of mathematics. By 1993, the lower primary grades of more than a thousand schools, from more than five Departments of Education in South Africa, were involved (Murray et al, 1998). Two Departments

compared project schools with control schools. When the frequencies of the number of correct answers for a particular test are plotted for students who participated in the project against the control schools, it is evident that the project students performed better than the students who experienced traditional teaching. Independent sources (James and Tumagole, 1994; Taylor et al, 1995; Newstead, 1996; 1997, as cited in Murray et al, 1998) conducted further evaluations of the project and the findings indicated that in the experimental schools there was a marked improvement in the Grade 1 – Grade 4 learners' mathematical conceptual understandings.

The findings of the experimental schools that participated in Murray, Human and Olivier's study (1993) link back to the international studies done (Cobb et al, 1991; Ball, 1993; Lampert, 2001; Good, 2008) and draw our attention to the kind of assessment required in successful reform curriculum and by implication, to the idea of diagnosis being an integral part of teachers' understanding of learners' mathematical thinking.

> What concerns [the teacher] is the ways in which the subject may become part of experience; what there is in the child's present that is usable to reference to it; to determine the medium in which the child should be placed in order that growth may be properly directed. (Dewey, 1902 as cited by Ball, 1993, p.23)

The teacher needs to consider carefully where the learner's "present [point of] reference" is (which includes the learner's social experiences and mathematical understandings) and how this can be used to "grow" or deepen the learners' mathematical thinking or understanding.

I propose that the complexity of the diagnosis is about understanding the *quality* of learners' thinking. This aligns with the statement by Cobb et al (1992 as cited in Murray et al, 1993, p.1) that "the central issue is not whether students are constructing [mathematical ways of knowing], but the nature or quality of those constructions." This also suggests that activities or assessment tasks that teachers design not only need to build on previous constructions, but should also be designed as a means to interpret the *quality* of learners' thinking and mathematical constructions (both previous and immediate).

Murray et al (1998) conclude that for success in problem-centred learning, teachers need a precise understanding of how to *interact* with learners' mathematical knowledge (Murray et al, 1998). This emphasises the need to have teachers in the Foundation Phase Numeracy Programme who can make decisions related to what information, physical objects and explanations they need to provide in order to create a learning environment that allows learners to process their personal and mathematical constructions (Murray et al, 1998).

Murray et al's view is a challenging one, particularly in view of research which shows that teachers struggle to move away from a conception of mathematics being a set of algorithms which are learned

through doing calculations with specific steps for each calculation (Wilson-Thompson, 2005). Wilson-Thompson argues that teachers tend to tell their learners what procedures they need to follow, but they struggle "to adopt a process-orientated view of learning" or to provide support "in the development of [learners'] own concepts" (p.68). This argument is significant to the current study in that it reminds us that although in theory notions on reform mathematics curriculum are not completely new in South Africa, teaching, learning and specifically assessment related to this type of curriculum are, in many ways, still in their infant stages. Wilson-Thompson concludes, with regard to the understanding of formative assessment, that although teachers formally understand the value of formative assessment in seeing evidence of learners' mathematical thinking, their "constructs about mathematical learning and assessment are still heavily influenced by the old curriculum and practices" (p.68). The new curriculum in South Africa, according to Wilson-Thompson, seems to have been implemented at the level of policy, but there appears to be little support around the shifts in the teaching of the content. This study continues with this idea, focusing primarily on teachers' ability to diagnose learners' processing of mathematical content in order to identify the gaps in their construction and the scaffolding they need.

### 2.4. Foundation Phase learners and the study of Number

The discussion up to this point has established that while a reform mathematics curriculum holds promise for change and improved learner performance, successful practice in the classroom requires teachers to have an unambiguous sense of the relationship between teaching and learning and assessment. Essential to this is teachers' understanding of how mathematical conceptual understandings are developed in the various areas of mathematics. It is through this understanding that teachers are able to align assessment practices to elicit learners' conceptual understanding, to focus on their difficulties and improve instruction (Biggs, 1996).

This section examines the ways in which teachers use formative assessment tasks diagnostically in the teaching of Number in the Numeracy Learning Programme in the Foundation Phase. The way in which learners acquire a conceptual understanding of number (number concept) is considered in the discussion that follows. Through this discussion, the conceptual difficulties that learners might experience in developing number concept and what needs to be considered by teachers in diagnosing learner difficulties in the teaching and learning experience are foregrounded.

A broad description of number concept is:

> the "feeling for" and understanding of the "how manyness" [numerosity] or value of a number. Learners with a good concept of number have developed many relationships among numbers, realise that numbers have relative magnitudes, and can perform the four main operations on numbers. For example, such learners will understand that "seven" is more than the counting of

> seven objects or the naming of a group of seven objects as "seven." They will understand that seven is one more than six or one less than eight, three more than four, forty-nine divided by seven. Seven like any other number is a complex set of ideas. (McDermott and Rakgokong, 1996, p.46)

Piaget's (as cited by Kamii, 1989) distinction between different types of mathematical knowledge is useful for developing a sense of the processes by which young learners learn about number and develop number concept, as described by McDermott and Rakgokong (1996). The first type of knowledge is "*physical knowledge,"* i.e. the knowledge that the learner gets from physical objects and manipulating them. This type of knowledge forms the base for the learner's knowledge of number: only by counting and handling real objects can the learner initially learn about number. The second type of knowledge is "*social knowledge."* This includes rules of behaviour and ways of communicating all the information that a group of people needs to function successfully as a group and more broadly, as a society. This type of mathematical knowledge includes: terminology, such as number names and notation, for example, the symbols for numbers and operations. This type of knowledge is arbitrary and differs from society to society. The learner can only learn "social knowledge" from others and cannot construct it for himself/herself. The third type of knowledge is "*logico-mathematical knowledge,"* and is the knowledge that learners construct by themselves, for themselves. In this type of mathematical knowledge, the learner thinks beyond the knowledge that was obtained from handling physical objects or from listening to others; it is internal knowledge formed in the brain and is decontextualised. The learner is able to notice relationships and patterns among numbers. For example, '9 + 9 = 18, therefore: 18 – 9 = 9.' It is actively constructed in the mind of the learner and by understanding more than that which is seen. It results from what Piaget (as cited by Kamii, 1989) calls "reflective abstraction."

Murray, Human and Olivier (1992) argue that learners need to be given the opportunity to construct their "logico-mathematical knowledge" of number by engaging in appropriate activities. The teacher is crucial in providing these appropriate opportunities and activities for the learners. In order to select appropriate activities, the teacher not only needs an understanding of the different types of mathematical knowledge (Piaget as cited by Kamii, 1989) and their role in the development of number concept, but also ways in which to elicit and monitor the difficulties that learners are experiencing when engaging with the different types of knowledge. Studies (Hart, 1982; Murray et al, 1992; Askew, Bibby and Brown, 2001) have shown that some of the difficulties learners experience when solving number problems are as a result of learners applying "social," and not "logico-mathematical knowledge," or learners not progressing conceptually in their "logico-mathematical knowledge" to apply more effective strategies. For example, using recalled and deduced number facts rather than counting as a strategy. Hart (1982) explains in his discussion of teaching number operations that the "emphasis must change from algorithm-learning to understanding the structure of the operations themselves and how and when they should be applied" (p.47). Learners need to be encouraged to

apply their “logico- mathematical” understanding of number to make mathematical decisions and to work with effective strategies. The challenge that teachers face is using assessment tasks as a tool to structure appropriate activities for learners to construct, progress and develop in their “logico-mathematical” understanding of number.

In general, there seems to be agreement in research studies that there are different levels and a sequence through which learners’ progress in developing an early number sense (Kamii, 1989; Askew and Brown, 2003; Murray et al, 1992). These levels and sequence are important to consider when diagnosing learners’ understandings, as evidence suggests that “learners can be taught to progress [using these levels]” (Askew and Brown, 2003, p.6). For example, in a research study conducted by Askew et al (2001), teachers worked with low attaining learners, between the ages of 7 and 8, who were relying heavily on counting methods for computation and were not effectively using known and derived number facts in their computations. The study investigated ways of developing the learners’ competence and confidence with numbers, by teachers identifying the number of facts the learners did know and using this knowledge as a way to get the learners to use these known number facts to deduce unknown number facts. In so doing, the learners developed more efficient ways of working with number and were not as heavily reliant on counting as a method of computation. In an assessment after the intervention had taken place and teachers had identified effective strategies to use with the learners, the low attaining learners in the study out-performed a control group, who initially had three times as many known or derived facts (Askew et al, 2001).

A broad description of the levels or sequence through which learners develop an early number concept is as follows (it is linked to the sophistication of the learners’ counting strategies): Murray et al, (1992): *Level 1* – the learner has not yet constructed the numerosities (value of a number) of a particular range of numbers and has to create each number anew before he/she can use it; and this has to occur repeatedly. For example, to compute 3 + 2, the learner has to count (probably using concrete apparatus or tally markings) “one, two, three,” before he/she can use 3 as a number. The learner will then count “one, two” before 2 can be used as a number. Finally, the learner will count “one, two, three, four, five,” even though the second computation comes immediately after the first. This is referred to as ‘*counting all*.’ *Level 2* – the learner has constructed the numerosities of a particular range of numbers. When asked to find out how many pieces of fruit he/she has, if the learner has 3 apples and his/her mother gave them 6 pears, he/she would initially say, “three, four, five, six, seven, eight, nine.” This is called ‘*counting on,’* because the learner does not need to ‘make’ the 3 first by counting “one, two, three.” Eventually the learner also begins to realise the commutative property of addition and that counting on from the bigger number is faster. The learner accepts numbers in a particular range as abstract wholes which exist in his/her mind independently of concrete apparatus or counting acts. This notion of number is still not sufficient, because the only way that a learner at this level can solve a problem, like 25 + 48, is to count in 1s from 48 onwards. *Level 3* – having constituted numbers in a particular number range as a whole, the learner must now be able to

decompose the number into smaller parts that he/she has chosen for convenience. For example, to add 25 + 48, the learner might think of 25 as 23 and 2, enabling him/her to add 2 to 48 giving 50, or alternatively, the learner might prefer to think of 25 as 20 and 5 and 48 as 40 and 8, which makes it possible to add like this: 20 + 40 → 60 + 8 → 68 + 5 → 73. Different learners find different strategies easier and therefore, learners should not be taught only particular ways to decompose. It is at this level that learners begin to use known facts and derived number facts. For example, the learner might know that the double of 7 is 14 and use this to 'figure out' that 14 + 1= 15, that is, one more than the double of 7. *Level 4* – at this level a number is treated by the learners as "so many tens" and "so many units," e.g. 54 is regarded as consisting of five tens and four units. True understanding of this concept of number implies that the learner can temporarily treat the 5 of 54 as only a 5, keeping in mind that it is really 5 tens and not 5 ones. This level is quite confusing for younger learners and is not seen as an absolute necessity to younger learners' understanding of number. What is important to highlight is that in a particular number range, a learner might operate at a different level, for example, at level 1 for two-digit numbers and higher levels for smaller numbers (Murray et al, 1992). Furthermore, as learners' number concept develops in the solving of problems, "…strategies are modified, some are complemented, some are abandoned, while some new ones are constructed from bits and pieces of existing procedures" (Mamasse, Bletsas and Marti, 2000, p.5).

Although there is some disagreement on the order of development of strategies involving the addition and subtraction of numbers from 20 to 100 (Askew and Brown, 2003), the levels discussed are useful for the purposes of this study in that it has been proposed that the "method of computation reflects the maturity of the child's number [concept]" (Murray et al, 1992).

I propose that the levels provide a tool to guide diagnostic assessment about the manner in which young learners are thinking about number. Teachers can therefore set mathematics activities and assessment tasks in which problems are posed and the learner's method of computation is observed and diagnosed to ascertain learner understandings and difficulties in number concept. This can be used to improve instruction, particularly with lower attaining learners, much like the project that Askew et al (2001) undertook.

### 2.5. Improving the teaching of young learners' understanding of Number

Once learner difficulties in the understanding of Number have been diagnosed through the assessment practice, what becomes important is how this information gets used to improve instruction. What does the literature suggest as ways in which the teaching of Number can be improved with young learners? Before attempting to answer this question, it is important to note that there are many factors that can be considered when teaching mathematics to learners who are experiencing difficulty (Haylock, 1991). For example, reading and language problems, perceptual problems, social problems and mathematics anxiety may all be contributing factors (Haylock, 1991).

While these factors will not be discussed in detail or considered in the current study, I am not suggesting that that they are not very real and pertinent considerations. For the purposes of this study, I firstly discuss some general notions of effective Numeracy teaching that are relevant to the current study and secondly, the specific ways to improve the teaching of Number to young learners.

In a study done by Askew, Brown, Johnson and William (1997) to identify and describe the general characteristics of effective Numeracy teaching, a significant finding was that there is an association between learner gains and teachers' beliefs about how learners learn and how best to teach Numeracy. Teachers who worked both with their learners' existing understandings (mathematically and socially) and taught mathematics as a set of connected ideas had classes that made greater gains than either the group of teachers who put more emphasis on learners' learning, or the group of teachers who focused primarily on the act of teaching. By implication, this suggests that to improve learners' mathematical understandings, teachers need to have the belief that working with learners' existing mathematical understandings is essential. This is particularly relevant when working with a constructivist view of learning. Teachers' ability to question at a high cognitive level is also noted as important when working with the learners' existing mathematical understandings (Bennett, 1976; Galton and Simon, 1980, as cited by Askew et al, 1997).

Haylock (1991), in his studies, found three important ways to help learners who were experiencing difficulty understand mathematical ideas and processes. Firstly, he found that it is important for someone to explain the mathematical ideas and processes to the learners and not just leave them to try and make sense on their own. He argues that in the explanation, it is important that learners are given practical experience of the mathematics and are not just told how to do the procedure. Secondly, he found that there need to be "discussions between [learners] and between teachers and learners" (p.47). He states that by articulating their mathematical ideas, learners are able to clarify their understanding of concepts and develop a sense of the language patterns of mathematics. Lastly, he found that learners who are experiencing difficulty with mathematical concepts are more likely to perform better if the mathematics is set within a context that is meaningful and to which learners can relate.

Murray et al (1992), Askew and Brown (2003) and Askew et al (2001) argue that teachers need to plan for the improvement of learner understanding, by carefully considering the maturity of the learners' number concept. This should include the understanding of number that learners bring with them from a social context. For example, very young learners often come into formal schooling being able to rote count. In creating a learning environment that is conducive to learners developing or improving their number concept, learners need to be given the opportunity to gain "physical knowledge" of number, for example, by counting real objects. They should also be given the necessary "social knowledge" regarding number by, for example, integrating number names with all counting activities. Most importantly, learners need to be given the opportunity to construct their

"logico-mathematical knowledge" of number by engaging in activities that encourage them to think about number, such as through carefully set word problems (Murray et al, 1992). In developing or improving number concept in young learners, teachers need to "…allow learners to acquire and apply knowledge of numbers, number relations and number operations based on the integration of understanding, techniques, strategies and application skills" (Askew et al, 1997, p.3). Activities or tasks, therefore, need to be planned so that learners have opportunities to apply skills, different strategies and techniques using number.

Through the study done by Askew and Brown (2003), which was specifically aimed at investigating ways of teaching learners to be numerate and to improve the teaching of Number, the following come up as points to consider: Young learners need to feel free to use a variety of ways, including conventional numerical symbols, to support simple problem solving, and not necessarily only use their "own idiosyncratic notation" (p.4). That is, learners should, in early development of number concept, be permitted to use numerical symbols if they have the capability and understanding and not be limited to solving problems by inventing idiosyncratic symbols. Learners also, most importantly, need to be encouraged to use more effective counting processes. Marmasse et al (2000) note that skilful counting as well as gradual understanding of the numerical system is what improves the learners' number concept. Therefore, learners need to be encouraged to progress through the levels of development of number concept and consequentially, their sophistication in counting skills. Marmasse et al (2000) note that learners with a better number concept are, "able to decompose numbers into smaller groups, usually around powers of 10 and 5, depending on the kind of problem, or regroup them later, simplifying their problem solving strategies" (p.5). This ability to regroup and decompose (derived facts) accelerates problem solving and improves number understanding (Marmasse et al, 2000). Given the mental strategies young learners use (decomposition and recomposition), Askew et al (2001) propose delaying the teaching of algorithms that focus on a digit's column value. Hence, learners' conceptual understanding of number needs to be developed first before particular methods or procedures are taught (McDermott and Rakgokong, 1996).

What seems essential for the improvement of Number teaching and implementing the suggestions made in the above literature is teachers' ability to assess learners' mathematical understandings of number continuously. Based on the diagnosis of the assessment, teachers then need to think reflectively about how to improve the teaching of Number.

### 2.6. Studies on formative assessment and on teachers' diagnostic assessment

The review thus far has argued that the *diagnosis* involved in assessment, and particularly assessment in Numeracy (in the area of Number) in the Foundation Phase, is an important consideration if teachers are to engage authentically with the notion of 'assessment for learning.' Teacher diagnosis "not only provides information that a student does not clearly understand a

particular topic; it also provides specific insight into *what it is that the student [does] or does not understand*" (Ciofalo and Wylie, 2006, p.2). This information is then used by the teacher to improve instruction. What is important in the diagnosis, and has not been specifically 'unpacked' in the review thus far, are some of the considerations for diagnostic thinking and as a consequence, diagnostic teaching.

As discussed in the opening section of the review, formative assessment has been suggested as an assessment practice that enables diagnostic thinking. Notwithstanding, that there are debates in the literature about the roles of teachers and learners in formative assessment (Cowie, 2005; Hodgen and Marshall, 2005) and more broadly about the conception of learning that underpins the idea of formative assessment (Hargreaves et al, 2005). For the purposes of this study, Black's (2003) definition is used. Formative assessment is defined as "a process, one in which information about learning is *evoked* and then *used* to modify the teaching and learning activities in which teachers and students are engaged" (p.2). At the centre of formative assessment is finding "ways to help students restructure their knowledge to build in new and more powerful ideas" (Black, 2003, p.10). In order for teachers to help learners restructure their knowledge and build new and more powerful ideas, teachers need firstly to be able to establish the existing knowledge and ideas that the learners have and secondly, use this information to restructure learners' knowledge through improved pedagogy. The ability to do this requires teachers to think diagnostically.

Therefore, learners' prior or existing knowledge (socially and mathematically) as well as the *quality* of the information that the teacher gains about learners' understanding of concepts and ideas are important considerations in formative assessment practices and in diagnostic teaching. It is for this reason that, as part of the review, I focus on studies that particularly look at the areas of prior knowledge and feedback as part of formative assessment practices.

A number of studies on teaching and assessment practices (Newmann et al 1996; Gipps, 1999; Boaler, 2001; Killen, 2003; Sato, Coffey and Moorthy, 2005) note the importance of taking prior knowledge into account. Boaler argues (2001) that it is not as simple as stating, as Delpit and Lubienski (as cited by Boaler, 2001) do, that structured approaches to the teaching of mathematics are more likely to achieve equity, because working class learners are more likely to learn in this way as a result of their differences in prior knowledge and experience. She argues that schools need to focus on "learning practices" (Boaler, 2001, p.10) and adjust both teaching and learning methods accordingly and explicitly. Boaler (2001) provides an example of this by saying that teachers need to provide contexts in which the requirements of a task are interpreted for learners who might need help. This can be done, for example, by discussing a context collaboratively, so as to navigate between different frames of reference (different prior knowledge). The significance of the study done by Boaler (2001) to the current study is that teachers finding ways of working with prior knowledge is an essential component to the success of formative assessment. Navigating between and taking prior

knowledge into account becomes central to the diagnostic assessment of Numeracy in the Foundation Phase.

Killen (2003) further illustrates the role that prior knowledge plays as part of formative assessment when he cites an example from a study that he conducted, which involved teachers giving their learners a test involving algebraic equations. The teachers are reported as being satisfied that those learners who did not do well, "had a 'poor' knowledge of basic algebra" (p.5). Killen, however, reports that interviewing the learners who had scored low marks in the test helped establish that in fact the learners' basic arithmetic skills were limited. This illustrates the need for the teachers to have considered the learners' prior mathematical knowledge before designing the test and also in the evaluation of the results. For effective diagnostic practices using formative assessment tasks, teachers need to evaluate their learners' prior knowledge (socially and mathematically) carefully.

Shepard (2000, p.11) perhaps captures the role of prior knowledge in constructivist learning and thus, formative assessment practices, most aptly when she says that "good teaching constantly asks about old understandings, in new ways, calls for new applications, and draws new connections." The teacher needs to ensure that the integration of teaching and formative assessment is designed in such a way that there is an allowance for relating old understandings to new understandings, so as to transfer knowledge and construct new knowledge (Shepard, 2000). I am of the opinion that by using formative assessment tasks diagnostically, this can be achieved in Numeracy teaching in the Foundation Phase.

The quality of the information gained about learners' understanding in diagnostic assessment using formative assessment practices is equally important to that of prior knowledge. Studies on formative assessment (Biggs, 1999; Shepard, 2000; Black, 2003) and diagnostic assessment (Hodgen and Marshall, 2005; Shute, 2008) note the feedback gained in assessment practices as an integral part of improving performance. Hodgen and Marshall (2005) argue that "the role of the teacher is to provide a sufficient structure or scaffold through the prior design of tasks and activities, to support those individual journeys and to regulate the learning by providing feedback in the enactment of the scaffold" (p.159). Hodgen's and Marshall's idea of supporting individual journeys highlights an important point, that feedback in formative assessment involves scaffolding of learners' learning by means of scaffolding of their learning process. By learning process I am referring to a cycle of events that takes place as part of using formative assessment diagnostically. Black and Wiliams (2006) present this cycle of events of formative assessment, as part of what they describe as, the "activity theory of formative assessment" (p.94). In their description of the activity theory of formative assessment, Black and Wiliams (2006) refer to the "subject classroom" as an "activity system." In the activity system they describe the relationships between what they term the *tools, subjects and objects/outcomes* (italics in original text). The relationship among these components forms an interactive system.

In their description of what *tools* are the most important to the development of formative assessment, Black and Wiliams (2006) include the following:

- Teachers' views and ideas about the nature of the subject, including pedagogical content knowledge
- Teachers' methods for enhancing the formative aspects of interaction, such as rich questions, ideas about what makes feedback effective […]
- Teachers' views and ideas about the nature of learning (p.94)

Black and Wiliams (2006) define *subjects* in the activity system as being made up of the teacher and the learner. They focus on the role that the teacher and the learner play in the formative process of the activity system. The *objects/outcomes* are described as the "expectations that teachers have of their [learners]" (Black and Wiliams, 2006, p.95). In the activity system, the teachers' expectations work in relation to tests that they set, as well as externally set tests and criteria (ibid).

Black and Wiliams (2006) argue that the role of the teacher needs to be understood by reference to the ways that he/she interacts with the components of the system. For example, as the teacher works with the feedback from the learning analysis, which comes from externally set tests and criteria, the teacher takes on the role of making pedagogical decisions on the methods and ways to work with the learners on the necessary content or skill. The teacher sets the expectations that he/she has for the learners.

Black and Williams (2006) explain that the teacher within the "activity system" (p.96) decides what role he/she will take in the interaction with the learners and in what form the formative feedback will be provided. These decisions are influenced by the views and ideas that the teacher has on the "nature of the subject and the view of learning" (Black and Wiliams, 2006, p.96). I suggest that examining how the components of the activity system and in particular how the teacher interacts with the components of the system, are useful in trying to understand the process of using formative assessment for diagnostic purposes.

While Black and Williams (2006) in their description of the activity system refer to feedback as the teacher's response to the learners based on what has been assessed from externally set tests and criteria, in this study, feedback is situated in two ways. It is used to refer to teachers' responses to learners' ideas during the lessons (feedback to learners). It also refers to the information teachers' gain in the formative process through their analysis of learners' responses to tasks (feedback to teachers). The main point of studying feedback in this way is to show that both types of feedback help teachers to make decisions about how to scaffold the learning process with the view to improving learning (Pryor and Crossouard, 2008). What is important is that feedback is "generally regarded as crucial to improving knowledge and skill acquisition" (Shute, 2008, p.153). Feedback to learners and

information about learners' understanding of the work gained through formative assessment practices are both crucial for diagnostic assessment. These kinds of feedback provide the teacher with the necessary insights to make diagnostic decisions or assessments.

In research that was conducted by Black (2003) with a group of 36 teachers, ways were explored on how to develop formative assessment practices within the classroom to elicit valid feedback, so that the teaching and learning experience could be facilitated or scaffolded. This data was captured after Black viewed some of the weak practices that teachers were pursuing. As part of the data captured, Black notes four areas that need to be developed in order to serve as catalysts in the feedback process. These are: improved questioning techniques (e.g. allowing for a wait time before answers are given), feedback through marking (e.g. improved quality of comments given to learners), peer assessment and self assessment (e.g. using peers as a means of evaluating work) and the formative use of summative tests (e.g. allowing learners to prepare for their summative test by engaging in formative processes). The depth of the forms of feedback that Black (2003) notes have since been extended. Firstly, a closer look at the roles of both teachers and learners in feedback and formative assessment have been considered and secondly, socio-cultural theorisation and its relation to feedback and formative assessment have been included (Black and Wiliams, 2009). More explicit strategies for both teachers and learners are highlighted by Black and Wiliams (2009) when engaging with feedback and formative assessment. It includes ideas such as:

> Clarifying and sharing learning intentions and criteria for success, engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding and providing feedback that moves learners forward, activating students as instructional resources for one another, activating students as the owners of their own learning. (pp.4-5)

The idea of making "learning intentions" clear so as to achieve success in the learning process is made explicit. Attention is drawn to the importance of classroom discussions being used to elicit evidence of "[learners'] understanding," and using learners as a "resource" for one another in their "own learning" is highlighted. The feedback/information gained through these formative strategies can be used diagnostically to assess learners' understanding.

In summary, it can be said that there are two important considerations when investigating teachers' diagnostic assessment using formative assessment tasks in the Numeracy Learning Programme. First, the teachers' ability to navigate between learners' prior knowledge and the new knowledge to be taught needs to be considered for analysis. Second, the manner in which the formative assessment process has been designed needs to be considered for analysis. Teachers' navigation is structured by the formative assessment process[7] that he/she follows. Within this process are two types of feedback: on-going feedback to learners and feedback to teachers. The former refers to what is commonly

[7] In Chapter Five I examine this process by following the "activity system" (Black and Williams, 1996, p.96)

meant by feedback- teachers responding to learners' contributions in the classroom. The latter refers to feedback/information gained by teachers when they analyse learners' responses to tasks.

*Summary*

The paradigm shift on views of learning has brought with it implications for teaching practice and forms of assessment. Learning is no longer thought of as something that can be measured in quantitative terms, but rather the quality of learners' learning has become a central focus. In alignment with constructivist theories of learning and in particular, for the purpose of this study, what teachers do in the learning process to diagnose and interpret learners' learning and how they work with the information gained in their teaching practice is important. Assessment practice needs to be aligned to the teaching practice, so as to allow teachers not to only assess learners' learning, but assess the *quality* of that learning. Assessment for learning (formative assessment) requires teachers who are able to reflect on activities, i.e. its weaknesses and strengths, and who are able to think diagnostically and with deeper insight about the teaching and learning process.

As theories of learning have shifted on the continuum from quantitative to qualitative, so too have thoughts on the teaching and assessment of mathematics changed. Mathematics is not solely thought of as a set of rules that needs to be memorised, but rather the quality of learners' understanding of mathematical concepts or skills is seen as important. South Africa has been no exception to this curriculum trend, with the introduction of the new mathematics curriculum. One implication of this for teacher assessment practices is that practices need to be effective in determining the quality of learners' understanding, so that the teaching and learning environment of mathematics can be altered accordingly. I argue that this requires not only a teacher who has a deep understanding of the constructs of the discipline, but one who has pedagogical content knowledge. Through the "pedagogical moves" in the instructional and assessment practice, the teacher interprets the learners' thinking and scaffolds the learning process. The challenge in South Africa remains where the mathematics curriculum has changed in theory, but in practice diagnostic use of formative assessment tasks with young learners seems few and far between.

Pedagogically, in the study of Number, learners engage with numbers in relation to different types of mathematical knowledge, i.e. "physical," "social" and "logico-mathematical knowledge." They progress through different levels of computation and understanding of number, for example, from rote counting to using known facts and derived facts to count and compute. To improve young learners' ability to work with number implies that the assessment practice used is a process that firstly provides the teacher with the opportunity to evaluate the thinking of the learners and secondly, provides detailed information for the teacher to determine the learners' understanding, both mathematically and socially. In summary it is argued in this study that information obtained from formative assessment can be used to diagnose learners' current understandings and misunderstandings.

In this study, formative assessment is argued as a process underlying diagnostic assessment. Formative assessment can be thought of as the assessment practice that allows for information to be gathered about the quality of learners' learning (diagnostic assessment), which in turn can be used during the teaching and learning programme. Aspects that are highlighted as pertinent to the success of formative assessment, and consequently diagnostic assessment, are the careful consideration of prior knowledge that the learners bring with them and the process of feedback in the instructional practice. The study argues that imperative in formative assessment is how teachers respond to learners' ideas as well as the ways they reflect on and analyse the feedback/information obtained from diagnostic assessment, with the view to 'scaffold' the teaching and learning process.

*Central claims that come from the literature*

There are three central claims in relation to the current study that emerge from the literature: Firstly, while understanding the quality of learners' thinking is central to formative assessment practices, (Shepard, 2000) what seems imperative in mathematics teaching and more specifically in diagnostic assessment is for teachers to understand the underlying process of learners' thinking (Murray et al, 1998). It is through understanding the *process* of learners' thinking that teachers are provided with an insight into the *quality* of learners' thinking and are able to interpret learners' mathematical understanding and difficulties (James, 1986; Ball, 1993). Secondly, not only is the mathematical reasoning of teachers important, but equally so is their pedagogical thinking (Ball et al, 2005) using assessment practices to diagnose learners' responses to specific mathematics activities or tasks. The "*pedagogical moves"* (see p.10) that teachers select and use are important in analysing how teachers work with formative assessment diagnostically. Thirdly, to elicit feedback/information about learners' thinking and use this information to evaluate their understandings using formative assessment practices is part of a 'scaffolded' process that takes place within the activity system (Black and Wiliams, 2006). Through the feedback/information gained, teachers are able to diagnose learners' difficulties and make decisions about how to 'scaffold' the learning process with a view to improve the learning (Pryor and Crossouard, 2008) by attending to their teaching.

## Chapter Three

## Research Design

### Introduction

This study explores the ways in which teachers use formative assessment tasks diagnostically in the teaching and learning of Number in the Numeracy Learning Programme in the Foundation Phase. It is further interested in how diagnostic assessment of learner difficulties is used to improve instruction. In addition to this, the study investigates the alignment between the assessment tasks that the teachers design and their diagnosis of learner difficulties. Finally, there is reflection on the teachers' thinking about how to improve their instruction in relation to the diagnosis of learning needs that the teachers discuss.

A qualitative design was chosen for this small scale case study (see explanation on data collection instruments, pp.27-28). As noted by McMillan and Schumacher (2006, p.315):

> Qualitative research is inquiry in which researchers collect data in face-to-face situations by interacting with selected persons in their settings (e.g. field research). Qualitative research describes and analyses people's individual and social actions, beliefs, thoughts and perceptions. The researcher interprets phenomena in terms of the meanings that people assign to them.

I chose this research design for the current study because it provided me with the opportunity to interpret and assign meanings to the practices of the teachers during teaching, as well as to the "thoughts and perceptions" they held about using formative assessment tasks diagnostically in the teaching and learning of Number in the Numeracy Learning Programme in the Foundation Phase.

### 3.1. Sample

*Subjects:* Three teachers (henceforth 'the teachers') were used for the purposes of the study and were selected according to the following criteria:

Firstly, the teachers taught in the Foundation Phase and were selected for their reputation as being 'strong' in Numeracy. I selected 'strong' Numeracy teachers as opposed to 'weak' teachers, because there seems to be much research on the teaching practices of 'weak' Numeracy teachers and I wanted to research what good teachers do when they work with formative assessment diagnostically. I learnt about their reputation on the basis of the following: During their pre-service training, they distinguished themselves as students both in the Foundation Phase Numeracy Methodology course

and on their practice teaching experience. Secondly, since graduation, the selected teachers had distinguished themselves in the community by their reputation among parents and fellow teachers as 'strong' Foundation Phase Numeracy teachers. I learnt this from colleagues, who at the time of this study, lectured to the teachers during their pre-service training, and also through colleagues who worked in the same schools as the teachers. Thirdly, the teachers had graduated from the University of the Witwatersrand in the last 10 years and whilst at the University, they had been trained in the teaching of Numeracy in the Foundation Phase from a socio-constructivist theoretical perspective. Their history of training in mathematics education was used to assume that their approach would conform to reform mathematics curriculum (Ball, 1993). Fourthly, the teachers chosen were teaching Grade Two in the Foundation Phase. This level was selected because the focus of the study is aligned with early mathematical understandings of number.

*Schools:* The schools that participated in the study were situated in the Johannesburg area and were selected on the sole criterion of being a school where one of the three teachers works. The schools in the study were not the object of analysis.

### 3.2. Data Collection Instruments

This study is a small scale case study. McMillan and Schumacher (2006, pp.26-27) define a case study as a study that, "examines a bounded system […]. The case may be a program, an event, an activity, or a set of individuals bounded in time and place." The current study examined three teachers as a "set of individuals." I wanted to understand how in their "bounded system," which in this study is the teachers' classrooms, they worked with formative assessment to diagnose the difficulties their learners were experiencing in Number.

I used semi-structured interviews in Phases One and Three (see below) of the research design. Methodologically, interviews are used as a means to "… yield information that represents reality more or less "as it is" through the response (and the filters) of an interviewee" (Henning, 2004, p.53). It is used as a technique to "collect qualitative data by setting up a situation (the interview) that allows the respondent the time and scope to talk about their opinions on a particular subject" (www.sociology.org.uk/methfi.pdf - Retrieved 15 Dec 2012, p.1). In this study the objective of the semi-structured interviews was to gain an insight into the process and the thinking that the teachers used when they worked diagnostically with formative assessment tasks in Number. I designed the questions that would be asked beforehand (see Appendices D and E), but the interviews were more conversational and the teachers were encouraged to elaborate on their responses.

Non-participant observations were used as a data collection instrument in Phases Two and Four (see below). Non-participant observations are "…a research technique of directly observing and recording without interaction" (McMillian and Schumacher, 2006, p.346). I attended two lessons for each

teacher. In the first lesson, I observed the administering of the formative assessment task (Phase Two). In the second lesson, I observed the follow-up teaching used by the teacher (Phase Four) once the diagnosis of learner difficulties was made in Phase Three. My attendance was purely observational. While I recorded what the teachers were doing, at no point did I interact with the teacher or learners during the lesson.

A video recording was done in Phase Four. A video recording was chosen as opposed to a tape recording because I wanted to capture the quality of the interaction between the teacher and the learners accurately, particularly the teacher's' explanations of the mathematics and the ways in which they engaged with the learners' thinking. While video recording what the teachers were doing, at no point did I interact with the teacher or learners during the video recording.

### 3.3. Data Collection

Shavelson, Li, Ruiz-Priom and Ayala (2002) and Biggs (2003) argue that one of the means to assist interpretation of learning that has taken place is to ensure that there is an alignment between constructs to be tested, teaching and the assessment process. The detail in alignment that I want to see from the study is what Shavelson et al (2002, p.5) refer to as "the assessment square." This is alignment between construct, assessment, observation and interpretation. "Construct" refers to the knowledge (the mathematical concepts and skills) that is assessed (ibid, p.6). "Assessment" refers to the physical assessment tool that is used to assess the learning of the knowledge that was taught (ibid, p.7). "Observation" involves "collecting and summarising students' behaviour in response to the assessment task" and includes looking at the empirical evidence on the level of the learners' performance (ibid, p.8). Lastly, "Interpretation" looks at whether the inferences and assessment made are valid in relation to the constructs the assessment task intended to measure (ibid, p.9).

This notion of the "assessment square" served as a conceptual metaphor and it guided the process of data collection. The design was not explicit to the teachers nor was it imposed on the teachers. Methodologically the research was not designed as an intervention in any way. Following the "assessment square," I divided the data collection process into four phases.

***Phase One*:** In this phase, I collected the assessment task that the teachers designed. I wanted to see what concepts and skills the teachers chose to assess in the area of Number.

I met with each of the teachers when they designed or selected the task that would be administered to the learners. The task was a formative assessment task relevant to Grade Two, covering the area of Number. The main aim was for me to have an opportunity to understand the ways in which the teachers aligned the task to the knowledge in Number that they wanted to assess. Furthermore, I wanted to examine the teachers' diagnosis of learner difficulties. This data was examined in Phase

Three of the research design (see below). In order to gather information about the teachers' understanding of the assessment task and alignment, I used a semi-structured interview (see explanation on data collection instruments, pp.27-28).

The interview was used firstly to discuss with the individual teachers what prior knowledge they deemed as important in response to the assessment task, and secondly, what they saw as the mathematical construct that the task would be testing. Thirdly, it was used to discuss how the assessment task had been aligned, both to the mathematical construct being tested, as well as to the assessment standards in the curriculum (see Appendix D). Each interview was taped and transcribed verbatim.

In an effort to capture the 'voice' of the teachers for this interview, I divided the data into four key segments. The first segment of the interview was structured to capture the teacher's understanding of assessment and different forms of assessment. The second segment was aimed at gathering the teacher's views on what guides her design of a formative assessment task (more specifically) in Numeracy. The third segment looked at the mental processes with which the teacher thought learners needed to engage, in order to acquire a sound understanding of number. The final segment was designed to capture the teacher's thoughts on the purpose of the designed task and what she expected to elicit about learner difficulties in Number. The data for the interview for each of the teachers was collated and captured and can be seen in Appendices A i, B i and C i (see explanation on use of appendices, pp.38-39). When the words of the teachers were captured, no grammatical alterations were made.

***Phase Two*:** In this phase, I focused on the aspect of observation as described by Shavelson et al (2002). "Observation" refers to the idea of collecting and summarising learners' behaviour in response to the assessment task. This includes looking at the empirical evidence on the level of the learners' performance. In this phase of the research, the teachers administered the assessment task. Each teacher administered the assessment task to their 'weak' group of learners in their ability teaching time[8] for Numeracy. Teacher A worked with a group of seven learners, Teacher B, with six learners and Teacher C, with seven learners. The formative assessment task was designed for the entire class, but because of the nature of Foundation Phase teaching, and the importance of the observations and assessments that teachers are expected to make as learners respond to tasks, ability teaching time was chosen. The 'weak' ability range was selected because I was particularly interested in how diagnostic assessment in formative assessment can be used with weaker learners. I observed the administering of the assessment task in each of the participating classes. This was an informal

[8] In the Foundation Phase, 'ability teaching time' is an approach to Numeracy teaching that the teacher can select to use when wanting to focus on a particular group of learners, for example the 'weak' learners. The rest of the class do organised, independent mathematics activities while this is happening. This gives the teacher an opportunity to focus on and assess a particular group of learners. It is a teaching strategy.

observation (no formal observation schedule was given) and was non-participant (see explanation on data collection instruments, pp.27-28). My observation was guided by the following questions:

- How does the teacher explain the task before administering it?
- In what ways does the teacher transmit criteria (implicit or explicit)?
- What resources are the learners given to complete the task?
- During the completion of the task, what interactive comments does the teacher make to the learners?
- Does the teacher help the learners or not? If so, how is this done?

The administering of the task was taped and transcribed. The data captured in the appendices for this phase is a combination of the verbatim transcriptions and my observation of what each teacher did (see Appendices A ii, B ii, and C ii) (see explanation on use of appendices, pp.38-39). Each of the teachers' "pedagogical moves" was coded (see explanation on coding, pp.32-36).

The teachers formatively assessed and marked the tasks and provided feedback comments. The teachers, of their own accord, designed assessment rubrics and recorded their diagnosis of learner difficulties (see Appendices A ii (R), B ii (R) and C ii (R)) (see explanation on use of appendices, pp.38-39). Once the tasks had been marked and assessed by the teachers, I was given an opportunity to look at the tasks and the diagnosis made by them.

***Phase Three*:** In this phase, I gathered data to analyse the teachers' interpretation of the assessment task given. According to Shavelson et al (2002), "Interpretation" looks at whether the inferences and assessment made are valid in relation to the constructs the assessment task intended to measure.

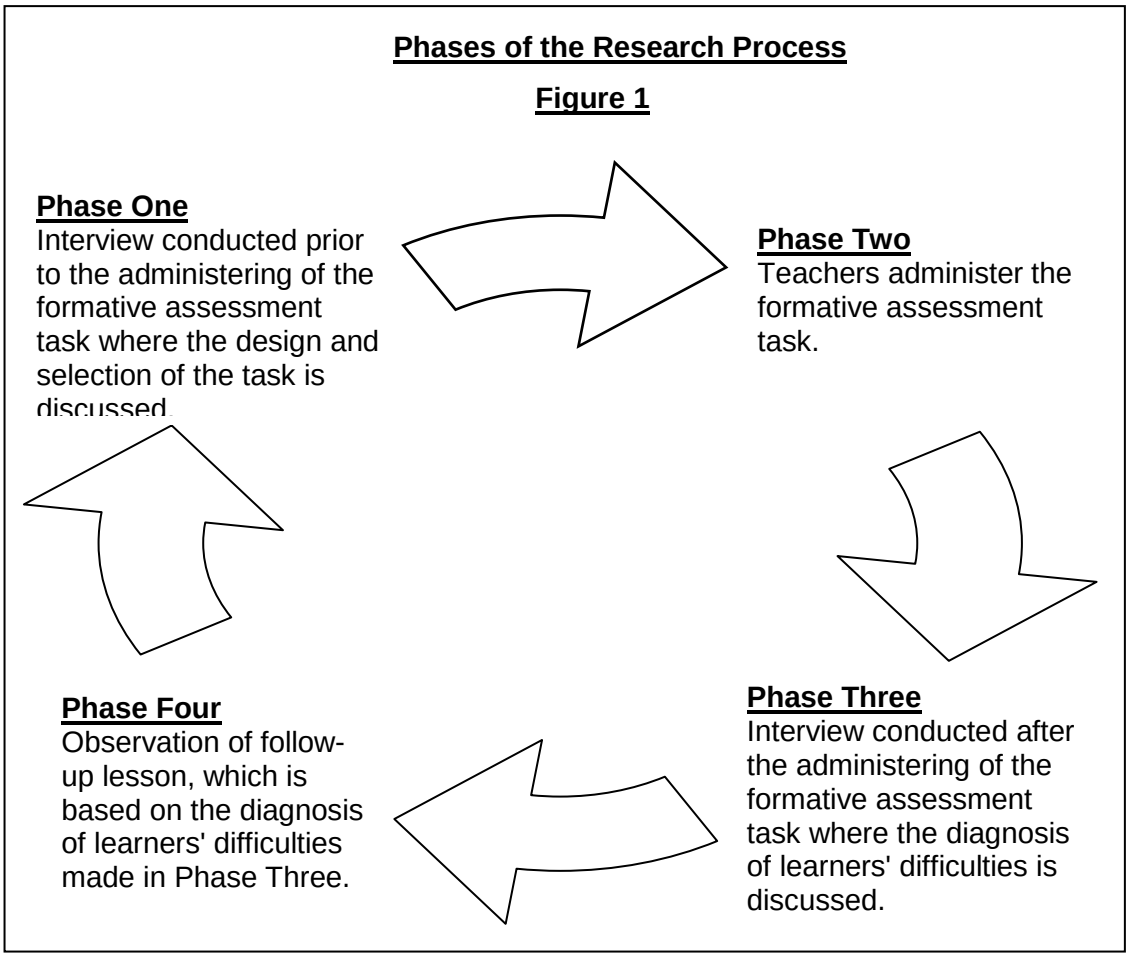
I used the recorded diagnosis of learner difficulties and the informal observation to plan a second semi-structured interview with each of the teachers to discuss the assessment made and the reasoning for their diagnosis. This interview was aimed at getting the teachers to elaborate on their initial predictions (see Phase One), the actual diagnosis of learner difficulties, challenges they experienced in the process of diagnosis, as well as how they planned to use the information gained from the assessment of the task to improve future instruction (see Appendix E). The interview was taped and transcribed verbatim.

I collated the interview data (see Appendices A iii, B iii and C iii) (see explanation on use of appendices, pp.38-39). I divided the data into three particular aspects. Firstly, how the teachers viewed formative assessment and the diagnosis of learning. Secondly, what information the teachers gained about learner difficulties through the diagnostic assessment and how this would be used to improve the teaching and learning experience of Number. Thirdly, I elicited what the cycle of activities

that were included in the research process helped the teachers to understand about formative assessment in the Numeracy Programme. When the words of the teachers were captured, no grammatical alterations were made.

***Phase Four***: I conducted a non-participant observation (see explanation on data collection instruments, pp.27-28) of each of the selected three classrooms. I used the non-participant observation as a tool to observe the follow-up lesson of the teachers, based on the diagnosis of learning made in the interview in Phase Three. Through this observation, I was able to observe the instructional practice of the teachers as they attempted to address the difficulties the learners were experiencing in Number.

This was a general observation of *one* (for there could be a series of lessons) of the Numeracy lessons, in which the teachers planned to work through the problems and create a better understanding with the selected group of learners, based on the difficulties diagnosed in the assessment task and what was discussed in the interview (see Phase Three). The general observation served as a mechanism to observe how, through the diagnostic use of formative assessment tasks, the teachers improved instruction and as a consequence, learners' learning. I video recorded each of the three observed lessons (see explanation on data collection instruments, pp.27-28).The video recordings were transcribed verbatim. The data from the video recordings and my observations of what each teacher did were used to capture the "pedagogical moves" of the teachers. The teachers' "pedagogical moves" were coded (see explanation on coding, pp.32-36).




### 3.4. Data Coding

I coded the "pedagogical moves" (Boaler, 2001, see Chapter Two, p.10) of the teachers in Phases Two and Four. "Pedagogical moves" refer to the methods and ways in which the teachers interact with the learners in the instructional practice of the 'scaffolded' formative assessment process. I tried to identify the pedagogical moves of the teachers as a way to understand and gain an insight into the process that is involved when the teachers work diagnostically with formative assessment to better understand learners' thinking about Number. The following sets of codes were used:

| Coding (pedagogical move) | Abbreviation | Meaning of Code | Example |
|---|---|---|---|
| Previously Taught Mathematical Knowledge | PTMK | The code was used when the teachers worked with mathematical concepts that had been previously taught to the learners. | Teacher C continues and asks the learners, "Now, what number on our number line would come after 9?"<br>Gordon: "10." |
| New Mathematical | NMK | The code was used when the teachers introduced new | Teacher B: "We're not able to count in 7s yet, so how can we break up |

| | | | |
|---|---|---|---|
| Knowledge | | mathematical knowledge or skills to the learners. | the 7 so that we can count how much there is altogether?" |
| Everyday Knowledge | ED | The code was used when the teachers worked with the everyday/ "common" knowledge of the learners. | Teacher A begins by setting a context. She tells them that they are going shopping at Woolworths to buy some items. |
| Embedded Mathematical Knowledge | EMBD | The code was used when the teachers embedded the mathematical knowledge in a context. | Teacher A states the first word problem as follows: "We buy 7 apples and then we buy 11 *more* apples, how many apples do we have altogether?" |
| Socialisation | SOC | The code was used when the teachers socialised the learners into mathematical terminology. | Another learner, Daniel, says, "I put the bigger number with the smaller number and counted all of it." Teacher A responds and says, "What is another word for 'put'?" "Can we say you *plussed*? A*dded*?" |
| Verbal Demonstration | VERB DEM | The code was used when the teachers asked the learners to explain their interpretation or thinking. | Once all the learners have attempted solving the problem, Teacher C selects a learner who has not managed to solve the problem correctly and asks him to verbalise the strategy that he used. She asks the learner, "How did you work it out?" |
| Visual Demonstration | VIS DEM | The code was used when the teachers asked the learners to demonstrate their thinking visually. It was also used when the teachers visually demonstrated to the learners to explain concepts. | Teacher B: "Now, I asked for 6 groups of 3, how many in *each* group?" "Can you show me your 6 groups please?" Teacher A revisits the learners' understanding of the (+) symbol. She explains, "Instead of writing '7 *plus* 11' or '7 *and* 11' to show what we did to get to the answer, a symbol (+) *(she writes this up on the white board)* is used to show that we are plussing or adding the numbers together." |
| Evaluation | EVAL | The code was used when the teachers wanted to diagnose or evaluate the learners' thinking or interpretation. | Teacher A says to one of the learners, "How did you count your blocks?" Thando: "I counted them all." |

| | | | |
|---|---|---|---|
| | | | Teacher A: “Is there a quicker way you could have counted?” |
| Validation | VAL | The code was used when the teacher praised or validated the learners’ efforts. | Teacher B also praises the learners for their efforts and makes comments such as, “Good, Ben, you’re checking. Right.” |
| Instruction Explicit | INSTEXP | The code was used when the teachers explicitly instructed the learners on what they were required to do. | Teacher C gives the learners a recording sheet. She explains to them that they need to record a number sentence and a picture for each of the seven word problems on the recording sheet. |
| Instruction Implicit | INSTIMP | The code was used when the teachers gave a more general instruction. | Teacher B continues and tells the learners that she is going to give them a problem that they need to solve independently in their pairs. |
| Explicit explanation | EXP | The code was used when the teachers gave the learners an explicit explanation of the mathematics involved. | Tristan: “No, we did it in 1s, 2s and 5s.”<br>Teacher B: “You did it in 1s, 2s and 5s. Because 5 plus 2 is 7 plus 1 is 8.” |
| Criteria Explicit | CRITEXP | The code was used when the criteria for assessment were made explicit to the learners. | Teacher B goes through each section carefully. She reads the instructions with the learners. For example, she reads the instruction out as follows: “*Double the numbers, showing me how you reached your answer. Write the answer on the line*.” |
| Criteria Implicit | CRITIMP | The code was used when the criteria for assessment were not made explicit to the learners. | At the end of the task, Teacher A takes in the papers that the learners are working on. This, together with her observation and discussion with the learners, is collated as the formative assessment task. She records and finalises the information on an assessment rubric. (See Appendix A ii (R), p.28). This rubric is not returned to the learners once the task has been finalised. |
| Concrete | CA | The code was used when the | Teacher C: “Let’s count 11 cards |

| | | | |
|---|---|---|---|
| Apparatus | | teachers used concrete apparatus to demonstrate visually to the learners. It was used when the teachers asked the learners to demonstrate their understanding visually using the concrete apparatus. | together."<br>Learners count: "1,2,3,4,5,6,…"<br>(Teacher C places 11 cards with school children printed on them in a vertical row).<br>Teacher B asks the learners to select the apparatus that they feel will be the most useful in solving the particular problem that they are working on in the assessment task. |
| Probing | PROB | The code was used when the teachers asked the learners a probing question. The learners were not given the opportunity to interpret the question actively. | Teacher B says to the learners, "Why did you count in 1s, when you have got a group of 2s? That was interesting." |
| Probing Questions and Active Interpretation | PROBQAIN | The code was used when the teachers asked the learners a probing question and allowed them to interpret actively with a verbal explanation. | Teacher A asks the learners to verbalise how they reached their solutions. For example, "… Neha, when you started off, how did you start counting your blocks?" |

**Assigning the code:** I used my discretion on how to code the moves and in instances where it was not clear, I made the decision on what, in my opinion, was the more likely. When the teacher's utterance or instructional practice integrated more than one pedagogical move, the relevant codes were assigned. The following is an example from a coded transcript (Teacher B, Appendix B iv, pp.19-20).

| | | |
|---|---|---|
| 4. | Teacher B explicitly demonstrates and puts out four paper plates to represent 4 groups. [VIS DEM; CA]. | VIS DEM; CA: Teacher B concretely puts out the four paper plates to represent the four groups. |
| 5. | Teacher B proceeds and says, "…Now I need 4 groups of 7, how much is in group one?" [PROBQAIN].<br>Learners: "7."<br>Teacher B puts 7 blocks into one paper plate (i.e. 7 blocks into one group). [VIS DEM; CA].<br>Teacher B: "In group two?"<br>Learners: "7."<br>Teacher B continues with this line of questioning until she has put out 7 blocks on four paper plates. | PROBQAIN; VIS DEM; CA: Teacher B is asking a probing question about the number of blocks in each group. The learners need to interpret actively. As the learners respond, Teacher B visually demonstrates. |
| 6. | Teacher B proceeds (using her blocks and paper plates) [CA] and asks the learners: "Can we count in 7s?" [PROB]. | CA; PROB; PROBQAIN; NMK; PTMK: Using the concrete apparatus, the teacher begins by probing the learners' thinking about whether they can count |

| | | |
|---|---|---|
| | Learners: "No."<br>Teacher B: "We're not able to count in 7s yet, so how can we break up the 7 so that we can count how much there is altogether?" [PROBQAIN; NMK; PTMK]<br>Brittney: "Break it up in 2s."<br>Victor: "2s, 5s." | in 7s. She probes their thinking further and gets them to think actively of ways in which they can count the groups of 7, which is new maths knowledge. The learners need to think about their previously taught maths knowledge of counting in groups and apply it to counting in 7s. |
| 7. | Teacher B breaks the 7 blocks in each of the 4 groups into a group of 5 and a group of 2 [VIS DEM; CA]. Once Teacher B completes breaking the 7 blocks into groups, she says to the learners, "So let's count how much there is altogether?" [VERB DEM].<br>All the learners count: "5, 10, 15, 20… 22, 24, 26, 28."<br>The learners first count in 5s and then in 2s. | VIS DEM; CA; VERB DEM: Teacher B visually demonstrates the breaking up of the group of 7. All the learners verbally have to count the groups of blocks in 5s and 2s. |

From the above example, it can be seen that the transcription of the teachers' moves is divided into three columns. The first column is numbered according to what, in my opinion, were the teaching 'steps' in the lesson. The second column is transcribed according to the pedagogical moves made by the teacher. Each of the moves was coded using the codes listed above (see pp.32-35). The third column explains exactly what the teacher is doing in the move and how it relates to a particular code or codes. This description provides justification for my coding decisions. The transcripts for each of the teachers pedagogical moves in Phases Two and Four are to be found in Appendices A ii and iv, B ii and iv and C ii and iv (see explanation on use of appendices, pp.38-39).

### 3.5. Analysis of Data

The data was analysed using three main sections. Firstly, I created a 'portrait' of each of the teachers. In creating this 'portrait,' I analysed the process and thinking that each of the teachers went through in the four phases of the research. Therefore, a 'portrait' of each of the teachers' use of formative assessment and their pedagogical moves through the phases of the research was created (see Appendices A i - iv, B i - iv, and C i - iv) (see explanation on use of appendices, pp.38-39).

Secondly, I coded the pedagogical moves of the teachers and presented and analysed it (see Chapter Four) using four categories. I used the literature (see Chapter Two) as a guide to help me decide on the categories and sub-categories.

The first category refers to the ways in which the teachers worked with content knowledge. To analyse this, I further divided the category into sub-categories. The sub-categories are: "previously taught mathematical knowledge," (Murray et al, 1992; Askew, 1997; Boaler, 2001; Good, 2008) "new

mathematical knowledge" (Murray et al, 1992; Ball, 1993; Mamasse, 2000; Lampert, 2001) and "everyday and embedded mathematical knowledge" (Haylock, 1991; Murray et al, 1992; Askew et al, 2001).

The second category refers to the pedagogical moves that the teachers used in their instructional practice. In this category the sub-categories are: "probing questions and active interpretation," (Hart, 1982; Cobb, 1991; Murray et al, 1992; Ball, 1993; Lampert, 2001) "verbal demonstrations," (James, 1986; Haylock, 1991) "visual demonstrations" and "concrete apparatus," (Piaget as cited by Kamii, 1989; Murray et al, 1992; McDermott and Rakgokong, 1996; Haylock, 1997) "explicit explanations" (Haylock, 1991) and "validation" (Haylock, 1991).

The third category refers to the teachers' practices of evaluation and was used to analyse how the teachers evaluated the learners' thinking, as well as how the teachers used criteria and instructions during evaluation. The sub-categories in this category include the pedagogical moves of: "evaluation," "explicit" and "implicit" criteria and "implicit" and "explicit" instructions (Shepard, 2000; Black, 2003)

The final category refers to how the teachers socialised (Murray et al, 1992; McDemott and Rakgokong, 1996; Askew et al, 2001) the learners into mathematical terminology. There are no sub-categories in this final category.

The examples that I chose from Appendices A, B and C to elaborate on the analysis were chosen based on the teacher that used the pedagogical move and type of mathematical knowledge the most. To determine which pedagogical move was used most often across the teachers, I counted all the pedagogical moves used by each of the teachers in Phases Two and Four. I classified the pedagogical moves along the four categories that I used to present and analyse the data (i.e. Content Knowledge, Instructional Practice, Practices of Evaluation and Socialisation (see explanation given above)). For example, under the category of 'Content Knowledge,' I tabulated how many times the teacher worked with everyday (ED) and embedded mathematical knowledge (EMBD) in Phases Two and Four, the latter being in response to the teacher's diagnosis discussed in Phase Three (see Chapter Four, p.43). The Table below presents the way I classified the pedagogical moves:

**Table 2: Everyday and Embedded Mathematical Knowledge**

| **Number of times the code was used in Phases Two and Four** | | | | | | |
|---|---|---|---|---|---|---|
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| | Phase Two | Phase Four | Phase Two | Phase Four | Phase Two | Phase Four |
| Everyday Knowledge | 1 | 1 | 0 | 0 | 0 | 1 |
| Embedded Mathematical Knowledge | 1 | 5 | 0 | 1 | 3 | 2 |
| **Number of times the code was used in Phase Four, in response to the teacher's diagnosis in Phase Three** | | | | | | |
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| Everyday Knowledge | 1 | | 0 | | 1 | |
| Embedded Mathematical Knowledge | 5 | | 1 | | 2 | |

I classified the pedagogical moves according to the types of mathematical knowledge to see whether the number of times that the teachers recruited the different types of mathematical knowledge and pedagogical moves can be used to validate my interpretation of the teachers' use of formative assessment diagnostically. In other words counting the pedagogical moves and the use of different types of mathematical knowledge helped the intravalidation process of this research (McMillan and Schumacher, 2006)

Thirdly, I analysed (see Chapter Five) the type of pedagogical moves that can describe the act of using formative assessment diagnostically in the teaching of Number in the Foundation Phase. I used Black and Wiliams' (2006) activity theory as a framework to structure the discussion and to analyse how the research questions are answered by the study. In this discussion, I also drew on the literature in order to compare the findings of the study with existing research, with particular emphasis on the idea of diagnosis in formative assessment tasks.

### 3.6. Use of Appendices

Initially, I captured the data for each teacher for each of the Four Phases of the Research process by creating an overall 'portrait' of the teachers. Appendices A, B, and C are the 'portraits' for each teacher, i.e. Appendix A is the data for Teacher A, Appendix B is the data for Teacher B and Appendix C is the data for Teacher C. The data captured in these appendices includes all the detail from what was transcribed and observed by me in the collection of the data. To indicate the four phases in each appendix, I have numbered them using Roman numerals, i.e. Phase One (i), Phase Two (ii), Phase Three (iii) and Phase Four (iv). In the phases where interviews were done, I sub-divided the interviews into segments (see Phases One and Three above) and numbered them accordingly. For example, in Phase One, there are four key segments to the interview and I numbered these as 1.1, 1.2, 1.3 and

1.4. In Phase Three, there are also four key segments and I numbered these as 3.1, 3.2, 3.3 and 3.4. I further divided each segment into paragraphs and I numbered these as paragraph 1, paragraph 2, etc. In Phases Two (teachers administer formative assessment task) and Four (follow-up lesson after the diagnosis has been made in Phase Three), I separated each teaching step (pedagogical move). I numbered each pedagogical move in running order, for example, pedagogical move 1 is number 1, pedagogical move 2 is number 2, etc.

From the overall 'portraits' of each of the teachers, I then selected what I thought was the most important or relevant data for the analysis and discussion of the findings (see Chapters 4 and 5). I selected this data based on the categories chosen in Chapter Four and also in relation to how I saw the data answering the research question of the study. When I refer to the data that I selected in these Chapters, I indicate it as follows: For Phases One and Three, which are the interviews, I refer the reader to the relevant data in the Appendix in the following way: Appendix A i, 1.2, paragraph 3, p.3. This means that the data is to be found in Appendix A, Phase One, in Section 1.2, paragraph 3 of that section, on page 3 of Appendix A. I have also highlighted in a light grey the relevant line in the actual Appendix. For Phases Two and Four, which are the lessons, I refer the reader to the relevant pedagogical move in the following way: Appendix C iv, pedagogical move 11, p.22. This means that the data is to be found in Appendix C, Phase Four, it is pedagogical move 11, on page 22 of the Appendix. The relevant pedagogical move is also highlighted in a light grey in the actual Appendix. At the end of Appendices A, B and C, I included the rubric that each of the teachers used in Phase Two. These I marked as Appendix A ii (R), Appendix B ii (R) and Appendix C ii (R). I also included in the appendices, Appendices D and E. Appendix D is the questions that were asked for the semi-structured interview in Phase One and Appendix E is the questions that were asked for the semi-structured interview in Phase Four.

### 3.7. Reliability/Validity (Rigour)

Reliability refers to the 'accuracy' with which the activity measures the skill or the attainment it is designed to measure (Gipps, 1995), while validity refers to the extent to which an activity measures what it purports to measure (Gipps, 1995). In order to promote the reliability in the content, the constructs and skills required in the tasks, I had an interview with the teachers before the tasks were administered and in which this was considered (see Phase One). I assessed the validity of the diagnosis made using the assessment tasks according to the alignment between the constructs and skills and the diagnostic assessment made by the teachers. This was analysed through the discussion that took place in the interview after the tasks were administered (see Phase Three).

As "validity implies proper interpretation and use of the information gathered through measurement" (McMillan and Schumacher, 2006, p.182), to ensure the proper interpretation of the data, multiple ways to corroborate the data were employed. Interviews before and after the teachers' administration

of the assessment tasks were conducted, as well as a field observation of each of the three classrooms.

I attempted to control the process of data collection from the beginning to the end, and in so doing enhance validity.

### 3.8. Ethical Considerations

At the outset of the study, the following was explained to the teachers: Firstly, the aim of the study, i.e. to investigate how they worked with formative assessment tasks diagnostically in the teaching of Number in the Numeracy Learning Programme in the Foundation Phase. Secondly, that the investigation was not a judgment of their teaching or teaching ability. Thirdly, that participation in the study was voluntary and should they wish to withdraw from the study at any point, they could do so with no adverse consequence. Fourthly, that the video and audio recordings (see Phases Two and Four) would not be used in any public forum. Finally, that anonymity in the final report is assured and that they were welcome to read drafts of the report to ensure that details were accurately recorded and reported. All the teachers signed letters of consent to participate in the study.

The learners in the teachers' classrooms were not directly involved in the study, as the focus was on the teachers and their use of formative assessment tasks. However, pseudonyms were used for the learners in the capturing of the data and letters of consent were obtained from the parents for the video-tape recording (see Phase Four).

Ethics Clearance was obtained from Wits School of Education: Protocol Number: 2008ECE262

### 3.9. Limitations of the research

This Research Project is a small scale case study and examines three teachers. Generalisations for all teachers cannot, therefore, be drawn from it. Although the importance of the learner in the formative process is acknowledged, the focus of this study is on the role of the teacher and conclusions cannot be drawn about the role of the learner when using formative assessment tasks diagnostically or the relation between the process of formative assessment and learners' learning and/or achievement. The formative assessment task was also administered to a small group of learners and a larger group may yield very different results. Furthermore, while the findings offer suggestions on the pedagogical moves that the teachers use to 'scaffold' their interaction with the learners during the formative assessment process, generalisations cannot be made. The findings of the study perhaps provide an opportunity for debate and discussion and create an interest for further investigation.

## Chapter Four

## Presentation and Analysis of Findings

### Introduction

The aim of this chapter is to present and analyse the 'scaffolded' process that the three teachers' undertake as they use formative assessment to interpret their learners' difficulties in Number and improve their teaching. The findings are presented and analysed based on Appendices A, B and C which are the 'portraits' of the teachers that were created from the collection of the research data for each teacher (see explanation on use of appendices, Chapter Three, pp.38-39) The presentation and analysis in this Chapter are done in relation to the sub-questions, focussing on the teachers' views, reflections and "pedagogical moves" (see Chapter Two, p.10) as they work with formative assessment diagnostically. The discussion is framed by four categories:

- **Content Knowledge:** The ways the teachers work with mathematical knowledge
- **Instructional Practice:** The pedagogical moves the teachers use during instruction
- **Practices of Evaluation:** The use of instructions and criteria during evaluation
- **Socialisation:** How the teachers socialise the learners into mathematical terminology

In each category I discuss the four phases of the research process, looking at the alignment between the interviews and the administering of the formative assessment task and the follow-up lesson based on the diagnosis discussed. Phases One and Three are the interviews and Phases Two and Four are the lesson observations.

### 4.1. Category 1 – Content Knowledge

Teachers' understanding and working with the mathematical ideas and concepts that learners bring with them to the mathematical context to create new understandings and ideas is argued by Askew et al (1997), Good (2008) and others as an important consideration when trying to improve learners' mathematical understandings. I have used this argument as a conceptual framework for the first category of my analysis, which I have headed as: 'Content Knowledge.'

The mathematical knowledge that is included under the heading of 'Content Knowledge' in this category is: previously taught mathematical knowledge, new mathematical knowledge, everyday mathematical knowledge and embedded mathematical knowledge. The discussion in this section analyses how the teachers recruit different types of mathematical knowledge for various purposes in their instructional practice when working with formative assessment diagnostically.

I analyse the mathematical knowledge by looking at how the teachers work with previously taught mathematical knowledge (PTMK) and new mathematical knowledge (NMK) in Phase Two and Phase Four. For both of these phases, I analyse the frequency with which the teachers use previously taught and new mathematical knowledge and the mode in which they engage with the previous and new mathematical knowledge. By "mode" I specifically refer to their use of everyday knowledge (ED) and embedded mathematical knowledge (EMBD). Everyday knowledge refers to the everyday experiences and knowledge that the learners bring with them to the mathematics context, and embedded mathematical knowledge refers to mathematical concepts that are embedded in a context, for example, in mathematical word problems. To analyse the frequency, I quantify the use of previous and new mathematical knowledge. I compare the use of previous and new mathematical knowledge between the three teachers in Phases Two and Four, as well as the use of previous and new mathematical knowledge in relation to the diagnosis discussed by the three teachers in the interview in Phase Three. In addition to this, I examine the relationship between what the teachers stated in their interviews in Phases One and Three and what they did in the classroom, as well as the link between their diagnostic assessment discussed in the interview (Phase Three) and what they do in Phase Four when they are attempting to address the problem.

**Table 1: Previous and New Mathematical Knowledge**

This Table is a quantitative comparison of the differences and similarities among the three teachers when working with previous and new mathematical knowledge in Phases Two and Four of the research process.

| **Number of times the code was used in Phases Two and Four** | | | | | | |
|---|---|---|---|---|---|---|
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| | Phase Two | Phase Four | Phase Two | Phase Four | Phase Two | Phase Four |
| Previously Taught Mathematical Knowledge | 2 | 4 | 3 | 3 | 2 | 11 |
| New Mathematical Knowledge | 1 | 9 | 0 | 5 | 0 | 2 |
| **Number of times the code was used in Phase Four, in response to the teacher's diagnosis in Phase Three** | | | | | | |
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| Previously Taught Mathematical Knowledge | 3 | | 3 | | 10 | |
| New Mathematical Knowledge | 9 | | 5 | | 2 | |

From Table 1 it is evident that Teacher A works more with new mathematical knowledge (10 times), as opposed to Teacher C who works more with previously taught mathematical knowledge (13 times).

Teacher B seems to work equally with both previously taught and new mathematical knowledge (six and five times, respectively). The Table also shows that in Phase Four, the use of previous or new mathematical knowledge for the three teachers is mainly in response to the teacher's diagnosis in Phase Three, based on the formative assessment task.

**Table 2: Everyday and Embedded Mathematical Knowledge**

This Table is a quantitative comparison of the differences and similarities among the three teachers when they work with everyday and embedded mathematical knowledge as a mode, in Phases Two and Four of the research process.

| **Number of times the code was used in Phases Two and Four** | | | | | | |
|---|---|---|---|---|---|---|
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| | Phase Two | Phase Four | Phase Two | Phase Four | Phase Two | Phase Four |
| Everyday Knowledge | 1 | 1 | 0 | 0 | 0 | 1 |
| Embedded Mathematical Knowledge | 1 | 5 | 0 | 1 | 3 | 2 |
| **Number of times the code was used in Phase Four, in response to the teacher's diagnosis in Phase Three** | | | | | | |
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| Everyday Knowledge | 1 | | 0 | | 1 | |
| Embedded Mathematical Knowledge | 5 | | 1 | | 2 | |

From Table 2 it can be seen that Teacher A recruits everyday knowledge the most, i.e. twice (once in Phase Two and once in Phase Four). Teacher B does not use everyday knowledge as a mode in either of the Phases and Teacher C only uses it once. In the administering of the formative assessment task (Phase Two), Teacher C uses embedded mathematical knowledge the most, i.e. three times, while Teacher A works with it once and Teacher B does not use it as a mode. In Phase Four, after the teachers diagnose the learners' difficulties in Phase Three, Teacher A recruits embedded mathematical knowledge the most, i.e. five times. Teacher C works with it twice and Teacher B recruits it once. In total, Teacher A works with embedded mathematical knowledge the most in the two Phases, i.e. six times. Teacher C, in total, works with it five times and Teacher B, in total, only works with it once. The Table also shows that when the teachers work with everyday and embedded mathematical knowledge in Phase Four, it is always in response to the teacher's diagnosis discussed in the interview in Phase Three.

In the following section, I discuss how the teachers recruit previously taught mathematical knowledge and how previous mathematical concepts are worked with in relation to everyday and embedded mathematical knowledge.

### 4.1.1. The use of previously taught mathematical content in Phase Two

Teachers A and C both work with previously taught mathematical content twice in the lesson. In both cases the teachers ask the learners to solve word problems. The word problems used by the teachers draw on everyday knowledge and the mathematical knowledge is embedded (see example Section 4.1.5, p.50, Appendix A iv, pedagogical move 13). The teachers use embedded mathematical knowledge to get the learners to draw on previously taught mathematical content. For example, Teacher A sets the context of the word problem in an everyday shopping experience and gives the following word problem: “We buy 7 apples and then we buy 11 *more* apples, how many apples do we have altogether? (Appendix A ii, pedagogical move 2, p.8). Teacher C gives the following word problem: “James has 8 cars. Thando has 4 *less*. How many cars does Thando have?” (Appendix C ii, pedagogical move 2, p.8). In both examples given, the questions the teachers ask require the learners to draw on their previously taught mathematical knowledge of counting, the value of number, mathematical terminology associated with addition and subtraction, understanding number symbols and writing number sentences when solving a word problem. These mathematical concepts are embedded in the everyday examples. Teachers A and C use embedded and everyday knowledge to evaluate the learners’ understanding and application of previously taught mathematical content.

In Phase Two, Teacher B asks questions which are intended to enable learners to draw from previously taught mathematical knowledge and use it to respond to the particular concepts being assessed. For example, she asks the question, “What do we do when we double?” (Appendix B ii, pedagogical move 4, p.10).The learners need to draw on their previous mathematical understanding that the double of a number means that you add the number twice or you multiply the number by 2. Learners are able to use this previous mathematical knowledge to answer the question in the formative assessment task that asks them to double the number, for example the double of 26. In this Phase, Teacher B does not use any embedded or everyday knowledge.

### 4.1.2. The use of previously taught mathematical knowledge in Phase Four

In Phase Four, Teacher A draws on the learners’ previous mathematical knowledge four times. For example, Teacher A says, “Can somebody remind me what’s…like if we’re putting things together, what another word for that is?” (Appendix A iv, pedagogical move 6, p.21). In order to respond to this question, the learners need to draw on previous knowledge about the mathematical terminology associated with addition. Teacher C works with the learners’ previous understanding of mathematical concepts a total of 11 times. For example, Teacher C says to the learners, “Now, what can you tell me about the number 10? Anything you know about the number 10” (Appendix C iv, pedagogical move 6, p.20). The learners need to draw on their previous mathematical knowledge about the number 10 in relation to other numbers. Teacher B uses previous knowledge three times in Phase Four. For example, she says to the learners, “If the blocks are already in 10s, so you and your partner need to

take?" (Appendix B iv, pedagogical move 2, p.19). The learners need to draw on their previous mathematical understanding of counting in groups.

In Phase Four, the teachers do not use everyday examples with embedded mathematical knowledge as a mode to recruit learners' previously taught mathematical knowledge. The teachers use everyday and embedded mathematical knowledge as a mode to introduce and consolidate concepts or skills that they have diagnosed as difficulties for the learners (see Section 4.1.5, pp.50-51).

The discussion continues by comparing the differences among the teachers in terms of consistency between the views they expressed in the interviews and their classroom practice. I also look at how the recruitment of previous mathematical knowledge is linked to the diagnosis discussed by the teachers in Phase Three.

### 4.1.3. The relationship between interviews and previously taught mathematical knowledge

In Phase One, in the initial interview, Teacher A talked about how important it is to work with the learners' previous knowledge in order to construct new knowledge. She says: "[the learners] have to have some kind of previous knowledge to build upon… [you need to make] sure you take into consideration their prior knowledge" (Appendix A i, 1.2, paragraph 3, p.3). In Phase Three, in the follow-up interview, she also explained how she perceives previous knowledge as forming part of the diagnosis of learning. She explained that in her view the diagnosis of learning involves "expand [ing] the learners' previous knowledge" (Appendix A iii, 3.1, paragraph 2, p.13). The pedagogical moves of Teacher A in Phase Four are consistent with her views on "using previous knowledge in order to construct knowledge" and "expanding the learners' previous knowledge." On three out of the four occasions that Teacher A works with previous mathematical knowledge in Phase Four, she asks the learners to count with her. Twice she draws on the learners' previous counting knowledge and uses the counting level on which the learners are working (counting in 1s), which is their previous mathematical knowledge, to construct new knowledge on counting in groups. An example of this would be:

> The learners each add 3 wooden cubes to the 2 that they have already and place the 5 wooden cubes in their 'basket' (circle drawn on white board). Teacher A asks the learners to count the eggs as they are placed in the basket. [Learners count in 1s].
>
> Once all the learners have 5 wooden cubes in their baskets, Teacher A says, Now who would like to tell me how they would like to find out how many we have altogether?
> Al: Count in 5s. (Appendix A iv, pedagogical moves 9 and 10, p.23).

In her pedagogical moves in the above example, Teacher A "expands the learners' previous knowledge" (counting in 1s) and constructs new knowledge by encouraging them to think of ways of counting the blocks altogether (counting in groups). Encouraging the learners to count in groups is aligned to her diagnosis of learning made in Phase Three (Appendix A iii, 3.2, paragraph 7, p.17) and to the point made by Teacher A that she wanted the diagnosis to be used as a means to expand the learners' previous knowledge.

In the other instance that Teacher A gets the learners to count in Phase Four, she does not use the learners' previous knowledge of counting in groups to encourage the learners to count in groups and does not link it to the diagnosis of learning. Teacher A simply asks the learners to count, "How many children are in the group?" (Appendix A iv, pedagogical move 2, p.20). The learners count in 1s.

By contrast, Teacher C does not discuss the importance of working with learners' understanding of previous mathematical concepts in either of the interviews. However, in practice in Phase Four, she works with previous mathematical knowledge a total of 11 times. In 10 out of the 11 times that Teacher C works in Phase Four with previously taught mathematical concepts, it is directly linked to her diagnosis of difficulties learners are experiencing. In Phase Three, she explained that when diagnosing the formative assessment task, the learners could not process the information in the word problems. She says:

> ...The learners were unable to break it down in their own minds and see, do I add? Do I subtract? The learners did not seem to understand the concepts of more and less (Appendix C iii, 3.2, paragraph 1, p.13).

Teacher C explained that the concepts of 'more' and 'less' had been taught in previous mathematical lessons. She explained that the Phase Four follow-up lesson would be structured to develop within the learners a sense of, "What makes a number more than another number? What makes it less?" (Appendix C iii, 3.2, paragraph 6, p.14). For example, in the lesson Teacher C says:

> Okay, what can you tell me about the number 11?
> Lebo: It's like, you take 10 and you put one more and it makes 11.
> Teacher C: You have 10 and you put *one more* and it makes 11. (Appendix C iv, pedagogical move 8, p.21)

The pedagogical moves in the above example are reflective of the diagnosis Teacher C discussed. Teacher C draws on the learners' previous knowledge of the value of number and number relations, which are related to the learners' conceptual understanding of the mathematical concepts of 'more' and 'less.' Based on her diagnostic assessment, she focuses on consolidating the understanding of the mathematical concepts of 'more' and 'less.'

In her description in Phase One of the 'learning path,' Teacher B stated that learning, teaching and assessment are understood as an integrated practice. Teacher B explained that understanding of learners' thinking includes two aspects. First, an understanding of their prior mathematical knowledge and second, taking the information that the teacher gets from any assessment task of learners' thinking and using this as a basis for their teaching (Appendix B i, 1.1, paragraph 6, p.2). During the interview in Phase Three, Teacher B discussed the diagnosis that the learners are experiencing difficulty counting in groups when solving word problems and instead they resort to counting in 1s, which leads to inaccuracies. She explained that in Phase Four, she wants the learners to show her "different ways of making 7 [by] putting it into groups" (Appendix B iii, 3.2, paragraph 9, p.16). In the instances that Teacher B draws on previous mathematical content in Phase Four, she links her pedagogical moves to the diagnosis she discussed in Phase Three. In two out of the three instances that Teacher B uses previous knowledge in Phase Four, she also links it to the new knowledge that she is introducing (see Section 4.1.5, pp.49-50). For example, she says, "We're not able to count in 7s yet, so how can we break up the 7 so that we can count how much there is altogether?" (Appendix B iv, pedagogical move 6, p.20). The learners need to think about their previously taught mathematical knowledge of counting in groups of 5 and 2 and apply it to counting in 7s, which is new mathematical knowledge.

*Summary of the use of previously taught mathematical knowledge*

In Phase Two, the teachers mainly use previously taught mathematical knowledge. Teachers A and C mostly use it to evaluate previously taught mathematical concepts and Teacher B uses it to enable learners to draw on prior mathematical knowledge in order to answer the questions in the formative assessment task. In keeping with the purpose that the teachers recruit previous mathematical knowledge in Phase Two, Teachers A and C use everyday and embedded knowledge, whereas Teacher B does not. In Phase Four, the frequency with which the three teachers recruit previously taught mathematical knowledge differs, but this is related to the purpose for which it is intended. Teacher C uses it most frequently as she diagnosed that the learners needed to consolidate the previously taught mathematical content of 'more' and 'less.' In most instances, recruitment of previously taught mathematical knowledge in Phase Four is related to the diagnostic assessment made by the teachers. Previously taught mathematical knowledge is used by Teachers A and B to introduce new mathematical knowledge. Everyday and embedded mathematical knowledge in this Phase is not used to recruit previous mathematical knowledge.

The focus of the diagnosis is the same for Teachers A and B, i.e. encouraging the learners to count in groups. Teacher C diagnoses that the learners need to consolidate the mathematical concepts of 'more' and 'less.' There is alignment between the recruitment of previously taught mathematical knowledge and the diagnoses discussed.

Having discussed how the three teachers articulate and practice working with previous mathematical knowledge, embedded and everyday mathematical knowledge in the Phases of the research process, I look more closely at how new mathematical knowledge is used by the teachers. The sequence of discussion follows the same format used in Sections 4.1.1. and 4.1.2.

### 4.1.4. The use of new mathematical knowledge in Phase Two

Teacher A is the only teacher that uses new mathematical knowledge in Phase Two (see Table 1, p.40). She uses it once to relate previous mathematical content to new mathematical content. She explains to the learners that 7 + 11 = 18 (previously taught mathematical knowledge) and if the position of the numbers on the left of the equal sign are reversed, the value stays the same and therefore, the answer remains the same, i.e. 11 + 7 = 18 (new mathematical knowledge) (Appendix A ii, pedagogical move 9, p.11).

As explained above, in Phase Two, Section 4.1.1. (see p.44), when the three teachers use an everyday context to embed mathematical concepts, the underlying purpose is to recruit previous mathematical knowledge and not new mathematical knowledge.

### 4.1.5. The use of new mathematical knowledge in Phase Four

In comparison to Teacher C, who, in Phase Four, mainly works with the learners' previous understanding of mathematical concepts, Teacher A, in Phase Four, works predominantly at introducing her learners to new mathematical knowledge. She works with new mathematical knowledge nine times, in contrast to Teacher C who works with it twice and Teacher B, five times (see Table 1, p.42)

In the next part of the discussion I look at how each of the teachers work with new mathematical knowledge and how the teachers use new mathematical knowledge to link to the diagnosis. I examine how they work with the modes of everyday and embedded mathematical knowledge and see the link between the modes being recruited to the diagnosis discussed.

The new mathematical knowledge that Teacher A introduces is based on her diagnosis of learning from Phase Three. Teacher A's lesson aim is to introduce the learners to the skill of counting in groups. The following is an example of how Teacher A works with new mathematical knowledge:

> Teacher A: Can you tell us a little bit more about how you did it so quickly?
> Christina: I counted in 10s.

> Teacher A: Okay. So from now on I want you to remember that when you are grouping things, guys, and you know how many are in the group, you must use the number to count. Keep the number in your head (Appendix A iv, pedagogical move 18, p.26).

In this example, Teacher A, in her teaching steps, encourages the learners to discuss quicker ways that they can count the apparatus. By doing this, Teacher A introduces the learners to the idea that counting in groups is quicker and more efficient. She also introduces the idea that if the quantity of the group is known, this can be used to count the total. For example, if there are 10 in a group then the learners can count in 10s. Counting in groups as a more efficient manner is new mathematical knowledge. It is linked to the diagnosis made by Teacher A in Phase Three, where she explained that she found the learners unable to count in groups.

In the first instance that Teacher C works with new mathematical knowledge, she introduces the learners to the idea that a numberline can start at any given number. In the second instance, she introduces them to matching a number to its value. In both cases where Teacher C works with new mathematical knowledge, it is aimed at developing the learners' conceptual understanding of the sequence and value of number. For example, she says:

> Teacher C: I've got some school children. If I want to put the same number of children as what this number is showing me, what do I need to do? How many do I need to put? (She shows them the number 9 on the number line and has cards with school children printed on them) (Appendix C iv, pedagogical move 4, p.19).

In this example, the learners are asked to match the numeral '9' to its value in pictures. This conceptual understanding is linked to the diagnostic aim of the lesson, which Teacher C explained is to consolidate the learners' understanding of the mathematical concepts of 'more' and 'less.' If the learners understand the order of numbers and how much a number is worth (numeral 9 means 9 'pictures' in value), they are able to determine whether a number or a value is 'more' or 'less' than another number or value.

The five times that Teacher B works with new mathematical knowledge are related to the diagnostic assessment that she discussed. Teacher B, in her teaching steps in Phase Four, wants to encourage the learners to break up numbers into groups that they are able to count more accurately. For example she says to the learners:

> Can you think of a quicker way than counting 2 plus 1 plus 1? What could you do with those two ones?
> Pearl: You can put them together, so that you can count in 2s (Appendix B iv, pedagogical move 17, p.24).

By asking the learners to think of a quicker way, Teacher B encourages them to move away from counting in 1s to 'chunking'[9] and counting in 2s, which is more efficient and accurate. Counting more accurately in groups is the focus of the diagnostic assessment made.

In two out the five times, Teacher B uses the learners' previous understanding of counting in groups to help construct a more advanced mathematical understanding of counting in groups, which is new mathematical knowledge. For example, she says to the learners:

> Now, you've got 6 groups of 3 in front of you, now I want you to help each other and break up the number 3 into chunks that you can count in. What are you going break up 3 into? (Appendix B iv, pedagogical move 11, p.21)

In this example, the learners are learning to 'chunk' and count in groups. They break the group of 3 into a group of 2 and 1. They then count all the groups of 2 and all the groups of 1. The learners use their previous knowledge of counting in 2s and 1s to help them count groups of 3s, which is new knowledge. Based on the diagnostic assessment discussed by Teacher B, counting in groups efficiently and accurately is the aim of the lesson.

I now discuss how the teachers recruit new mathematical knowledge and work with it in relation to the modes of everyday and embedded mathematical knowledge. I also discuss how the mode is used to link back to the diagnostic assessment discussed.

Out of the three teachers, Teacher A uses the most word problems with everyday life examples in which new mathematical knowledge is embedded. She uses it five times, as opposed to Teacher B using it once and Teacher C twice (see Table 2, p.43). The frequency of use differs between the teachers, but for all three teachers the new mathematical knowledge embedded in the word problems is in relation to the diagnostic assessment discussed in Phase Three. An example of how the teachers do this can be seen in the following:

> Teacher A: The Easter bunny comes into our garden, and he knows that in that garden he has to leave enough boxes of eggs for 4 children. There are 10 Easter eggs inside each box. How many Easter eggs are there altogether? (Appendix A iv, pedagogical move 13, pp.24-25).

When the learners solve the problem they need to work out that if there are 4 children and they each get 10 Easter eggs, this means that there are 4 groups of 10 and they need to count in 10s four times. The learners need to use a more advanced mathematical understanding of counting in groups, as

[9] 'chunking' – term used by Teacher B to describe the grouping of quantities. For example, 20 can be grouped or 'chunked' in groups of 2s, 5s or 10s. It is intended as a method/strategy to assist in making counting more manageable and efficient.

opposed to counting in 1s, to solve the problem. By working with and counting in groups, the learners are working with the new mathematical knowledge that Teacher A is introducing. The new mathematical knowledge is based on what she diagnostically assessed, i.e. to encourage the learners to start counting in groups. The everyday context with the new mathematical knowledge embedded is useful for Teacher A's aim, because it provides an everyday context that the learners can relate to and draw on, but it also places the learners in a position where they actively have to apply new mathematical knowledge (counting in groups). The learners need to think actively of ways to work out how many Easter eggs there will be altogether if there are 10 Easter eggs in each box and 4 children.

Similarly to Section 4.1.3, I compare the consistency between what the teachers discuss in their interviews and how this aligns to the practical implementation in the context of the classroom.

#### 4.1.6. The relationship between interviews and new mathematical knowledge

In the interviews conducted with the teachers, Teacher A, in her Phase Three interview, talked about formative assessment tasks being used to "[integrate] previous knowledge with new knowledge" (Appendix A iii, 3.1, paragraph 5, p.14). In practice, out of the nine times that she works with new mathematical knowledge in her Phase Four lesson, she integrates it twice with previous mathematical knowledge (see examples, Section 4.1.3, p.45, Appendix A iv, pedagogical moves 9 and 10). Teacher B, in both her Phases One and Three interviews, talked about the 'learning path' as a process of building on or revising and consolidating the existing mathematical knowledge that the learners have (Appendix B i, 1.1, paragraph 3, p.1 and Appendix B iii, 3.1, paragraph 4, p.14). As discussed in Section 4.1.3, we find evidence of this in her teaching practice when Teacher B uses previously taught mathematical knowledge to link to the diagnosis discussed (see example Section 4.1.3, p.47, Appendix B iv, pedagogical move 6). Teacher C, in the Phase One interview, talked about three types of knowledge, i.e. "physical knowledge," which she explained as the mathematical knowledge the learners gain by working with physical/concrete apparatus, "social knowledge," which she referred to as the mathematical knowledge (including the mathematical language) the learners acquire by discussing mathematical concepts with their peers and "logico-mathematical knowledge," which Teacher C explained as the mathematical knowledge that the learners have once they are able to verbalise their understanding of the mathematical concept and apply the concept in calculations (Appendix C i, 1.3, paragraph 1, p.5). She did, however, not mention how new mathematical knowledge might form a part of this.

*Summary of the use of new mathematical knowledge*

In Phase Two, Teacher A is the only teacher who recruits new mathematical knowledge to introduce a new concept. In Phase Four, there are two main ways that new mathematical knowledge is used by the teachers in the instructional practice. While the frequency varies among the three teachers, new

mathematical knowledge is recruited by the teachers firstly as a manner in which to introduce new skills and concepts and secondly, it is worked with in relation to the learners' prior mathematical knowledge. The new mathematical knowledge recruited by the teachers is always in relation to the diagnosis discussed in Phase Three. The modes of everyday and embedded mathematical knowledge are used by the teachers to provide the learners with a context to which they can relate, and with which they actively need to work and apply the embedded mathematical knowledge, i.e. the new mathematical knowledge.

*Overall summary of the ways the teachers work with mathematical knowledge*

On analysing the teachers recruitment of previously taught mathematical knowledge and new mathematical knowledge, it can be seen that Teachers A and C particularly differ. It could be suggested that Teacher A, in her pedagogical moves, is more inclined to recruit new mathematical knowledge as opposed to previously taught mathematical knowledge. In contrast, Teacher C, in her pedagogical moves, is more inclined to recruit previously taught mathematical knowledge as opposed to new mathematical knowledge.

I propose that for both of these teachers, it is not about one teacher being more inclined to work with one type of mathematical knowledge over another. The teachers' recruitment of previously taught mathematical knowledge and new mathematical knowledge is aligned to the diagnostic assessment discussed by the teachers in Phase Three. Teacher A's diagnosis revealed a need to introduce and get the learners to work towards the more advanced counting skill of counting in groups. For this purpose, Teacher A, in her pedagogical moves, recruits new mathematical knowledge more frequently for her Phase Four lesson, as she introduces the learners to the new mathematical skill of counting in groups as a more efficient way. Teacher C's diagnosis is that the learners are finding it challenging to understand the mathematical concepts of 'more' and 'less,' which are concepts that have been previously taught. For this purpose, Teacher C, in her pedagogical moves, recruits previously taught mathematical knowledge more frequently for her Phase Four lesson as she works to consolidate the learners' previously taught understanding of the concepts.

Teacher B recruits both previously taught and new mathematical knowledge. In all instances it is aligned to the diagnostic assessment made. The diagnostic assessment revealed a need to work with the learners on counting in groups and to introduce the learners to the idea that numbers can be grouped differently in order to count efficiently and accurately. For this purpose, Teacher B, in her pedagogical moves, in her Phase Four lesson, works with the learners' previously taught mathematical knowledge of counting in groups and introduces them to the new mathematical knowledge that numbers can be grouped differently to facilitate counting.

The mode in which the teachers use previously taught mathematical knowledge and new mathematical knowledge is also determined by the purpose for which it is intended. In Phase Two the teachers use embedded mathematical knowledge in everyday contexts as a way to evaluate the learners' understanding of concepts that have been previously taught. The embedded mathematical knowledge is related to the concepts being assessed in the formative assessment task. In Phase Four, after the teacher's diagnosis has been discussed in Phase Three, everyday and embedded mathematical knowledge is not used by the teachers as a means to evaluate the learners' understanding as it was when the formative task is being administered, but rather it is used in response to the diagnosis of learning needs. For example, Teacher A uses it to introduce the new mathematical skill of counting in groups for efficiency and Teacher C uses it to consolidate the learners' understanding of the mathematics terminology of 'more' and 'less.'

The type of mathematical knowledge recruited is not only determined by the diagnosis of learning needs, but also by the task or content being taught. For example, previous mathematical knowledge is not only used to consolidate previously taught mathematical concepts in response to a diagnosis made, but is also used to enable learners to draw on knowledge of previously taught mathematical concepts when the formative task is being administered, and is also worked with in relation to new mathematical knowledge when new mathematical concepts are being introduced.

### 4.2. Category 2 - Instructional Practice

Ball et al (2008) talks about the pedagogical thinking that teachers need to do to support the mathematical learning of their learners. In the analysis of this category, I discuss the instructional practice of the teachers in an effort to understand the pedagogical thinking of the teachers when working with formative assessment diagnostically.

To analyse the teachers' instructional practice, I examine the teachers' use of six instructional practices, which I refer to as "pedagogical moves": probing questions and active interpretation (PROB/PROBQAIN), verbal demonstrations (VERB DEM), visual demonstrations (VIS DEM), concrete apparatus (CA), explicit explanations (EXP) and validations (VAL). To analyse each of these moves I quantify the frequency of use in Phases Two and Four. I do so by comparing the use of each move between the teachers, and comparing the use of each move in relation to the diagnosis made in the interview in Phase Three. I then conduct the analysis of the teachers' instructional practice by using the first pedagogical move of "probing questions and active interpretation" as a lens through which to view the way in which the teachers implement the other five pedagogical moves (i.e. "verbal demonstrations," "visual demonstrations," "concrete apparatus," "explicit explanations" and "validations") in their classroom practice when engaging with formative assessment. I do this because "probing questions and active interpretation" is the pedagogical move that is used the most by the teachers. Furthermore, the consistency is examined between what was articulated by the teachers

about their instructional practices in the interviews in Phases One and Three and of how this is implemented when attempting to address the learning difficulties as diagnosed.

**Table 3: Instructional Practice**

This Table is a quantitative comparison of differences and similarities among the three teachers' instructional practice and how their pedagogical moves are aligned, in Phase Four, to the diagnosis discussed in the interview in Phase Three.

| **Number of times the code was used in Phases Two and Four** | | | | | | |
|---|---|---|---|---|---|---|
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| | Phase Two | Phase Four | Phase Two | Phase Four | Phase Two | Phase Four |
| Probing | 0 | 1 | 0 | 2 | 0 | 0 |
| Probing questions and active interpretation | 11 | 24 | 5 | 16 | 7 | 28 |
| Explicit Explanation | 2 | 8 | 0 | 8 | 0 | 5 |
| Validation | 1 | 5 | 1 | 2 | 1 | 2 |
| Verbal Demonstration | 3 | 3 | 1 | 4 | 2 | 3 |
| Visual Demonstration | 2 | 4 | 1 | 10 | 1 | 8 |
| Concrete Apparatus | 3 | 7 | 2 | 13 | 1 | 13 |
| **Number of times the code was used in Phase Four, in response to the teacher's diagnosis in Phase Three** | | | | | | |
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| Probing | 1 | | 2 | | 0 | |
| Probing questions and active interpretation | 19 | | 16 | | 28 | |
| Explicit Explanation | 8 | | 8 | | 4 | |
| Validation | 4 | | 2 | | 2 | |
| Verbal Demonstration | 3 | | 4 | | 2 | |
| Visual Demonstration | 3 | | 10 | | 5 | |
| Concrete Apparatus | 7 | | 13 | | 10 | |

From Table 3 the following can be seen:

There are only three instances when "probing questions" are used without "active interpretation." In the analysis, "probing questions" and "active interpretation" are integrated and discussed as one code. In total, "probing questions and active interpretation" is used predominantly by Teachers A and C, with a total of 35 times each. Teacher B uses it a total of 21 times. Out of the three teachers, Teacher A uses "probing questions and active interpretation" the most when administering and working with the

formative assessment task in Phase Two. Teacher A works with it in Phase Two 11 times, as opposed to Teachers B and C who work with “probing questions and active interpretation” five and seven times in Phase Two, respectively.

In Phase Two, Teacher A uses “explicit explanations” twice. She is the only teacher that uses “explicit explanations” in this Phase. Out of the three teachers, the total number of times that Teacher C uses “explicit explanations” is the least. In Phases Two and Four, Teacher A uses “explicit explanations” a total of 10 times. Teacher B works with it eight times and Teacher C, five times.

All three teachers use “validation” once in Phase Two. Teacher A uses “validation” the most in Phase Four, i.e. five times. Teachers B and C each use “validation” twice in Phase Four.

Although the frequency of “verbal demonstrations” being used by the three teachers is, on average, the same, i.e. Teacher A a total of six times, Teachers B and C a total of five times each, Teacher A uses “verbal demonstrations” the most when administering the formative assessment task in Phase Two. She uses it three times, as opposed to Teacher B who uses it once and Teacher C who uses it twice. Teacher A also uses “visual demonstrations” the most in Phase Two, but the least in Phase Four. Teachers B and C go from using “visual demonstrations” once in Phase Two to 10 and eight times in Phase Four, respectively. Teacher A works with “visual demonstrations” twice in Phase Two and in contrast to Teachers B and C, she uses “visual demonstrations” four times in Phase Four.

All three teachers use very little “concrete apparatus” in Phase Two. After the diagnosis has been discussed in the interview in Phase Three, Teachers B and C use “concrete apparatus” more frequently in their moves, i.e. 13 times each compared to Teacher A, who uses “concrete apparatus” seven times.

The above description is a summary of all the pedagogical moves used by the teachers in Phases Two and Four. In order to foreground the key differences between the moves, I have created Table 4.

**Table 4: Total of pedagogical moves used in the instructional practice in Phases Two and Four**

| | Teacher A | Teacher B | Teacher C |
|---|---|---|---|
| Probing questions and Active Interpretation | 35 | 21 | 35 |
| Explicit Explanation | 10 | 8 | 5 |
| Validation | 6 | 3 | 3 |
| Verbal demonstration | 6 | 5 | 5 |
| Visual demonstration | 6 | 11 | 9 |
| Concrete Apparatus | 10 | 15 | 14 |

From Table 4, the following is evident when comparing the totals (Phases Two and Four) of the pedagogical moves that are used most frequently by the teachers:

All the teachers use “probing questions and active interpretation” and “concrete apparatus” frequently in their pedagogical moves. Teachers A and B use “explanations” frequently and Teachers B and C use “visual demonstrations” as well. Out of the three teachers, Teacher A uses “validation” the most frequently.

In Phase Four, after the diagnosis of learning has taken place in the interview in Phase Three, the instructional practice of the teachers is mostly in response to the diagnostic assessment discussed (see Table 3, p. 54). However, there are differences that can be noted between the teachers in the frequency of the pedagogical moves they use in response to the diagnosis. Table 3 shows that out of the three teachers, Teacher B is the most consistent in Phase Four, with her instructional practice being aligned to the diagnosis made. For example, the 13 occasions that she works with “concrete apparatus” are all related to the diagnosis. The eight times that she “explicitly explains” to the learners are all in response to the diagnosis. Similarly, the rest of the pedagogical moves of Teacher B are all aligned to the diagnosis discussed. It can also be seen that Teachers B and C consistently relate “probing questions and active interpretation” to the diagnosis discussed, which is different to Teacher A who uses “probing questions and active interpretation” 19 out of 24 times in response to the diagnosis. Teachers A and B, in their instructional practice in Phase Four, consistently relate “visual demonstrations” and “concrete apparatus” to the diagnosis discussed. However, Teacher C uses “visual demonstrations” and “concrete apparatus” a total of 21 times in Phase Four ( eight times and 13 times, respectively) and a total of 15 times (five and 10 times, respectively) are aligned to the diagnosis discussed. (More on the pedagogical moves relating to the diagnosis made in Section 4.2.2. pp.62-64).

In the section that follows, I analyse the instructional practice of the three teachers when administering the formative assessment task in Phase Two. I do this by examining and comparing how the teachers use the six pedagogical moves in their instructional practice.

### 4.2.1. Instructional Practice in Phase Two

In the following section I discuss how the teachers use the pedagogical move of “probing questions and active interpretation” in their instructional practice.

#### 4.2.1.1. "Probing questions and active interpretation"

In the analysis of the instructional practice of the teachers in Phase Two, the most frequently used pedagogical move is "probing questions." These are questions that encourage the learners to interpret their own thinking actively in relation to the mathematical content of the formative assessment task. The following are two examples of the 11 times that Teacher A uses "probing questions" in Phase Two to get the learners to interpret actively what they did in a solution of a problem:

> Teacher A: How did you draw that?
> Neha: I drawed 7 rectangles in a line and 11 rectangles in a line and I counted them all and got 18. (Appendix A ii, pedagogical move 5, p.9), or
>
> Teacher A: How can we write what we have done?
> Neha: We can write 7 + 11 = 18.
> Teacher A: Can we write it differently? (Appendix A ii, pedagogical move 9, p.11)

In the first example, Teacher A probes the learner to think actively through what her own thinking was when solving the problem. She asks the learner to articulate the method that she used and encourages her to interpret the mathematical content, i.e. 7 rectangles and 11 rectangles equals 18 rectangles. In the second example, Teacher A asks a "probing question" to get the learner to interpret what she did mathematically in a concrete and 2D form, and to think actively of how to represent this as an algorithm. Teacher A probes the learner's interpretation further by asking her to think of an alternative way to represent the mathematical content, i.e. 11 + 7 = 18.

In Phase Two, Teachers B and C use "probing questions and active interpretation" less than Teacher A does. They use it five and seven times, respectively (see Table 3, p.54). However, both teachers ask "probing questions" to assist the learners in their thinking as they complete the formative assessment task. For example, "How are you going to draw this for me? How are you going to do it?" (Appendix B ii, pedagogical move 7, p.11), or "Tell me what you think you must do...You know what to do, how can you work it out?" (Appendix C ii, pedagogical move 14, p.10). The learners respond to the teachers' questions by explaining the strategies and methods that they use to approach the mathematical problem posed by the teacher. By explaining, the learners actively think through the process, their strategies, methods and how to work with the mathematical content in the formative task.

I now use the pedagogical move of "probing questions and active interpretation" as a lens through which to consider and discuss how the teachers use the other pedagogical moves of "verbal demonstration," "visual demonstration," "concrete apparatus," "explicit explanations" and " validation" in their administering of the formative assessment task in Phase Two.

4.2.1.2. "Probing questions and active interpretation" and "verbal demonstrations"

**Table 5**

| **"verbal demonstrations" used in relation to "probing questions and active interpretation" (Phase Two)** | | |
|---|---|---|
| **Teacher A** | **Teacher B** | **Teacher C** |
| 3 out of 3 | 1 out of 1 | 2 out of 2 |

In Phase Two, Teacher A uses "verbal demonstrations" three times when administering the formative assessment task. Teacher B uses it once and Teacher C twice (see Table 3, p.54). In all of these instances, the teachers use it in relation to "probing questions and active interpretation." The three teachers ask the learners to verbalise their strategies/ideas when solving problems. The combined use of the codes encourages the learners to reflect on and actively interpret their own thinking as they verbalise their thoughts. The teachers also use the combined codes in an attempt to understand the ways in which the learners are thinking and the strategies that they are using to solve the problems (see Section 4.3, for more on how the teachers' evaluate the learners' thinking, pp.78-88). The following is an example of this:

> Teacher A: What did you do? Tell me how you did this?
> Nondu: I put my blocks in two lines.
> Teacher A: You mean 7 in one line and 11 in another?
> Nondu: Yes. Then I counted 5…10 and the 3 left over. (Appendix A ii, pedagogical move 5, pp.9-10)

The "probing question/s" can be thought of as the catalyst/s that incite the verbalisation and encourage reflective thinking. In the example, as the learner verbalises her method, she reflects actively on her thinking. It is "probing questions" that begin the verbalisation, "What did you do?" "Tell me how you did this?" These questions demand more than a "Yes/No" answer and consequently the learner needs to verbalise her thinking, "I put my blocks in two lines. Then I counted 5…10 and the 3 left over."

4.2.1.3. "Probing questions and active interpretation" and "visual demonstrations"

**Table 6**

| **"visual demonstrations" used in relation to "probing questions and active interpretation" (Phase Two)** | | |
|---|---|---|
| **Teacher A** | **Teacher B** | **Teacher C** |
| 1 out of 2 | 1 out of 1 | 1 out of 1 |

In total the teachers work with “visual demonstrations” four times in Phase Two (see Table 3, p.54). In three instances that the teachers work with “visual demonstrations” in their instructional practice, “visual demonstrations” are used in relation to “probing questions and active interpretation.” In the following example, Teacher A provides the learners with a “visual demonstration” when she writes an alternative number sentence on the whiteboard for the learners.

> Teacher A: How can we write what we have done?
> Neha: We can write 7 + 11 = 18.
> Teacher A: Can we write it differently?
> Learners: (no response).
> Teacher A: We can also write it as 11 + 7 = 18 (Teacher A writes this up on the whiteboard).
> (Appendix A ii, pedagogical move 9, p.11)

Teacher A, in this example, uses “probing questions” to get the learners to think actively of alternative mathematical ways to represent the number sentence. She says to the learners, “How can we write what we have done?...Can we write it differently?” When the learners are unable to provide an answer, Teacher A visually demonstrates and writes the alternative number sentence on the whiteboard.

#### 4.2.1.4. “Probing questions and active interpretation” and “concrete apparatus”

**Table 7**

| **“concrete apparatus” used in relation to “probing questions and active interpretation” (Phase Two)** | | |
|---|---|---|
| **Teacher A** | **Teacher B** | **Teacher C** |
| 1 out of 3 | 1 out of 2 | 0 out of 1 |

Of the six times that the teachers work with “concrete apparatus” in Phase Two (see Table 3, p.54), Teachers A and B each work with it once in relation to “probing questions and active interpretation.” Teacher C does not use “concrete apparatus” in relation to “probing questions and active interpretation.” A probing question is used by Teachers A and B to get the learners to think actively about how they are going to solve the problem. Simultaneously, the teachers encourage the learners to use the “concrete apparatus” to help them interpret the problem and “show” the teacher how they reached the solution (see Section 4.3, for more on how the teachers’ evaluate the learners’ thinking, pp.78-88). An example of “concrete apparatus” being used in relation to “probing questions and active interpretation” can be seen in the following:

> Teacher B: How are you going to do it? Use the blocks to show me how you are going to build the number. I need to see how you made it. (Appendix B ii, pedagogical move 7, pp.11-12)

Teacher B is probing the learners to think about how they are going to solve the problem in the formative task, and at the same time asks the learners to use the "concrete apparatus" (blocks) to "show" how they are going to build the number. By asking them to "show" their thinking, the teacher is hoping to "see" and gain an insight into it.

On the four occasions when "concrete apparatus" is not used in relation to "probing questions and active interpretation" in this Phase, the teachers give the learners "concrete apparatus" as a means to assist them in working out the mathematical concepts or problems. In Appendix C ii, pedagogical move 10, p.9, there is an example of this when Teacher C gives the learners word problems on work cards and provides them with the matching "concrete apparatus." The following is an example of a word problem given:

> Mom has 5 cups, she buys 7 *more* cups. How many cups does she have altogether?" (Appendix C ii, pedagogical move 12, p.10). [The learners receive a container with cups in it and use the actual objects to help them interpret and solve the mathematical concepts embedded in the word problem. The learners take 5 cups and add 7 more cups and then count up the cups to see how many there are altogether.]

4.2.1.5. "Probing questions and active interpretation" and "explicit explanations"

**Table 8**

| **"explicit explanations" used in relation to "probing questions and active interpretation" (Phase Two)** | | |
|---|---|---|
| **Teacher A** | **Teacher B** | **Teacher C** |
| 1 out of 2 | 0 out of 0 | 0 out of 0 |

Teacher A is the only teacher that uses "explicit explanations" in Phase Two, whilst administering the formative assessment task (see Table 3, p.54). She links it once to "probing questions and active interpretation." Teacher A uses a "probing question" to encourage the learners to think actively of an alternate way to represent the number sentence "7+11=18." When there is no response from the learners, she "explicitly explains" that it can also be written as "11 + 7 = 18" (Appendix A ii, pedagogical move 9, p.11). The other instance that Teacher A "explicitly explains" in this Phase is in Appendix A ii, pedagogical move 10, pp.11-12. In this instance, Teacher A explains to the learners:

> Instead of writing '7 *plus* 11' or '7 *and* 11' to show what we did to get to the answer, a symbol (+) is used to show that we are plussing or adding the numbers together.

In Phase Two, Teacher A uses "explicit explanations" when the learners are unable to respond using their current mathematical knowledge, i.e. "7 + 11 = 18" is the same as "11 + 7 = 18". She also uses

"explicit explanations" when she wants to explain a particular mathematical idea to them, i.e. the (+) sign is used to show when numbers are being added together.

4.2.1.6. "Probing questions and active interpretation" and "validation"

**Table 9**

| **"validation" used in relation to "probing questions and active interpretation" (Phase Two)** | | |
|---|---|---|
| **Teacher A** | **Teacher B** | **Teacher C** |
| 0 out of 1 | 0 out of 1 | 0 out of 1 |

The three teachers each "validate" the learners once in Phase Two (see Table 3, p.54). "Validation" is not used in relation to "probing questions and active interpretation." For example, Teachers B and C validate the learners' efforts as the learners complete the task and say things such as, "You are superstars!" (Appendix B ii, pedagogical move 8, p.12) or "Well done, I can see that you are on the right track!" "Keep trying!" (Appendix C ii, pedagogical move 15, p.10). The teachers use "validation" to encourage the learners and to affirm their thinking.

*Summary of the pedagogical moves used by the teachers during instruction in Phase Two*

"Probing questions and active interpretation" is the pedagogical move that is used the most frequently in the instructional practice of the teachers in Phase Two. In this Phase, "probing questions and active interpretation" is used to encourage the learners to interpret actively and reflect on the mathematical content or concepts being assessed in the formative task. When the teachers use "verbal demonstrations" in their pedagogical moves, it is always based on getting the learners to interpret actively their strategies and methods used in the solving of mathematical problems that make up the assessment task. In all instances, it is linked to "probing questions and active interpretation." This gives the teachers the opportunity to gain an insight into the learners' mathematical thinking. "Visual demonstrations" are not used frequently by the teachers in this Phase. When "visual demonstrations" are used, three out of the four instances are used together with "probing questions" and getting the learners to interpret actively. "Concrete apparatus," in this Phase, is used by the teachers as a way for the learners to "show" their active interpretation of the mathematical problems or it is given by the teachers to the learners to "assist" them in "concretely" working out the mathematical problem. Teacher A is the only teacher that uses "explicit explanations" in this Phase. In the first instance, she uses it to explain a new mathematical concept and in the second instance, to explain how the mathematical symbol of addition is used. "Validation" is used very little in Phase Two.

In the next section, I discuss the instructional practice of the teachers in Phase Four, after the diagnostic assessment has been made and reflected on in the interview (Phase Three). I use the

same six pedagogical moves that were used in Section 4.2.1 to examine and compare the teachers' instructional practice.

### 4.2.2. Instructional Practice in Phase Four

As in Section 4.2.1.1, I discuss how the teachers use the pedagogical move of "probing questions and active interpretation" in their instructional practice in Phase Four.

#### 4.2.2.1. "Probing questions and active interpretation"

Similarly to Phase Two, "probing questions and active interpretation" is the most frequently used pedagogical move in Phase Four. However, Teacher B uses it the least in this Phase (16 times), compared to Teachers A and C who use it 24 and 28 times, respectively (see Table 3, p.54). All 16 and 28 times that Teachers B and C use "probing questions and active interpretation" in their pedagogy, they link it to the diagnostic assessment made (see Table 3, p.54). An example of this in Teacher B's teaching practice can be seen in the following:

> Teacher B: Right, now...Pearl and Tristan, how did you break up your 8? Did you make it in 4s, 2s and 1s?
> Tristan: No we did it in 1s, 2s and 5s. (Appendix B iv, pedagogical move 13, p.22)

In this example Teacher B uses the probing question, "…How did you break up your 8?" to encourage the learners to think actively of ways in which the value of the number that they are working with can be grouped. The learner has to think actively about how 8 as a value can be broken up into groups. By Teacher B using a "probing question" to encourage the learners to think actively about the grouping of numbers, she is linking to the diagnosis made. In the interview in Phase Three, Teacher B explained that the primary difficulty that the learners were experiencing with number in the formative task was the ability to count in groups (Appendix B iii, 3.2, paragraph 9, p.16).

Teacher C also uses "probing questions and active interpretation" to link to the diagnostic assessment made. In the interview in Phase Three, she explained that the lesson in Phase Four would be focused on developing the learners' conceptual understanding of the mathematical concepts of 'more' and 'less' (Appendix C iii, 3.2, paragraph 6, p.14). The link between the diagnosis and "probing questions and active interpretation" in Phase Four can be seen when Teacher C interacts with the learners in the following way:

Teacher C: What is one less than 12?
Susan: 11.
Teacher C: 11. Why? Would it be bigger or smaller? (Appendix C iv, pedagogical move 10, pp.21-22) or

Pointing to the three different columns of children, Teacher C asks the learners questions such as, Is this row the same as this row? (Pointing to the row of 9 cards and the row of 11 cards).
Learners: No.
Teacher C: Why?
Masego: It's two more. (Appendix C iv, pedagogical move 9, p.21)

In both of the above examples, Teacher C uses "probing questions" in her pedagogical moves to encourage the learners to think actively about the value of numbers in relation to each other, i.e. "What is one less than 12? Why? ..." "Is this row the same as this row? Why? ..." By probing the learners to think actively about the value of numbers in relation to each other, Teacher C encourages the development of the learners' conceptual understanding of numbers being 'more' and 'less' than each other, i.e. 11 is one less than 12 or the value of this row is not the same as the value of that row because there are two more in that row. In this way, Teacher C makes the link to the diagnosis made.

Teacher A, 19 out of the 24 times that she uses "probing questions and active interpretation," links it to the diagnosis that she discussed in the interview in Phase Three (see Table 3, p.54). In Phase Three, Teacher A explained that based on her diagnostic assessment she wanted to "get the learners to start counting in groups" (Appendix A iii, 3.2, paragraph 7, p.17). The following is an example of how Teacher A uses "probing questions and active interpretation" to link to her diagnosis:

Now I don't want to know how many there are yet, I want somebody to try and tell me what we can do to try and find out how many eggs there are?
Al: We can count in 2s. (Appendix A iv, pedagogical moves 3-4, p.20)

In this example, Teacher A uses a "probing question" to get the learners to think of various ways that the 'eggs' can be counted. In so doing, the learners actively think of options and one learner proposes counting in 2s which is linked to the diagnosis made of encouraging the learners to count in groups.

The 5 times that Teacher A does not directly link "probing questions and active interpretation" to the diagnosis made, she relates the probing to other aspects and concepts of the mathematics curriculum. For example, she says to a learner:

And then you said by putting them together what are we actually doing, Daniel?
Daniel: Adding, plussing them. (Appendix A iv, pedagogical move 7, p.22)

In the above example, Teacher A uses "probing questions and active interpretation" to socialise the learners into mathematics terminology, i.e. the terminology associated with addition. This is not explicitly linked to the diagnosis discussed (Appendix A iii, 3.2, paragraph 7, p.17). It could, however, be argued that an understanding of addition, i.e. repeated addition, is important for "counting in groups" and consequently is linked to the diagnosis. "Socialisation" will be discussed in more detail in Section 4.4. (see pp.88-93).

In the next section of the discussion, I once again (see Section 4.2.1.1.) use the pedagogical move of "probing questions and active interpretation" as a lens through which to examine the link between the diagnostic assessment and the remaining pedagogical moves that are implemented in classroom practice by the teachers in Phase Four.

4.2.2.2. "Probing questions and active interpretation" and "verbal demonstrations"

**Table 10**

| **"verbal demonstrations" used in relation to "probing questions and active interpretation" (Phase 4)** | | | |
|---|---|---|---|
| | **Teacher A** | **Teacher B** | **Teacher C** |
| | 3 out of 3 | 2 out of 4 | 3 out of 3 |
| **"verbal demonstrations" used in Phase Four, in response to the teacher's diagnosis in Phase Three** | | | |
| | Teacher A | Teacher B | Teacher C |
| | 3 out of 3 | 4 out of 4 | 2 out of 3 |

In Phase Four, Teachers A, B and C each use "verbal demonstrations" three, four and three times, respectively (see Table 3, p.54). "Verbal demonstrations" for Teachers A and C are always related to "probing questions and active interpretation." Three out of the four instances that Teacher B uses "verbal demonstrations" are related to "probing questions and active interpretation" (see Table 10). An example of "verbal demonstrations" being related to "probing questions and active interpretation" can be seen in the following:

> Teacher C: Wandi, do you want to tell me what you have written?
> Wandi: Uh…9. 9 plus 2 equals 11. (Appendix C iv, pedagogical move 13, p.22)

Teacher C uses a "probing question" to encourage the learner to interpret actively and verbalise how he has solved the problem. As the learner does this, the teacher is able to gain an insight into his thinking (See Section 4.3, p.78-88, for more on how the teachers evaluate the learners' thinking).

Each time that Teachers A and C use “verbal demonstrations” and “probing questions and active interpretation,” it is related to the diagnosis discussed in the interview in Phase Three. An example of this can be seen when Teacher A asks the learners to verbalise how they reached the solutions to the word problems. She says, “…Neha, when you started off, how did you start counting your blocks?” (Appendix A iv, pedagogical move 16, p.25).

In the example, the learner is encouraged to verbalise and interpret her solution actively. Teacher A makes the link to the diagnosis, i.e. counting in groups, by asking the learner to describe how she counted the blocks.

On the two occasions where “verbal demonstrations” are not used in relation to “probing questions and active interpretation,” Teacher B asks the learners to count in groups to reach the solution (see example, Appendix B iv, pedagogical move 13, p.22).

In the four instances that Teacher B uses “verbal demonstrations” in Phase Four, the “verbal demonstrations” are all linked to the diagnosis made (see Table 10). For example:

> Teacher B: Kabelo, can you describe to me how you broke up 8 [blocks]?
> Kabelo: I decided to do it in 2s. (Appendix B iv, pedagogical move 13, p.22)

In this example, Teacher B uses a “probing question” to get the learner to interpret actively and verbalise how they “broke up” or grouped the 8 blocks in order to count. By Teacher B doing this, the link to the diagnosis is made, i.e. to encourage the learners to count in groups.

4.2.2.3. “Probing questions and active interpretation” and “visual demonstrations”

**Table 11**

| **“visual demonstrations” used in relation to “probing questions and active interpretation” (Phase Four)** | | | |
|---|---|---|---|
| | **Teacher A** | **Teacher B** | **Teacher C** |
| | 4 out of 4 | 10 out of 10 | 6 out of 8 |
| **“visual demonstrations” used in Phase Four, in response to the teacher’s diagnosis in Phase Three** | | | |
| | **Teacher A** | **Teacher B** | **Teacher C** |
| | 3 out of 4 | 10 out of 10 | 5 out of 8 |

In Phase Four, Teacher A uses “visual demonstrations” the least in her instructional practice, i.e. four times. Teacher B uses “visual demonstrations” 10 times and Teacher C uses them eight times (see Table 3, p.54). In total, “visual demonstrations” in the teachers’ instructional practice in Phase Four is used 22 times. “Visual demonstrations” in Phase Four is used in two ways. Firstly, it is used by the

teachers to demonstrate a concept/skill visually. Secondly, it is used by the teachers to get the learners to demonstrate visually their understanding of a mathematical problem/concept/skill.

Out of the 22 times that "visual demonstrations" is used, 20 times are related to "probing questions and active interpretation" (see Table 11). The following are examples illustrating this:

> Teacher B: Show me 4 groups of 7. When I say 4 groups of 7, how many groups am I asking for? (Appendix B iv, pedagogical move 3, p.19) and
>
> Teacher C: Okay, what can you tell me about the number 11? *(She places the number 11 card on the number line after the number 10)*. (Appendix C iv, pedagogical move 8, p.21)

The purposes of the "visual demonstrations" are different for each of the teachers. In the first example, Teacher B uses a "probing question" to get the learners to interpret their own thinking actively in relation to the mathematical content, i.e. "When I say 4 groups of 7, how many groups am I asking for?" In responding to the questions, the learners are asked to show their understanding visually. Teacher B uses it as a means to gain an insight into the learners' conceptual understanding about the mathematical problem. In the example for Teacher C, the "probing question" is asked, i.e. "What can you tell me about the number 11?" Instead of the learners visually demonstrating their understanding as in the example for Teacher B, Teacher C visually demonstrates to the learners where the number 11 would be on the numberline. Teacher C provides a "visual demonstration" to assist the learners with their understanding of the mathematical content when responding to the "probing question." The learners are able to "see" that the number 11 comes after the number 10 on the numberline and are able to use this to develop their conceptual understanding about the number 11 in relation to other numbers. For example, the learners can now respond that "11 comes after the number 10" or "11 is one more than 10," etc.

When the teachers use "visual demonstrations" in their instructional practice, 18 out of 22 times they are used in response to the diagnostic assessment discussed. Teacher A uses "visual demonstrations" in relation to the diagnostic assessment three out of four times, Teacher B, all 10 times and Teacher C, five out of eight times (see Table 11). The following is an example of Teacher B using "visual demonstrations" in relation to the diagnostic assessment discussed:

> Teacher B: Now I need 4 groups of 7, how much is in group one?
> Learners: 7.
> Teacher B puts 7 blocks onto one paper plate (i.e. 7 blocks into one group).
> Teacher B: In group two?
> Learners: 7.

> Teacher B continues with this line of questioning until she has put out 7 blocks on 4 paper plates. (Appendix B iv, pedagogical move 5, pp.19-20)

Teacher B uses a “probing question” to get the learners to think actively about how to group the blocks, i.e. “Now I need 4 groups of 7, how much in each group?” When the learners respond, Teacher B places 4 blocks on 7 separate paper plates. She “visually demonstrates” to the learners how to group 4 groups of 7 physically. Each group of 4 will be counted 7 times. This links to the diagnosis of encouraging the learners to ‘chunk’ (group of 4 on one paper plate) and count in groups (count each group of 4 seven times).

On the four occasions that “visual demonstrations” in Phase Four is not used directly in response to the diagnosis discussed (see Table 11), it is used to socialise the learners into mathematical symbols and to introduce new mathematical knowledge. For example, Teacher A uses a “visual demonstration” not explicitly related to the diagnosis discussed when she asks a learner to “demonstrate visually” the mathematical symbol used for addition (Appendix A iv, pedagogical move 7, p.22). This is done with the intention of socialising the learners into the mathematical symbols used for the four operations (see Section 4.4, pp.88-93). Teacher C uses “visual demonstrations” that are not directly related to the diagnosis discussed on three occasions. On all three occasions she uses the “visual demonstrations” to introduce the learners to new mathematical knowledge. For example, she visually demonstrates the start of the numberline. She shows the learners that the numberline will start at the number 9. This is new mathematical knowledge for the learners, as previously taught numberlines would have started at 0 (Appendix C iv, pedagogical move 3, p.18).

Although the four “visual demonstrations” that Teachers A and C use are not explicitly linked to the diagnosis discussed in the interview in Phase Three, they are part of developing mathematical constructs that the learners need in order to understand the concepts that the teachers are teaching in response to the diagnosis made in the interview in Phase Three. The idea of addition and an understanding of the value of numbers is important in developing a conceptual understanding of grouping and numbers being ‘more’ or ‘less’ than another number.

There is a close relationship in the instructional practice of the teachers between “visual demonstrations” and “concrete apparatus.” In the 22 instances that “visual demonstrations” are used (see Table 3, p.54) by the teachers, 21 times they are used together with “concrete apparatus.” For example, Teacher A “visually demonstrates” to the learners how to regroup their 5 wooden blocks (“concrete apparatus”) as she teaches them how to count in groups (Appendix A iv, pedagogical move 11, p.23). Teacher C, using picture cards (“concrete apparatus”), “visually demonstrates” to the learners the different values of numbers. For example, 9 picture cards are 1 less than 10 picture cards (Appendix C iv, pedagogical move 6, p.20).

4.2.2.4. "Probing questions and active interpretation" and "concrete apparatus"

**Table 12**

| **"concrete apparatus" used in relation to "probing questions and active interpretation" (Phase Four)** | | | |
|---|---|---|---|
| | **Teacher A** | **Teacher B** | **Teacher C** |
| | 2 out of 7 | 10 out of 13 | 8 out of 13 |
| **"concrete apparatus" used in Phase Four, in response to the teacher's diagnosis in Phase Three** | | | |
| | **Teacher A** | **Teacher B** | **Teacher C** |
| | 7 out of 7 | 13 out of 13 | 10 out of 13 |

In Phase Four, Teacher A uses "concrete apparatus" in relation to "probing questions and active interpretation" the least, i.e. two out of seven times. Teacher B, 10 out of 13 times and Teacher C, eight out of 13 times (Table 12). For example:

> [Teacher B gives the learners 70 unifix blocks (*concrete apparatus)*].
> Teacher B: If the blocks are already in 10s, so you and your partner need to take? (Appendix B iv, pedagogical move 2, p.19) or

> Teacher B says: Now, you've got 6 groups of 3 in front of you, now I want you to help each other and break up the number 3 into chunks that you can count in. What are you going to break up 3 into? (Appendix B iv, pedagogical move 11, p.21)

In these examples, Teacher B asks the learners to use the "concrete apparatus" to work out actively the solution to a mathematical problem that she asks them to solve. She poses the problems using "probing questions," i.e. "If the blocks are already in 10s, so you and your partner need to take? What are you going to break 3 into?" She tells the learners to use the "concrete apparatus" to work out the solutions to the problems.

When "concrete apparatus" is used by the teachers and it is not in relation to "probing questions and active interpretation," it is used by the teachers to "demonstrate visually" to the learners or it is used by the learners to "demonstrate visually" to the teacher (see Section 4.2.2.3, pp.65-67). "Concrete apparatus" is also given to the learners to assist them in physically working out their solutions. Examples of this can be seen in Appendix A iv, pedagogical move 9, p.23 and Appendix C iv, pedagogical move 12, p.22.

In the instructional practice of the teachers in Phase Four, the use of "concrete apparatus" by Teachers A and B in all instances is used in response to the diagnosis discussed in the interview in

Phase Three. Teacher C uses “concrete apparatus” in relation to the diagnosis discussed 10 out of 13 times (see Table 12). An example of the way in which the teachers use “concrete apparatus” in relation to “probing questions and active interpretation” can be seen in the following example from Teacher A:

> Each learner gets two little wooden cubed blocks to place inside the container.
> Teacher A: How many children are there in a group?
> Together with Teacher A, the learners count that there are seven learners in the group.
> Teacher A: Now I don’t want to know how many there are yet, I want somebody to try and tell me what we can do to try and find out how many eggs [wooden cubed blocks] there are.
> Al: We can count in 2s. (Appendix A iv, pedagogical moves 2 – 4, p.20)

Teacher A gives the learners wooden blocks as “concrete apparatus” with which they can work. The learners need to use the “concrete apparatus” to help them work out how many blocks (‘eggs’) there are in the group if each learner has 2 wooden blocks. As the learners work with the “concrete apparatus” and realise that the blocks need to be counted in 2s, the link to the diagnosis is made.

The three times that Teacher C does not directly relate “concrete apparatus” to the diagnosis is at the start of the lesson in Phase Four. She uses “concrete apparatus” to introduce and set up the numberline on which the learners will work for the rest of the lesson (see example Section 4.2.2.3, p.67, Appendix C iv, pedagogical move 3).

4.2.2.5. “Probing questions and active interpretation” and “explicit explanations”

**Table 13**

| **“explicit explanations” used in relation to “probing questions and active interpretation” (Phase Four)** | | | |
|---|---|---|---|
| | **Teacher A** | **Teacher B** | **Teacher C** |
| | 6 out of 8 | 7out of 8 | 4 out of 5 |
| **“explicit explanations” used in Phase Four, in response to the teacher’s diagnosis in Phase Three** | | | |
| | Teacher A | Teacher B | Teacher C |
| | 8 out of 8 | 8 out of 8 | 4 out of 5 |

Teachers A, B and C use “explicit explanations” eight, eight and five times respectively in their instructional practice in Phase Four (see Table 3, p.54). Out of the 21 times that the teachers use “explicit explanations,” it is related to “probing questions and active interpretation” 17 times (see Table 13). In these instances, the teachers use “explicit explanations” after “probing questions and active interpretation” has been used in the instructional practice and there has been a response from the learners. The teachers use “explicit explanations” to explain or reiterate a solution/method/response

that the learners give, to introduce new mathematical knowledge and to socialise the learners into mathematical terminology.

An example of how the teachers work with “explicit explanations” in relation to “probing questions and active interpretation” to introduce new mathematical knowledge in Phase Four can be seen in the following:

> Teacher A: Can you tell us a little bit more about how you did it so quickly?
> Christina: I counted in 10s.
> Teacher A: Okay. So from now on I want you to remember that when you are grouping things, guys, and you know how many are in the group, you must use the number to count. Keep the number in your head. (Appendix A iv, pedagogical move 18, p.26)

In this example, Teacher A is probing by asking the learner to tell the group how she solved the problem. When the learner responds, Teacher A uses the learner’s response to “explain explicitly” to the group what they need to do when they are counting items in groups. In this example, the purpose of Teacher A’s explanation, after the “probing questions and active interpretation” has taken place, is to introduce the learners to new mathematical knowledge, i.e. counting in groups.

Secondly, “explicit explanations” are also used in relation to “probing questions and active interpretation” to reiterate and explain a method/strategy used by the learners. The following is one such example:

> Teacher B: Right, now…Pearl and Tristan, how did you break up your 8? Did you make it in 4s, 2s and 1s?
> Tristan: No we did it in 1s, 2s and 5s.
> Teacher B: You did it in 1s, 2s, and 5s. Because 5 plus 2 is 7 plus 1 is 8. (Appendix B iv, pedagogical move 13, p.22)

In this example, Teacher B is probing the learners’ thinking by asking them to interpret actively how they have solved the problem. The learners respond and Teacher B “explicitly explains” to reiterate and reinforce to the learners why they have chosen the particular method. She says, “You did it in 1s, 2s, and 5s. Because 5 plus 2 is 7 plus 1 is 8.”

Thirdly, “explicit explanations” are used in relation to “probing questions and active interpretation” to socialise the learners into mathematical terminology. An example of this from Teacher C is:

> Teacher C asks the learners, Now what can you tell me about the number 10? Anything that you know about the number 10.
> Natasha: It's almost like 9, but you have to get one more to make it 10. (Appendix C iv, pedagogical move 6, p.20)

Teacher C uses an "explicit explanation" and repeats what the learner has said, emphasising the mathematical term 'more,' i.e. "So it's nearly the same amount as 9, but if I add one *more* it's going to be?" In so doing, the teacher socialises the learner into the mathematical terminology.

There are four instances in the instructional practice of the teachers when "explicit explanations" are not used in relation to "probing questions and active interpretation." In these instances it is used to 'tell' the learners what is happening in the lesson or it is used when the learners are asked a probing question by the teacher, but are not given an opportunity to interpret the question actively. The following is an example of when an "explicit explanation" is used to 'tell' the learners what is going to happen in the lesson:

> Teacher C explains to the learners that they are going to build a numberline and even though they know that there are numbers that come before 9, for today their number line is going to start with the number 9. (Appendix C iv, pedagogical move 3, p.18).

In this example, she "explicitly explains" to the learners where the numberline on which they are currently working is going to start.

An example where an "explicit explanation" is used when the learners are not given the opportunity to interpret actively can be seen in the following:

> Teacher A: 7 children and they each have 2 Easter eggs, how many do they have altogether? So let's write, Neha, she had 2, so write that first 2 down… (Appendix A iv, pedagogical move 7, pp.21-22)

In this example, Teacher A asks the "probing question," but does not give the learners an opportunity to interpret actively and goes on to "explain explicitly" to the learners how they need to go about working out the groups.

For 20 out of the 21 times that "explicit explanations" are used in Phase Four, the teachers make links to the diagnosis discussed (see Table 13). Examples of how the teachers, through their "explicit explanations," make links to the diagnosis discussed can be found in the examples discussed above (see Section 4.2.2.5, pp.70-71, Appendix A iv, pedagogical move 18; Appendix B iv, pedagogical move 13 and Appendix C iv, pedagogical move 6). Teacher A makes the link when, in her "explicit

explanation," she explains to the learners how to count when grouping. Teacher B "explicitly explains" to the learners what they did when they 'broke' up their group of 8. In so doing, she makes the link to the diagnosis, which is to encourage the learners to 'break' numbers up when counting. Teacher C, in her "explicit explanation," makes the link to the diagnosis when, in her explanation, she highlights the value of the number 9 in relation to the number 10. As she does this, she makes the link to the diagnosis because the understanding of the value of numbers is important for developing the learners' conceptual understanding of numbers being 'more' or 'less' than one another.

4.2.2.6 "Probing questions and active interpretation" and "validation"

**Table 14**

| **"validation" used in relation to "probing questions and active interpretation" (Phase Four)** | | | |
|---|---|---|---|
| | **Teacher A** | **Teacher B** | **Teacher C** |
| | 5 out of 5 | 2 out of 2 | 2 out of 2 |
| **"validation " used in Phase Four, in response to the teachers' diagnosis in Phase Three** | | | |
| | **Teacher A** | **Teacher B** | **Teacher C** |
| | 4 out of 5 | 2 out of 2 | 2 out of 2 |

In Phase Four, Teacher A uses "validation" as a pedagogical move the most, i.e. five times. Teachers B and C each use "validation" twice in their lesson (see Table 3, p.54). In every instance that the teachers "validate" the learners, it is in relation to "probing questions and active interpretation." "Validation," as in Phase Two (see Section 4.2.1.6, p.61), is used to encourage the learners and affirm their thinking. The following is an example:

> Al: We can count in 2s
> Teacher A: Why would we want to do that?
> Al: Because it is a quicker way.
> Teacher A: Oh, very good, did you hear that? (Appendix A iv, pedagogical move 4, p.20)

In the above example, the "validation" that the teacher gives happens after the learner's thinking has been probed and the learner has to interpret actively, i.e. "Why would you want to do that?" After the learner gives a reason ("active interpretation") for his chosen response, Teacher A validates the learner's efforts and affirms his thinking by encouraging the other learners in the group to listen to the response given by the learner, i.e. "Oh, very good, did you hear that?"

When "validation" is used by the teachers it is always, except on one occasion (Teacher A), in relation to the diagnosis discussed by the teachers (see Table 14). "Validation" always occurs after "probing questions and active interpretation." The "probing questions and active interpretation" is always linked

to the diagnosis. Consequently, the “validation” is linked to the diagnosis. An example of this can be seen in the following:

> Teacher A: Did anyone do it differently to Neha?
> Thando: I counted in 5s.
> Teacher A: Okay, very clever. (Appendix A iv, pedagogical move 17, p.25).

Teacher A asks a probing question that encourages the learners to interpret actively what they have done. A learner responds and says that he counted in 5s. By the learner counting in groups, the link to the diagnosis is made. Teacher A “validates” the learner’s effort and thinking by saying, “Okay, very clever.” The “validation” is, therefore, linked to the response given, which in turn is linked to the diagnosis.

*Summary of the pedagogical moves used by the teachers during instruction in Phase Four*

In Phase Four, there are differences in the frequency with which the teachers use the pedagogical moves. The pedagogical moves in the instructional practice of the teachers are, however, mainly selected in response to the diagnosis discussed in the interview in Phase Three. Similarly to Phase Two, “probing questions and active interpretation” is the most frequently used pedagogical move in Phase Four, and it is used by the teachers in relation to the five other pedagogical moves. In the instances where “probing questions and active interpretation,” together with the other pedagogical moves, is not used by the teachers in response to the diagnosis discussed, it is used to develop other aspects, skills and concepts of the mathematics curriculum. For example, to socialise the learners into mathematical terminology or to introduce new mathematics knowledge.

There is a close relationship in the instructional practice of the teachers between particular pedagogical moves. For example, not only are “visual demonstrations” and “concrete apparatus” used in relation to “probing questions and active interpretation,” but the moves are also used in relation to each other. Throughout the instructional practice of the teachers, “concrete apparatus” is used together with “visual demonstrations.”

The frequency and combining of pedagogical moves is closely related to the purpose for which they are intended. For example, “concrete apparatus” is used by the teachers together with “visual demonstrations” to “demonstrate visually” to the learners or it is used by the learners to “demonstrate visually” their mathematical understanding to the teacher. “Explicit explanations” are used in conjunction with “probing questions and active interpretation” in order to explain or reiterate a solution, a method or a response that the learners have provided, to introduce new mathematical knowledge and to socialise the learners into mathematical terminology.

Thus far, I have discussed how the teachers use the six pedagogical moves in Phases Two and Four of the research process, and how in Phase Four this relates to the diagnosis of learning needs. In the next section I discuss the consistency between what the teachers articulate about their instructional practice in the interviews (Phases One and Three) and how this is implemented. I also discuss the relationship between what the teachers discuss as their intentions to address the learning difficulties diagnosed and how this manifests in practice in the lesson in Phase Four.

4.2.2.7. The relationship between interviews and instructional practice

In the interview in Phase One, Teacher A explained that "formative assessment is a tool for getting learners to try out first, by constructing what they understand the task to be" (Appendix A i, 1.1, paragraph 3, p.2). She explained that, "In the learners constructing what they understand the task to be," it is important for her to "see the process" (Appendix A i, 1.1, paragraph 2, p.2). In the designing of the formative task, Teacher A said that she needed to consider how, through the task, she would get the learners to show their understanding (Appendix A i, 1.2, paragraph 3, p.3). In other words, she had to think about how she could "see the process" or see the learners' understanding. In the follow-up interview in Phase Three, she explained that, "In administering the lesson you have to be very careful to guide [the learners] in an appropriate manner so that they are not just sitting there…Based on your questioning and the process learners need to [show you their understanding and not just give an answer]" (Appendix A iii, 3.1, paragraph 3, pp.13-14). Evidence of Teacher A giving the learners an opportunity to construct their understanding and her trying to understand and "see" the learners thinking, as well as guide them in their understanding, can be seen in her use of the pedagogical move of "probing questions and active interpretation" in both Phases Two and Four (see examples Section 4.2.1.1, p.57 and Section 4.2.2.1, pp.62-64).

While Teachers B and C in practical implementation use "probing questions and active interpretation" frequently and in a similar way to Teacher A (see examples Section 4.2.1.1, p.57 and Section 4.2.2.1, pp.62-64), they did not, in their interviews, specifically talk about questioning, "seeing the process" or getting the learners to construct understanding through a "process." When Teacher B talked about a "process," she spoke about it in the context of a 'learning path' (Appendix B iii, 3.1, paragraph 4, p.14), and when Teacher C talked about "process" she spoke about it in the context of the learners processing information from word problems (Appendix C iii, 3.2, paragraph 5-6, p.14). The teachers' views on "process" differ, in that Teacher A spoke about it in relation to the learners' constructing understanding, Teacher B described "process" as part of a long term plan and Teacher C spoke about it in terms of processing information as part of mathematical word problems.

Linked to the idea of "seeing the process" and constructing understanding, Teacher A, in her interview in Phase One, talked about two important mental processes, with which she believed learners needed to be given the opportunity to engage. Firstly, she explained that the learners needed the

opportunity to “verbalise their understanding” (Appendix A i, 1.3, paragraph 2, p.5). In the Phase One interview, she explained that verbalisation was important for the mental processes that learners needed to develop in order to understand number. In this interview, she explained that by the learners verbalising what they understand, “The teacher is provided with valuable insight into the quality of the learners’ number understanding that otherwise might be lost” (Appendix A i, 1.3, paragraph 2, p.5). In Phase Three, after the assessment task had been administered, Teacher A also explained that verbalisation is so important in diagnosing learners’ difficulties, “because it is part of the process of constructing knowledge and conceptualising a concept…without that language, there’s kind of no reflection on their understanding” (Appendix A iii, 3.2, paragraph 3, p.16).

Although “verbal demonstrations” is not frequently used by the teachers in either Phase Two or Four, Teacher A implements it the most in classroom practice. Examples of Teacher A implementing “verbal demonstrations” can be seen in Phase Two (see example Section 4.2.1.2, p.58) and Phase Four (see example Section 4.2.2.2, p.64). Teacher B did not talk about “verbal demonstrations” in her interviews but implements it practically once in Phase Two and four times in Phase Four (see example Section 4.2.2.2, p.65). Teacher C, in her interview in Phase One, explained that one of the criteria that she would be looking for when the learners are solving their mathematical problems would be the learners’ “ability to verbalise their solutions” (Appendix C i, 1.2, paragraph 5, p.4). While Teacher C, in the interview, spoke about “verbal demonstrations” as an important criterion in the solving of mathematical problems, she only uses it five times in practice (see example Section 4.2.2.2, p.64). When comparing the teachers’ thoughts on verbalisation, we see that Teacher A spoke about it as a mental process that is specifically linked to diagnosing learners’ difficulties and provides an opportunity for the teacher to gain an insight into the learners’ thinking. Teacher B spoke about it more in relation to being a criterion, i.e. assessing whether the learners can or cannot verbalise the solution to problems.

The second mental process that Teacher A, in her Phase One interview, explained as related to learners developing an understanding of number is being able to use “concrete apparatus” to represent their understanding (Appendix A i, 1.3, paragraph 1, pp.4-5). Both Teachers B and C in their interviews also placed emphasis on the learners working with “concrete apparatus” as an important mental process (Appendix B i, 1.3, paragraph 1, p.5 and Appendix C i, 1.3, paragraph 1, p.5). Teacher A explained that for learners to understand number, they needed to see it in its concrete form and then move towards a more abstract understanding (Appendix A i, 1.3, paragraph 1, pp.4-5). In this Phase One interview, Teacher A also listed the learners’ ability or inability to work with “concrete apparatus” as an important criterion in the designing of the assessment task. Teacher B, in her Phase One interview, explained that in the designing of her assessment task, she would allow the learners to work with “concrete apparatus” (Appendix B i, 1.3, paragraph 2, p.5). She explained that the learners “Need to experience using real objects in order to understand what is written at an abstract or representational level” (Appendix B i, 1.3, paragraph 1, p.5). She also explained that she would encourage the learners to see the connection between the concrete representation and the 2D

representation. When Teacher C discussed the use of “concrete apparatus” in Phase One, she explained that in her opinion, learners needed to engage with “physical knowledge” (Appendix C i, 1.3, paragraph 1, p.5) as one of the three types of knowledge that is important for the development of a sound number concept. In the designing of her assessment task, she chose the manner in which the learners display their solutions using concrete apparatus as well as the manner in which they display their solutions using pictorial representation as a criterion (Appendix C i, 1.4, paragraph 2, p.6). In the Phase One interview, the teachers share an understanding of “concrete apparatus” being a part of the mental process that is needed to develop a conceptual and physical understanding of number, which eventually leads to a more abstract understanding.

In Phase Two, while the teachers talked about the use of “concrete apparatus” in much detail in the Phase One interview and two of them, Teachers A and C, listed it as criteria, it is not used frequently by the teachers. In this Phase, the teachers primarily give the learners “concrete apparatus” to assist them as they solve the problems of the formative assessment task (see examples Section 4.2.1.4, pp.59-60). In the other instances, “concrete apparatus” is used when the learners are asked to “show” their solutions (see examples Section 4.2.1.4, p.59, Appendix B ii, pedagogical move 7).

Similar to all the pedagogical moves, it is in the Phase Four lesson when the link to the diagnosis of the difficulties learners are experiencing has been made, that the teachers use “concrete apparatus” more frequently as a pedagogical move. It is in this Phase that we see more practical evidence of the teachers using “concrete apparatus, as part of a mental process, to develop the conceptual understanding of number (see examples Section 4.2.2.4, pp.68-69). This is consistent with their views expressed in their interviews in Phase One. In this Phase, for the most part, the teachers also use “concrete apparatus” directly related to the diagnosis discussed in Phase Three (see examples Section 4.2.2.4, pp.68-69). In the practical implementation, concrete apparatus is used in similar ways by the teachers to “demonstrate visually” to the learners or it is used by the learners to “demonstrate visually” to the teacher. It is also given to the learners to assist them in physically working out their solutions.

Although the teachers do not specifically in the interviews refer to “visual demonstrations,” there is much evidence of this in the practical implementation as they work with “concrete apparatus” (see examples Section 4.2.2.3, pp.65-67).

“Explicit explanations” and “validation” are not specifically spoken about in the interviews with the teachers, although they are practically implemented as pedagogical moves. “Explicit explanations” will, however, be looked at and discussed in relation to making criteria explicit in Section 4.3.4. (see pp.86-88).

Teachers A, B and C, in their Phase Three interviews, all talked about how the diagnosis of learning needed to be used to inform the follow-up lesson. In her interview, Teacher A explained that the information gathered about the learners' learning from the task will be used in designing the follow-up lesson (Appendix A iii, 3.1, paragraph 2, p.13). Teacher B placed emphasis on the role that the teachers' ability to reflect played, not only in diagnosing the learners' learning, but in altering the teaching programme or 'learning path' accordingly. She said it was important for the teacher to, "Look at the results of the assessment and reflect on them, to set the basis for the next lesson" (Appendix B iii, 3.1, paragraph 1, p.13). Teacher C, in her interview, talked about how the diagnosis of learning informed how the teacher "….is going to support the learners through" (Appendix C iii, 3.3, paragraph 3, p.15). Evidence of the teachers using the information gathered in the diagnosis, reflecting on the results of the diagnosis and using the information to support the learners can be seen throughout the teachers' use of the pedagogical moves in Section 4.2.2. pp.62-73.

*Overall summary of category of the pedagogical moves used by the teachers during instruction*

In this category, the frequency with which the teachers, in their instructional practice, engage with the six pedagogical moves could present itself as an opportunity to suggest that one teacher is pedagogically stronger than another. However, I would like to propose that similar to Category One, where content knowledge is recruited in alignment with the purpose for which it is intended, so too is the frequency of the pedagogical moves used by the teachers in alignment with the purpose for which it is intended. For example, Teacher A uses "probing questions and active interpretation" aligned to the diagnosis less than Teachers B and C, who consistently align "probing questions and active interpretation" to the diagnosis discussed. It could be suggested that Teacher A does not consistently align herself to the diagnosis discussed and is the weaker teacher. However, on analysis of the instances where she does not use it directly in alignment with the diagnosis discussed, she relates the "probing questions and active interpretation" to other concepts or aspects of the curriculum. As explained in the example in Section 4.2.2.1, p.63, Appendix A iv, pedagogical move 7, Teacher A uses it to socialise the learners into the mathematics terminology associated with addition. This might not be directly aligned to the diagnosis discussed, but an understanding of addition is important for the conceptual understanding of counting in groups. Counting in groups is mathematically related to repeated addition, i.e. 2 + 2 + 2 is the same as 3 x 2, which is the same as 3 groups of 2. When Teacher C (see example Section 4.2.2.3, p.66, Appendix C iv, pedagogical move 8) uses "concrete apparatus" to set up the numberline on which the learners will work for the rest of the lesson, initially it is not directly related to the diagnosis, but the numberline later in the lesson is used to 'scaffold' the learners' understanding of numbers being 'more' or 'less' in value, which is directly related to the diagnosis discussed. In other words, the frequency of the teachers' pedagogical moves being related to the diagnosis of learning difficulties cannot solely be used to explain the ways the teachers use formative assessment diagnostically. The pedagogical moves used by the teachers are used for

various purposes throughout the lessons. I propose that the alignment to the intended purpose is what is important and not necessarily the frequency.

In the same way, in Phase Two the frequency and use of the pedagogical moves is determined by the type of assessment task set. For example, Teachers B and C do not use “explicit explanations” in their pedagogical moves. I propose that this is not because Teacher A is the stronger teacher, but rather that the way in which the tasks are designed and administered are different. Teacher A works through the assessment task with the learners (see Appendix A ii). There is more interaction between the teacher and the learners when the assessment task is administered and hence more “explicit explanations.” Teacher C works with the learners initially, but the learners work independently on the actual assessment task (see Appendix C ii) and Teacher B gives the learners a formatted, structured task to complete independently (see Appendix B ii). There is less interaction between the learners and Teachers B and C when the assessment task is administered and, therefore, no “explicit explanations.” The same reason applies to why Teacher A uses more “probing questions and active interpretation” in Phase Two. There is more interaction between Teacher A and the learners as she administers the task and, therefore, more opportunity to ask probing questions and get the learners to interpret actively. Teachers B and C work less with the learners as the designing of the assessment task requires the learners to work independently and, therefore, there is less opportunity for “probing questions and active interpretation.”

### 4.3. Category 3 – Practices of Evaluation

For teachers to make the ‘right’ pedagogical choices (Ball, 1993) in their mathematical teaching, Murray (2000) and James (1986) argue that assessing or evaluating learners’ thinking in relation to mathematical conceptual understandings, is important. The following category analyses the practices of evaluation that the teachers use when working with formative assessment diagnostically.

This category is divided into two sections. In the first section I discuss the practices of evaluation that the teachers use to diagnose the learners’ mathematical thinking when working formatively in their instructional practice. To analyse this practice, I quantify how frequently the pedagogical move “evaluation” (EVAL) is used by the teachers in Phases Two and Four. I do so by comparing the use of the pedagogical move among the teachers and comparing the use of the pedagogical move in relation to the diagnosis discussed in the interview in Phase Three. I continue by discussing the relationship between “probing questions and active interpretation” and “evaluation.” In the second section, I discuss the practices of evaluation that the teachers use when working with criteria in formative assessment. Included in criteria are the instructions that the teachers issue as part of their pedagogical moves. I quantify the frequency with which the teachers use the pedagogical moves of “criteria explicit” (CRITEXP), “criteria implicit” (CRITIMP), “instruction explicit” (INSTREXP) and “instruction implicit” (INSTRIMP) in Phases Two and Four. I do so by comparing both the use of the

pedagogical moves among the teachers and the use of the pedagogical move in relation to the diagnosis made in the interview in Phase Three.

In the final section of the analysis of this category, I discuss the consistency between what the teachers discuss in the interviews in Phases One and Three and what manifests in classroom practice in relation to "evaluation," "criteria explicit," "criteria implicit," "instruction explicit" and "instruction implicit."

In this first section of the analysis, I examine and compare how the teachers use the pedagogical move of "evaluation" to diagnose the learners' thinking when working with formative assessment in their instructional practice in Phases Two and Four.

**Table 15: Practices of Evaluation when working with: "evaluation"**

This Table is a quantitative comparison of the differences and similarities among the three teachers when using the pedagogical move "evaluation" in Phases Two and Four. "Evaluation," in this context, refers to an evaluation practice that is used as a pedagogical tool by the teachers to try to diagnose the learners' thinking as they teach. This Table also compares how "evaluation" as a pedagogical move is aligned, in Phase Four, to the diagnosis discussed in the interview in Phase Three.

| **Number of times code used in Phases Two and Four** | | | | | | |
|---|---|---|---|---|---|---|
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| | Phase Two | Phase Four | Phase Two | Phase Four | Phase Two | Phase Four |
| Evaluation | 9 | 17 | 6 | 12 | 7 | 21 |
| **Number of times code used in Phase Four, in response to the teacher's diagnosis in Phase Three** | | | | | | |
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| Evaluation | 16 | | 12 | | 21 | |

From Table 15 it is evident that in Phase Two, the frequency with which the teachers use "evaluation" as a pedagogical move is similar, i.e. Teacher A, nine times, Teacher B, six times and Teacher C, seven times. In Phase Four, Teacher B uses "evaluation" as a pedagogical move the least, i.e. 12 times. Teacher A uses it 17 times and Teacher C uses it the most, i.e. 21 times. In total, the teachers use "evaluation" 22 times in Phase Two and 50 times in Phase Four. 49 out of the 50 times in Phase Four, "evaluation" is used in response to the diagnosis of learning discussed in the Phase Three interview.

In this Category the discussion follows a similar format to that of Category One (see pp.41-53).

I now discuss “evaluation” as a pedagogical move in relation to “probing questions and active interpretation” in Phases Two and Four.

### 4.3.1 The use of “evaluation” in Phase Two

In Phase Two, “evaluation” is used as a means to diagnose the learners’ understanding of concepts or strategies that they need or use when working through the assessment tasks. “Evaluation,” as a pedagogical move in this Phase, is mostly used by the teachers in relation to “probing questions and active interpretation.” Out of the 22 times that “evaluation” is used in the administering of the formative tasks (see Table 15, p.79), it is related to “probing questions and active interpretation” 20 times. The following are examples of the teachers working with “probing questions and active interpretation” in relation to “evaluation”:

> Once the learners have completed their 2D representation and number sentence to the word problem, Teacher A asks the seven learners to verbalise the strategies that they used to reach the answer.
> Teacher A asks questions such as, What did you do? Tell me how you did this. Why did you do it this way? (Appendix A ii, pedagogical move 5, p.9).

> Teacher B reads the instructions and simultaneously asks the learners questions about the concepts that are being covered in that section of the assessment task. For example, with the ‘Doubling and Halving’ section of the assessment task, Teacher B asks the learners, What do we do when we double? Please tell me what we do? (Appendix B ii, pedagogical move 4, p.10)

> Once all the learners have attempted solving the problem, Teacher C selects a learner who has not managed to solve the problem correctly and asks him to verbalise the strategy he used. She asks the learner, How did you work it out? (Appendix C ii, pedagogical move 5, p.8).

In each of the above examples, the teachers ask probing questions such as, “What did you do? Tell me how you did this.” “What do we do when we double?” and “How did you work it out?” By asking probing questions, the learners need to interpret their own thinking actively. As the learners verbalise their thinking, the teachers are able to evaluate and gain an insight into the learners’ understanding of concepts or the strategies that the learners are using. For example, the learners respond to the “probing questions and active interpretation” saying, “I drawed 7 rectangles in a line and 11 rectangles in a line and I counted them all and got 18.” (Appendix A ii, pedagogical move 5, p.9); or “Do it on an abacus. Draw how you did it.” (Appendix B ii, pedagogical move 4, p.10); or “I took the 8 cars and I plussed it to the 4 cars and I got 11 cars” (Appendix C ii, pedagogical move 5, p.8).

When “evaluation” is not used with “probing questions and active interpretation,” it is used in Phase Two by Teacher B once in relation to “visual demonstration,” and by Teacher C once in relation to “validation.” As Teacher B checks the learners’ understanding of the ‘breaking up of number’ before the assessment task is completed independently, she asks the learners to “demonstrate visually” how they would break up the number 53 (Appendix B ii, pedagogical move 4, p.11). As the learners do this, Teacher B observes their methods and “evaluates” their understanding of the concept. Teacher C “validates” the learners’ understanding as she “evaluates” their thinking. For example, as the learner responds with a method, she says, “Keep trying. Think about what I have taught you” (Appendix C ii, pedagogical move 15, p.10). Teacher C “evaluates” the learner’s method and then “validates” him to encourage him to think differently.

### 4.3.2. The use of “evaluation” in Phase Four

In Phase Four, “evaluation” is mostly used to evaluate the learners’ thinking and understanding of the concepts or skills that form the focus of the lesson. The focus of the lesson is based on the diagnosis discussed in the interview in Phase Three. Teacher B uses “evaluation” the least in this Phase, i.e. 12 times, Teacher C the most, i.e. 21 times and Teacher A, 16 times (see Table 15, p.79). In total, out of the 50 times that the teachers use the pedagogical move, every instance is in relation to “probing questions and active interpretation.” An example of Teacher C using “probing questions and active interpretation” in relation to “evaluation” can be seen in the following:

> Teacher C: Why did you choose this number, Lebo? Are we counting backwards or are we counting forwards?
> Lebo: Forwards.
> Teacher C: Are the numbers getting bigger or smaller?
> Learners: Bigger. (Appendix C iv, pedagogical move 7, pp.20-21)

In this example, the “probing questions” that the teacher asks not only encourage the learner to interpret actively, but through the active interpretation, the teacher is able to diagnose the learners’ thinking. In the example of Teacher C, as the learner responds to the two “probing questions,” i.e. “Why did you choose this number, Lebo?...Are the numbers getting bigger or smaller?”, the teacher is able to “evaluate” whether the learner is able to see the relationship between counting forwards or backwards and the value of numbers.

In Phase Four, there is only one instance where “evaluation” as a pedagogical move is not in response to the diagnosis discussed by the teachers. In this instance, Teacher A uses “evaluation” in relation to socialising the learners into the mathematics terminology for addition. See example: Appendix A iv, pedagogical move 7, p.22.

In every other instance that “evaluation” is used by the teachers in their lessons in Phase Four, it is related to the diagnosis of learning discussed. In the example above (Section 4.3.2, p.81, Appendix C iv, pedagogical move 7), as the learner responds and the teacher “evaluates” the learners’ thinking, it is directly linked to the diagnosis discussed. Teacher C questions the learner and “evaluates” the learner’s understandings and misunderstandings of the relationship between counting forwards and backwards and the value of numbers. As she does this she makes the connection to the diagnosis of learning needs, which is to develop the learners’ conceptual understanding of the value of numbers being ‘more’ or ‘less’ than one another.

*Summary of the teachers’ use of “evaluation"*

“Evaluation,” as a pedagogical move in Phase Two, is used as a means to diagnose the learners’ understanding of concepts or strategies that they need or use when working through the formative assessment tasks. In Phase Four, “evaluation” is mostly used to evaluate the learners’ thinking and understanding of the concepts or skills that form the focus of the lesson. The purpose of “evaluation” as a pedagogical move depends on the aim of the lesson. In Phase Two, “evaluation” is mostly used in relation to “probing questions and active interpretation.” In the two instances that it is not used in relation to “probing questions and active interpretation,” it is used with “visual demonstration” and “validation.” In Phase Four, “evaluation” is always in relation to “probing questions and active interpretation.” It is also always, except for one occasion, in relation to the diagnosis discussed by the teachers in the interview in Phase Three.

In the second section of the analysis, I examine and compare the practices of evaluation that the teachers use in their pedagogical moves when working with criteria and instructions in Phases Two and Four. This includes the teachers working with criteria (“explict and implict”) and instructions (“explicit” and “implicit”) in their instructional practice.

**Table 16: Practices of Evaluation when working with: “criteria” and “instructions”**

This Table compares the teachers’ practices of evaluation when working with criteria and instructions in formative assessment. It is a quantitative comparison of the differences and similarities between the teachers in Phases Two and Four. It also examines how the teachers’ practices of evaluation, i.e. criteria and instructions are aligned in Phase Four to the diagnosis discussed in the interview in Phase Three.

| Number of times code used in Phases Two and Four | | | | | | |
|---|---|---|---|---|---|---|
| | Teacher A | | Teacher B | | Teacher C | |
| | Phase Two | Phase Four | Phase Two | Phase Four | Phase Two | Phase Four |
| Instruction Explicit | 1 | 5 | 1 | 1 | 2 | 1 |
| Instruction Implicit | 1 | 1 | 1 | 3 | 3 | 2 |
| Criteria Explicit | 0 | 0 | 2 | 0 | 1 | 0 |
| Criteria Implicit | 3 | 0 | 0 | 0 | 1 | 0 |

| Number of times the code was used in Phase Four, in response to the teacher's diagnosis made in Phase Three | | | |
|---|---|---|---|
| | Teacher A | Teacher B | Teacher C |
| Instruction Explicit | 5 | 1 | 1 |
| Instruction Implicit | 1 | 3 | 1 |
| Criteria Explicit | 0 | 0 | 0 |
| Criteria Implicit | 0 | 0 | 0 |

From Table 16 the following can be seen:

In Phase Two, there is very little difference between the teachers use of "explicit instructions." Teacher C uses them twice and Teachers A and B, once. In Phase Four, after the diagnosis in the interview in Phase Three, Teacher A uses them five times in her pedagogical moves, as opposed to Teachers B and C who each use it once. "Implicit instructions" are used the most by Teacher C in Phase Two. Teacher C uses them three times and Teachers A and B, once. In Phase Four, Teacher B uses "implicit instructions" the most, i.e. three times, Teacher C, twice and Teacher A, once. Teacher C works the most with instructions in this Phase, i.e. five times.

In Phase Two, Teacher A's criteria that she uses to evaluate the learners are "implicit" three times, whereas Teacher B's criteria are made "explicit" to the learners twice. Teacher C is the only teacher who works with "criteria explicit" and "criteria implicit" during evaluation. She works with each type of criteria once.

In Phase Four, the "instructions" given by the teachers are predominately in response to the diagnosis discussed. The teachers do not work with 'formal' criteria in Phase Four.

In this Category the discussion follows a similar format to that of Category One (see pp.41-53).

I now discuss the "instructions" and the "criteria" that the teachers use during evaluation in Phases Two and Four.

### 4.3.3. The use of “instructions” and “criteria” in Phase Two

In Phase Two, the teachers use “implicit instructions” five times, with Teacher C using it the most, i.e. three times (see Table 16, pp.82-83). The “implicit instructions” are used in a similar way by Teachers A and C, when they ask or tell the learners that they are going to solve word problems, but do not give the learners specific instructions on how to do it. For example, Teacher A (Appendix A ii, pedagogical move 1, p.7), before she sets the context of the word problem, tells the learners that they are going to solve a word problem, but does not tell the learners the steps she wants them to use to solve it. No “explicit instructions” are given on how to do it. Teacher B (Appendix B ii, pedagogical move 2, p.10) asks the learners to follow with her as she reads through the instructions with them. At this stage, Teacher B does not give the learners a detailed explanation of the instructions (she does so later).

Each of the teachers in this Phase use “explicit instructions” once. For example, Teacher B gives the learners “explicit instructions” when she goes through the assessment task with the learners and explains the instructions to them. For example, she reads the instruction out as follows:

> *Double the numbers, showing me how you reached your answer. Write the answer on the line*.
> She explains the instruction by saying:
> You need to show me how you doubled the number and got the answer. Then you write the answer on this line_____ (Teacher B points to the answer line). (Appendix B ii, pedagogical move 3, p.10)

Teacher B does not just read the instructions to the learners, but makes sure that the learners understand explicitly what the instruction means and requires them to do, i.e. “You need to show me how you doubled the number and got the answer…”

In Phase Two, the teachers work with the criteria that they use to evaluate the learners differently. Teacher A does not make her “criteria explicit,” Teacher B makes her “criteria explicit” and Teacher C works with both “explicit” and “implicit” criteria during evaluation.

Teacher A, throughout the administering of the task, works with an assessment rubric. She does not tell the learners what criteria are being used to evaluate them, i.e. the criteria are “implicit.” For example, in Appendix A ii, pedagogical move 4, p.8, as the learners solve their problems, Teacher A observes their methods and strategies and records it on the assessment rubric (Appendix A ii (R), p.28). She watches how they work with concrete apparatus, how they represent the solution in 2D and finally do a number sentence. In Appendix A ii, pedagogical move 8, p.11, as the learners verbalise their methods, the various strategies are assessed by Teacher A and the learners’ understanding and difficulties are noted on the assessment rubric. At the end of the assessment task, Teacher A uses the assessment rubric to record her observation of the learners’ methods and strategies, and to record the

discussions that she had with the learners as they completed the task. This makes up the formative assessment task (Appendix A ii, pedagogical move 12, p.12). At no stage does the teacher discuss the criteria on the rubric or make it "explicit" to the learners.

Teacher B, in Phase Two, makes the criteria that she uses to evaluate "explicit" to the learners as she reads through the instructions explicitly and carefully (see example above Section 4.3.3, p.84, Appendix B ii, pedagogical move 3). The "explicit instructions" in this example are specifically aimed at making the "criteria explicit" to the learners. By telling the learners that she wants them to show her how they doubled the number and got to the answer, the learners know exactly what is required of them and the criteria that are used to evaluate them are made "explicit." The second way that the criteria that are used to evaluate the learners are made "explicit" to the learners is through the assessment rubric (Appendix B ii (R), pp.26-27). For example, some of the criteria listed in the assessment rubric are: the learners' ability to double, halve, compare whole numbers and solve problems using addition and subtraction. The assessment rubric, with the criteria listed, are "explicit" to the learners as they complete the task.

Teacher C works with "explicit" and "implicit" criteria once each during evaluation. When she hands out the assessment task and the recording sheet to the learners, she gives the learners "explicit instructions" on how she wants them to record their response (Appendix C ii, pedagogical move 11, p.10). In so doing, the criteria that are used to evaluate the learners are made "explicit" to them. At the end of the assessment task, like Teacher A, Teacher C finalises her assessment of the learners on an assessment rubric. She does not make the learners aware of the criteria being used to evaluate them in the assessment rubric and the criteria remain "implicit" (Appendix C ii, pedagogical move 17, p.11).

*Summary of the teachers' use of " instructions" and "criteria" during evaluation in Phase Two*

In this Phase, "implicit instructions" are used by the teachers in two ways. Firstly, when the learners are told to solve word problems independently and secondly, when the teachers ask them to read through and follow the instructions of the assessment task. "Explicit instructions" are used by the teachers when they give the learners detailed instructions on how to complete the assessment task or how to do something as part of the assessment task, for example, how to use a particular counting strategy. Teachers A and C use assessment rubrics but do not make the rubric or the criteria that are used to evaluate the learners "explicit" to them. The criteria remain "implicit" to the learners. Teacher B designs the assessment task so that the learners are able to see the assessment rubric at the back of the task. The criteria that are used to evaluate the learners are made "explicit" to them. When Teachers B and C give "explicit instructions," it is directly related to making "criteria explicit." The instructions are given in detail so that the learners know what is required and expected of them as they complete the assessment task. There is a relationship between the instructions being "explicit" and the criteria being made "explicit" (this will be discussed below in Section 4.3.4).

### 4.3.4 The use of “instructions” and “criteria” in Phase Four

In Phase Four, the teachers, in their instructional practice, do not work with assessment rubrics and do not list particular criteria during evaluation. Teacher A uses “explicit instructions” five times in this Phase and Teachers B and C each use it once. In each instance that these are used by the teachers, they use them in relation to the diagnosis discussed in the interview in Phase Three. Examples of how Teacher A uses “explicit instructions” in her pedagogy and how it is linked to the diagnosis can be seen in the following:

> Teacher A: So how many groups of 2 were there actually?
> Nondu: 7.
> Teacher A: 7, right. So let’s do 7 twos. So its 2 + 2 + 2 + 2…because we’re just showing what we actually did. (Appendix A iv, pedagogical move 7, p.22) or
>
> Teacher A instructs the learners to draw their 4 boxes and to place 10 Easter eggs (wooden cubes) in each box. (Appendix A iv, pedagogical move 14, p.25)

In the examples, Teacher A gives the learners “explicit instructions” on what to do. In the first example, she tells the learners how to write a number sentence that represents 7 groups of 2. As Teacher A instructs the learners, she “explicitly explains” and makes the link to the diagnosis, which is to promote the learners’ understanding of the mathematical concept of “groups of.” In this example, that would mean that 7 groups of 2 are represented as 2 + 2 + 2 + 2 + 2 + 2 + 2 =… In the second example, Teacher A gives the learners “explicit instructions” on what she wants them to do with their concrete apparatus. She instructs them to put the blocks into 4 groups of 10. As the learners do this, the link to the diagnosis is made which is to encourage the learners to count in groups instead of singles.

“Implicit instructions” are used six times in Phase Four. Teacher A uses them only once. Teacher B uses it three times and Teacher C uses it twice (see Table 16, pp.82-83). On four out of the six occasions that the teachers use “implicit instructions” (Appendix A iv, pedagogical move 13, pp.24-25; Appendix B iv, pedagogical move 9, p.21 and Appendix C iv, pedagogical move 11, p.22), they give the learners a word problem to solve independently. They do not give the learners specific instructions on how to solve the problems. The “implicit instructions” are all related to the diagnosis discussed. For example, Teacher A, Appendix A iv, pedagogical move 13, pp.24-25, gives the learners an “implicit instruction” that they are going to solve a word problem independently. The word problem reads as follows:

> The Easter bunny comes into our garden and he knows that in that garden he has to leave enough boxes of eggs for 4 children. There are 10 Easter eggs inside each box. How many Easter eggs are there altogether?

The word problem relates to the diagnosis; it encourages the learners to count in groups, i.e. the solution involves counting 4 groups of 10.

On two occasions (Appendix B iv, pedagogical move 2, p.19 and Appendix C iv, pedagogical move 1, p.18), when the teachers give "implicit instructions," it is not related to the learners independently solving word problems. Teacher B gives the learners an "implicit instruction" that they are going to be working with paper plates to represent their groups. The idea of groups is directly related to the diagnosis discussed in the interview in Phase Three, which is to develop the learners' group counting skills. Teacher C, in her "implicit instruction," asks the learners to name things that they can use to count. This instruction is more in relation to the learners' previous mathematical knowledge, rather than the diagnosis, which is to develop the learners' understanding of the value of numbers.

What is interesting to note in this Phase, and is similar to Phase Two, is that the "explicit instructions" given by the teachers are used to make the criteria used to evaluate the learners "explicit" to the learners. For example, by instructing the learners on how to write the number sentence (see example, Section 4.3.4, p.86, Appendix A iv, pedagogical move 7) or how to work with their concrete apparatus (see example, Section 4.3.4, p.86, Appendix A iv, pedagogical move 14), the learners know what is expected of them and the criteria are made "explicit," i.e. how to write a number sentence that represents counting in groups and how to organise their concrete apparatus when counting in groups.

*Summary of the teachers' use of "instructions" and "criteria" during evaluation in Phase Four*

In this Phase, the teachers do not work with criteria to evaluate the learners in an "explicit" or "implicit" way. When the teachers give "explicit instructions," the criteria used to evaluate the learners are made "explicit" to the learners through the instructions given. When "implicit" instructions are given to the learners, these are appropriate to the type of task given. In this Phase, "implicit instructions" are mostly given when asking the learners to solve word problems independently. The instructions given to the learners in this Phase are primarily related to the diagnosis discussed in the interview in Phase Three.

In the final section of this category, I discuss the consistency between the teachers' instructional practice with regards to: "evaluation," "criteria explicit," "criteria implicit," "instruction explicit," "instruction implicit" and the interviews in Phases One and Three.

### 4.3.5. The relationship between interviews and practices of evaluation

In the interview in Phase One, Teacher A talked about how in the designing of the assessment task, she planned the criteria that she would use to evaluate the learners to frame the assessment task (Appendix A i, 1.2, paragraph 3, p.3). There is evidence of the planned criteria that Teacher A used in

the assessment rubric (Appendix A ii (R), p.28) that she records on in Phase Two. These important criteria that are used to evaluate the learners are not made "explicit" to the learners as they complete the task. Teacher B, in Phase One, discussed the idea of assessment being part of a 'learning path.' She explained that on the formative assessment task, there would be "a formal rubric [that] gets sent home to the parents where they have the opportunity to look at the assessment, comment on it, and if they have any queries, to come to [the teachers]" (Appendix B i, 1.1, paragraph 2, p.1). In the formative assessment task of Teacher B, in Phase Two, there is an assessment rubric at the back of the task that the learners complete (Appendix B ii (R), pp.26-27). In this way, the criteria that are used to evaluate the learners are made "explicit" to the learners. Teacher C, in this first interview, explained that for the assessment task, she designed a rubric where she intentionally tried to 'break' up what skills she would be assessing as the learners completed their solutions (Appendix C i, 1.2, paragraph 7, p.4). Evidence of this rubric can be seen in Phase Two when she collates her observations and findings of the learners' understanding (Appendix C ii (R), p.25). Teacher C does not make the criteria that are used to evaluate the learners "explicit" to the learners. All the teachers, in Phase Two, use rubrics but they do not all use the criteria in an "explicit" way. In the interviews, the idea of "evaluating" the learners' thinking was spoken about by the teachers in relation to the pedagogical move of "probing questions and active interpretation" (see Section 4.2.2.7, p.74). For example, when Teacher A talked about how important it was for her to "see the process" (Appendix A i, 1.1, paragraph 2, p.2), or how she needed to consider how through the task she would get the learners to show their understanding (Appendix A i, 1.1, paragraph 3, p.2). This relates to the diagnosis of learners' thinking or "evaluation." It could be proposed that as the teachers work with "probing questions and active interpretation" and "evaluate" the learners' thinking, the criteria that are used to evaluate the learners are made more "explicit" to the learners (see example, Section 4.2.2.1, p.63, Appendix A iv, pedagogical moves 3-4). In this example, as the teacher is asking the learners to think of ways in which to count the 'eggs,' the criteria used to evaluate the learners becomes more "explicit," i.e. counting in groups.

### 4.4. Category 4 - Socialisation

An important aspect of young learners developing their early mathematical understandings is to be exposed to what Piaget (as cited by Kamii, 1989) refers to as "social mathematical knowledge." This type of mathematical knowledge as described by McDermott and Rakgokong (1996) includes mathematical terminology such as: number names and notation, for example, the symbols for numbers and operations.

In this category, I discuss how the teachers "socialise" (SOC) the learners into mathematical thinking and particularly mathematical terminology when working diagnostically with formative assessment. To analyse this, I quantify how frequently the teachers "socialise" the learners' mathematical thinking in Phases Two and Four. I compare among the teachers how frequently they use the pedagogical move

of “socialisation.” I also compare how frequently the teachers use the move in relation to the diagnosis discussed by the teachers in the interview in Phase Three. In a similar way to Categories 2 and 3, I discuss the relationship between the pedagogical move of “probing questions and active interpretation” and “socialisation.” I continue the analysis by discussing the relationship between what the teachers articulate in their interviews and how this is put into practice as the teachers work with addressing the learning difficulties of the learners.

**Table 17: “Socialisation”**

This Table is a quantitative comparison of the differences and similarities among the teachers when working with the pedagogical move of “socialisation” in the Phases. It also compares how “socialisation” is aligned in Phase Four to the diagnosis discussed in the interview in Phase Three.

| **Number of times code used in Phases Two and Four** | | | | | | |
|---|---|---|---|---|---|---|
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| | Phase Two | Phase Four | Phase Two | Phase Four | Phase Two | Phase Four |
| Socialisation | 4 | 3 | 1 | 0 | 4 | 10 |
| **Number of times code used in Phase Four, in response to the teacher’s diagnosis in Phase Three** | | | | | | |
| | **Teacher A** | | **Teacher B** | | **Teacher C** | |
| Socialisation | 3 | | 0 | | 10 | |

From Table 17 it is evident that in total, “socialisation” is used nine times in Phase Two. Teachers A and C each use “socialisation” four times when administering the formative task. This is different to Teacher B, who uses it once. In Phase Four, Teacher C works with “socialisation” 10 times, as opposed to Teacher A, who uses it three times. Teacher B does not use “socialisation” at all in Phase Four. In Phases Two and Four, Teacher B uses “socialisation” the least. In all instances that “socialisation” is used in Phase Four, it is in response to the diagnosis made.

In this Category the discussion follows a similar format to that of Categories One and Three (see pp.41-53 and pp.78-88).

I now discuss “socialisation” in relation to “probing questions and active interpretation” in Phases Two and Four.

### 4.4.1. The use of "socialisation" in Phase Two

Out of the four times that Teacher A uses "socialisation" (see Table 17, p.89), it is linked to "probing questions and active interpretation" twice. An example of this can be seen in the following:

> Daniel: I put the bigger number with the smaller number and counted all of it.
> Teacher A: What is another word for 'put'? Can we say you plussed? (Appendix A ii, pedagogical move 6, p.10).

Teacher A "socialises" the learner into the mathematical terminology of addition by integrating the terminology with a "probing question." She says, "Can we say you *plussed*?" As the learners actively interpret the question, they need to interpret the language as well. The two other instances in which Teacher A socialises the learners into the mathematical terminology are through a word problem (with embedded mathematical knowledge), and an "explicit explanation" and "visual demonstration." Teacher A gives a word problem that reads as follows:

> We buy 7 apples and then we buy 11 *more* apples, how many apples do we have altogether? (Appendix A ii, pedagogical move 2, p.8)

In the word problem, Teacher A emphasises the word ***"more"*** and in so doing, she encourages the learners to interpret the word actively in relation to the embedded mathematical knowledge. As the learners interpret the word "more" and relate it to addition, the learners are socialised into the mathematical terminology. In the final part of the assessment task, Teacher A "socialises" the learners into the mathematical terminology for addition and the symbol used for addition when she gives the following "explicit explanation" and "visual demonstration":

> Instead of writing 7 plus 11 or 7 and 11 to show what we did to get to the answer, a symbol (+) *(she writes this up on the white board)* is used to show that we are plussing or adding the numbers together. (Appendix A ii, pedagogical move 10, pp.11-12)

Through the "explicit explanation," the teacher socialises the learners into terminology for addition, i.e. ***"plus"*** and ***"and."*** By giving a "visual demonstration," Teacher A "socialises" the learners into the symbol that is used for addition.

Teacher B works with "socialisation" only once in Phase Two (see Table 17, p.89). In this instance, "socialisation" is used in relation to "probing questions and active interpretation." Teacher B goes through the instructions of the assessment task and encourages the learners to verbalise their understanding of the concepts. As the learners verbalise and actively interpret their understanding, Teacher B "socialises" them into the mathematical terminology associated with addition. She does so

by asking the "probing question," "What do we mean by *more*?" (Appendix B ii, pedagogical move 4, p.10). The learners need to interpret the word *"more"* actively in order to respond to the question and are socialised into the mathematical terminology.

In the four instances that Teacher C "socialises" the learners into the mathematical terminology in this Phase (see Table 17, p.89), only once is it in relation to "probing questions and active interpretation." This occurs in Appendix C ii, pedagogical move 14, p.10. As the learners complete the assessment task, Teacher C asks the learners "probing questions." For example, she says, "Why are you plussing?" "What word tells you this in the word problem?" To respond to the question the learners need to interpret actively which word in the word problem told them to "plus." In the case of this example, it is the word "more." As the learners actively interpret the word "more," they are "socialised" into the mathematical terminology for addition. In the three other instances in this Phase that Teacher C "socialises" the learners into mathematical terminology, she does so through word problems and embedded mathematical knowledge. For example, in Appendix C ii, pedagogical moves 2 and 7, pp.8-9:

> *[Teacher C reads the word problem to the learners]:*
> James has 8 cars. Thando has 4 *less*. How many cars does Thando have?... [*After the learners have attempted to solve the word problem],* Teacher C then reads the word problem again, and this time emphasises the word *less.* She asks the learners to give words that mean the same as "less."
> The learners respond and say, fewer, take away and minus.

As Teacher C reads the word problem to the learners, she emphasises the word *"less."* As the learners interpret the word problem, they need to understand the embedded mathematical knowledge, which is that the word *"less"* implies that they need to subtract. After the learners attempt to solve the problem and are unable to interpret the embedded mathematical knowledge, Teacher C assists the learners in understanding that the problem is asking them to subtract. She does so by asking the learners to give her words that mean the same as *"less."* The learners respond and say, "fewer," "take away" and "minus." As the learners give synonyms for the word *"less,"* they are "socialised" into the mathematical terminology associated with subtraction.

### 4.4.2. The use of "socialisation" in Phase Four

In Phase Four, after the diagnosis has been discussed, Teacher A works with "socialising" the learners into mathematical terminology three times. Teacher C works with "socialisation" 10 times and Teacher B does not work with the pedagogical move of "socialisation" at all in this Phase. In every instance that "socialisation" is used by Teachers A and C, which is 13 times in total, it is used in

relation to the diagnosis made (see Table 17, p.89), and 12 out of the 13 times it is used in relation to "probing questions and active interpretation."

An example of Teacher C working with "socialisation" in relation to "probing questions and active interpretation" and linked to the diagnosis discussed which is to develop the learners' conceptual understanding that the value of numbers can be "more" or "less" than one another, can be seen in the following:

> Wandi: Uh…9. 9 plus 2 equals 11.
> Teacher C: Okay, what in your mind told you…where to start?
> Wandi: From 9.
> Teacher C: From 9 and then what did you do, you added…?
> Wandi: 2 more.
> Teacher C: What wording told me if I must plus or minus?
> Wandi: More (Appendix C iv, pedagogical move 13, pp.22-23).

In this example, Teacher C asks a "probing question" which encourages the learners to interpret actively, i.e. "Okay, what in your mind told you…where to start?" As the learner actively interprets, Teacher C makes the link to the diagnosis by encouraging the learner to think about the number in relation to other numbers, i.e. that 9 in relation to 11 is two more. She says, "From 9 and then what did you do, you added…?" The learner responds and says, "2 more." Simultaneously, as Teacher C makes the link to the diagnosis, she socialises the learners into the mathematical terminology of "plus," "minus," "added" and "more."

The one time that Teacher C does not "socialise" the learners into the mathematical terminology in relation to "probing questions and active interpretation" in this Phase is when she gives the learners a word problem with embedded mathematical knowledge. The word problem reads as follows:

> There are 9 children in Mrs Rabbit's class. There are 2 *more* children than this in Mrs Hare's class. How many children are there in Mrs Hare's class? (Appendix C iv, pedagogical move 11, p.22)

As the learners read the word problem, they need to interpret that to work out 2 "*more"* mathematically, they need to add. By reading the word problem, they are socialised to recognise that the wording "more" is related to the mathematical terminology of addition. The learners' conceptual understanding of "more" is developed through the word problem and the link to the diagnosis is made, which is to develop the learners' mathematical understanding of "more" and "less."

*Summary of the use of "socialisation" during Phases Two and Four*

In Phase Two, the teachers use "socialisation" primarily in relation to "probing questions and active interpretation" and embedded mathematical knowledge. The teachers expose the learners to the mathematical terminology by asking the learners to interpret probing questions actively or to interpret embedded mathematical knowledge in word problems. The teachers also "socialise" the learners into the mathematical terminology using "explicit explanations" and "visual demonstrations."
In Phase Four, in all the instances in which Teachers A and C use "socialisation" to give the learners' access to the mathematical terminology, it is related to the diagnosis made.

In the final part of this category I discuss what the teachers explained about "socialisation" in their interviews and how this gets implemented in classroom practice.

### 4.4.3 The relationship between interviews and "socialisation"

The only teacher that spoke about "socialisation" in any form in her interview was Teacher C. In her Phase One interview, Teacher C referred to what she calls, "social knowledge." She described it in the following way:

> Then there will be a sort of opportunity for them to talk about it, get information from their peers…or me as the educator would step in and give them the social knowledge to actually clarify their thinking. So social knowledge will come in from the talking and the actual language being used during that talking period, the terms they're using – "add," "subtract." (Appendix C i, 1.3, paragraph 1, p.5).

In this explanation, Teacher C referred to "social knowledge" as two-fold. Firstly, she referred to the knowledge that the learners gain from interacting and talking to their peers (while acknowledged as formative, this has not been a focus of this study). Secondly, she talked about the "social knowledge" that the teacher exposes the learners to in relation to mathematical terminology. We see evidence of Teacher C "socialising" the learners into the mathematical terminology in both Phases Two and Four (see examples Section 4.4.1. and 4.4.2, pp.90-92).

It can be suggested that the reason Teacher C works the most with "socialisation" is that the focus of her lesson after the diagnosis is to develop the learners' conceptual understanding of the values of numbers being "more" or "less" than one another. Teacher C, therefore, works closely with the terminology as she develops the conceptual understanding.

## Chapter Five

## Discussion of Findings

The presentation and analysis of the findings indicate that as the three teachers of the study work with formative assessment diagnostically they follow a carefully planned, 'scaffolded' process (re phases).The pedagogical moves and decisions that they make in their instructional practice are related to the purpose for which they are intended in the process of using formative assessment diagnostically in the teaching and learning of Number.

The idea of using formative assessment to inform pedagogical decisions or what has become known as "assessment for learning" (Shepard, 2000, p.6) has evoked a number of research studies and has been a topic of interest at all levels of schooling for over a decade. Various aspects of formative assessment have been researched and more recently, the idea of using formative assessment diagnostically in the teaching and learning programme is being investigated.

My aim in this chapter is to answer the three sub questions of the research. I structured my discussion of the questions around Black and Wiliams' (2006) activity theory of formative assessment (see Chapter Two of this Research Report, pp.21-23). In doing so, I attempt to construct a framework to analyse how the 'scaffolded' process, described in Chapter Four, helps the teachers as they formatively try to diagnose and address the difficulties learners are experiencing in Number. The analysis will show that the teachers' views about the nature of the subject and the way in which it is taught, and more broadly their views about learning are demonstrated by the pedagogical moves (Boaler, 2001) they select in the course of the 'scaffolded' process, and are crucial for understanding what aspects of formative assessment promote the practice of diagnosis in the teaching and learning experience (see Sub-question 1).

My analysis of the 'scaffolded' process draws in particular on Ball et al's (2005; 2008; 2009) notion of "mathematics knowledge for teaching" and Boaler's idea of "pedagogical moves" (2001). Ball et al's (2005) analysis points to the "mathematical reasoning and pedagogical thinking" (see Chapter Two of this Research Report, p.9) that the teacher requires for the teaching of mathematics. Drawing on this idea, I specifically focus on the pedagogical thinking of the teachers as they work with formative assessment tasks diagnostically in the teaching of Number. In an effort to unpack the pedagogical thinking of the teachers, I examine what Boaler (2001, see Chapter Two of this Research Report, p.10) refers to as the "pedagogical moves" that the teachers use as they 'scaffold' their interaction with the learners during the formative assessment process. In this study, "pedagogical moves" refers to the methods and ways that the teachers work diagnostically with formative assessment in their instructional practice.

Black and Wiliams (2006, p.94), in their description of the activity theory of formative assessment, refer to the "subject classroom" as an "activity system." In the activity system they describe the relationships between what they term the *tools, subjects and objects/outcomes* (italics in original text). The relationship among these components forms an interactive system (see Chapter Two of this Research Report, pp.21-22). It is the ways in which the components interact with each other that is useful for my task here, which is to explain the mode in which the teachers use formative assessment for diagnostic purposes, by following a 'scaffolded' process.

I propose that understanding the kind of pedagogical moves that the teachers make as they work with a 'scaffolded' process of formative assessment is important for understanding how formative assessment is being used diagnostically.

**Table 18**

**Main research question and sub-questions**

| **Main research question** |
|---|
| What process of formative assessment do Grade Two teachers use to diagnose and address learner difficulties in the concept of number, and to improve their methods of instruction? |
| **Sub-questions** |
| 1. What aspects of formative assessment promote the practice of diagnosis in the teaching and learning experience? |
| 2. What do the teachers understand as the relationship between formative assessment and diagnostic assessment? |
| 3. How do the teachers use diagnostic assessment to interpret the learners' difficulties and attend to/improve their teaching? |

To begin my discussion I examine the teachers' views and ideas about the nature of the subject and the way in which it is taught. By looking at the teachers' views and ideas about mathematics (and in particular the teaching of Number) and the way it is taught, I am trying to see how through the teachers' instructional practice, their understanding of the relationship between diagnostic and formative assessment is demonstrated (Sub-question 2). Furthermore, I am hoping to gain an insight into how this view of the subject influences the way in which formative assessment is used diagnostically to improve their teaching of Number (Sub-question 3).

*Teachers' views and ideas about the nature of the subject and the way in which it is taught*

To understand the teachers' views and ideas about the nature of the subject, (Black and Williams, 2006) I examine how the teachers' views and ideas about the nature of the subject can be seen in the types of mathematical knowledge that they recruit in general, and in the mathematical knowledge they recruit specific to Number. I further examine the relation between the types of mathematical knowledge recruited and the pedagogical moves selected as the teachers formatively work and diagnose the difficulties the learners are experiencing in Number.

The teachers' views on the nature of the subject and the way in which it is taught can be seen in the manner in which they recruit the different types of mathematical knowledge, i.e. "physical," "social" and "logico-mathematical knowledge" (Piaget as cited in Kamii, 1989, see Chapter Two of this Research Report, p.15) in their pedagogical moves. Rakgokong and McDermott (1996) discuss the different types of knowledge as a process by which young learners learn about number and develop number concept.

By selecting certain pedagogical moves during their instructional practice, the teachers recruit the different types of mathematical knowledge in varying frequencies. This depends on the purpose for which the recruitment of the knowledge is intended. I argue that what is important is that the moves are seen as relational and that the purpose for which the moves are intended will influence the frequency or the sequence.

Table 19 shows how the above types of knowledge are aligned to the pedagogical moves in the study:

**Table 19**

| Types of Mathematical Knowledge | Pedagogical Move |
|---|---|
| Physical Mathematical Knowledge | concrete apparatus (CA), visual demonstration (VISDEM) |
| Social Mathematical Knowledge | socialisation (SOC) |
| Logico-mathematical knowledge | probing questions and active interpretation (PROBQAIN), verbal demonstration (VERBDEM) and evaluation (EVAL) |

In the above Table, I aligned "physical mathematical knowledge" with the pedagogical moves of "concrete apparatus" and "visual demonstration" because this is whenever, in the teachers' pedagogical moves, there is a visual or physical/concrete demonstration done or given. I aligned "social mathematical knowledge" with the pedagogical move of "socialisation" because this is when in the instructional practice, the teachers socialise the learners into the mathematical terminology. "Logico-mathematical knowledge" is aligned with "probing questions and active interpretation," "verbal

demonstration" and "evaluation" because these are the pedagogical moves that are used by the teachers when the learners need to actively apply the mathematical understandings that they have constructed.

Teacher C is the only teacher who, in her Phase One interview, explained the different types of mathematical knowledge as part of the mental processes with which, she believed, learners needed to engage as they develop their understanding of number (Appendix C i, 1.3, paragraph 1, p.5, see Chapter Four, Section 4.1.6, p.51).

In Phase Two, the teachers work with "concrete apparatus," (CA) which is aligned with "physical mathematical knowledge" a total of six times (see Table 3, p.54). In Phase Four, this changes to a total of 33 times (see Table 3, p.54). In Phase Four, which is after the diagnosis of the learners' difficulties has been discussed, the teachers recruit "physical mathematical knowledge" far more frequently as they introduce new mathematical knowledge (Teachers A and B), or consolidate the understanding of a previously taught mathematical concept (Teacher C). Another example of the varying frequencies with which the teachers work with the different types of mathematical knowledge can be seen in the way Teachers B and C use "social mathematical knowledge" (which is aligned to the pedagogical move of "socialisation" (SOC)) in their pedagogical moves in Phase Four. For example, Teacher B, in this Phase, does not recruit "social mathematical knowledge," which is in contrast to Teacher C, who recruits "social mathematical knowledge" 10 times (see Table 17, p.89). The use of the mathematical knowledge is once again determined by the purpose for which it is intended. Teacher C's lesson is focussed on consolidating the learners' understanding of the mathematical concepts of 'more' and 'less.' As part of this understanding, the learners need to understand the mathematical terminology which, as described by Rakgokong and McDermott (1996), is "social mathematical knowledge." Consequentially, Teacher C recruits "social mathematical knowledge" frequently in her pedagogical moves. Teacher B does not recruit "social mathematical knowledge" because the focus of her lesson is on developing a new mathematical skill, for which she recruits "physical mathematical knowledge" and "logico-mathematical knowledge" predominantly.

Evidence of all the teachers recruiting and working with "logico-mathematical knowledge" can be seen in the pedagogical moves of "probing questions and active interpretation" (PROBQAIN) and "verbal demonstration" (VERB DEM). Through these pedagogical moves, the learners engage in an "active process of mental construction and sense making" (Shepard, 2000, p.6) and internally construct ideas on the relationships and patterns between numbers (Rakgogong and McDermott, 1996). As the learners' thinking is probed, they are encouraged to develop an abstract understanding of number, (i.e. the teachers enact the learners' "logico-mathematical" understanding). The pedagogical move of "evaluation," (EVAL) which is aimed at diagnosing the learners' thinking, is used frequently in both Phases Two and Four and can also be regarded as a move that the teachers use when working with the "logico-mathematical knowledge" of the learners. As the learners are encouraged to interpret

actively through probing questions and discuss their thinking, the teachers use this as an opportunity to “evaluate” the “logico-mathematical” thinking of the learners as part of the diagnostic process of formative assessment. (“Probing questions and active interpretation,” “verbal demonstration” and “evaluation” are discussed in further detail below).

“Physical mathematical knowledge,” “social mathematical knowledge” and “logico-mathematical knowledge” are not the only types of mathematical knowledge that can be used to describe the teachers’ views and ideas about the nature of mathematics. Hodgen and Marshall (2005) and Good (2008) claim that in assessment practice, teachers need to work meaningfully with the previous knowledge and social experiences that the learners bring with them. This is supported by the findings of a number of studies on the role of previous knowledge in formative assessment practices in mathematics (Boaler, 2001; Killen, 2003; Sato et al, 2005). In the study there is evidence of the three teachers recruiting previously taught mathematical knowledge (PTMK) in their pedagogical moves for selected purposes. In their interviews, Teachers A and B explained the role of previous knowledge. Firstly, they spoke about it in relation to constructing knowledge and secondly, in the diagnostic process as an important consideration in the planning of the follow-up lesson. In practice, the findings showed that Teachers A and B recruit previously taught mathematical knowledge to construct new mathematical knowledge, based on the diagnosis made in Phase Three and Phase Four. Teacher C did not talk about the role of previously taught mathematical knowledge in her interviews, but in practice recruits it the most as she works on consolidating the learners’ understanding of the mathematical concepts that were diagnosed as difficulties.

In their instructional practice, the teachers work with the learners previously taught mathematical knowledge but also work with the learners’ everyday knowledge (ED) and embedded mathematical knowledge (EMBD) within a familiar context. In Phases Two and Four, the teachers recruit everyday knowledge and embedded mathematical knowledge for different purposes. In Phase Two, everyday knowledge is used to provide a context to evaluate the learners’ understanding of previously taught mathematical concepts and in Phase Four, the learners are given a context in which they have to actively apply the new mathematical knowledge and skill/s taught. Haylock (1991) suggests that working within a meaningful context for learners who are experiencing difficulty in mathematics is likely to assist them with their mathematical understanding. This sense of context relates to the earlier point made by Hodgen and Marshall (2005) and Good (2008) that teachers’ working with the social experiences of learners is important.

The teachers’ specific views on the way Number should be taught, based on the diagnosis discussed in Phase Three, can also be seen in the pedagogical moves of Teachers A and B as they work on moving the learners to the next ‘level’ in developing an early number concept (Kamii, 1989, Murray et al, 1992; Askew and Brown, 2003). In the interview in Phase Three, Teachers A and B both diagnose that the learners need to be encouraged to “start counting in groups” (Appendix A iii, 3.2, paragraph 7,

p.17) and not “resort to [counting] in 1s” when working independently (Appendix B iii, 3.2, paragraph 5, p.15). In the pedagogical moves in Phase Four, the teachers introduce the new mathematical knowledge (counting in groups) and work at encouraging the learners to progress from *Level 1 – Counting all* to *Level 2 – Counting on* (Murray et al, 1992). As the teachers recruit the new mathematical knowledge, they work in relation to other areas of mathematical knowledge such as previously taught mathematical knowledge or pedagogical moves such as “concrete apparatus,” (CA) “probing questions and active interpretation,” (PROBQAIN) “verbal demonstration,” (VERB DEM) “visual demonstration,” (VIS DEM) “explicit explanation” (EXP) and “evaluation” (EVAL). This suggests that the teachers view the teaching of Number as a progressive process. With these moves, the teachers integrate and simultaneously develop their learners’ “physical mathematical knowledge” and “logico-mathematical knowledge.” The pedagogical moves used by the teachers in the ‘scaffolded’ formative process are not only used to attend to the diagnosis discussed, but are also used in diagnosing the difficulties the learners’ are experiencing (this is discussed in further detail below).

In summary, the teachers’ views of the subject and the way in which it is taught is centred on working with the different types of mathematical knowledge and recruiting the type of knowledge based on the purpose for which it is intended. Included in this is working with meaningful contexts and using previous mathematical understanding in developing new mathematical understanding. The teachers’ views of the subject and the way in which is taught is also seen in the pedagogical moves that are used by the teachers in the formative process. By the teachers making decisions on when and how the different types of mathematical knowledge are recruited and which pedagogical moves are used in the formative process, their understanding of the relationship between diagnostic and formative assessment is demonstrated (Sub-question 2).The recruitment of the different types of mathematical knowledge and pedagogical moves are firstly used to help the teachers to diagnose the learners’ difficulties and secondly, they are used to help the teachers work with the diagnosis in the formative assessment process. This offers an insight into the process that the teachers use when working with formative assessment diagnostically to improve their teaching of Number (Sub-question 3).

Next in the discussion I look at the methods and pedagogical moves that are used by the teachers to ‘scaffold’ the process of formative assessment. This analysis is aligned with what Black and Wiliams (2006) refer to as the methods that the teachers use in the instructional practice to enhance the formative aspects of the interactions that take place in the activity system. By examining the methods and pedagogical moves that the teachers use (i.e. their instructional practice) as they work with formative assessment for diagnostic purposes, key aspects of formative assessment that promote the practice of diagnosis in the teaching and learning experience can be explicated (Sub-question 1). In my analysis of the teachers’ instructional practice, I discuss which of the pedagogical moves used by the teachers demonstrates in particular their view of the relationship between formative and diagnostic assessment (Sub-question 2). By foregrounding the pedagogical moves the teachers use most, the phases that together construct the ‘scaffolded’ process, the learning analysis the teachers construct

throughout the full cycle of events, and by drawing out from this analysis their views of learning in general, I am able to show how the teachers use formative assessment, diagnostically, that is to understand their learners' difficulties and to improve their teaching (Sub-question 3).

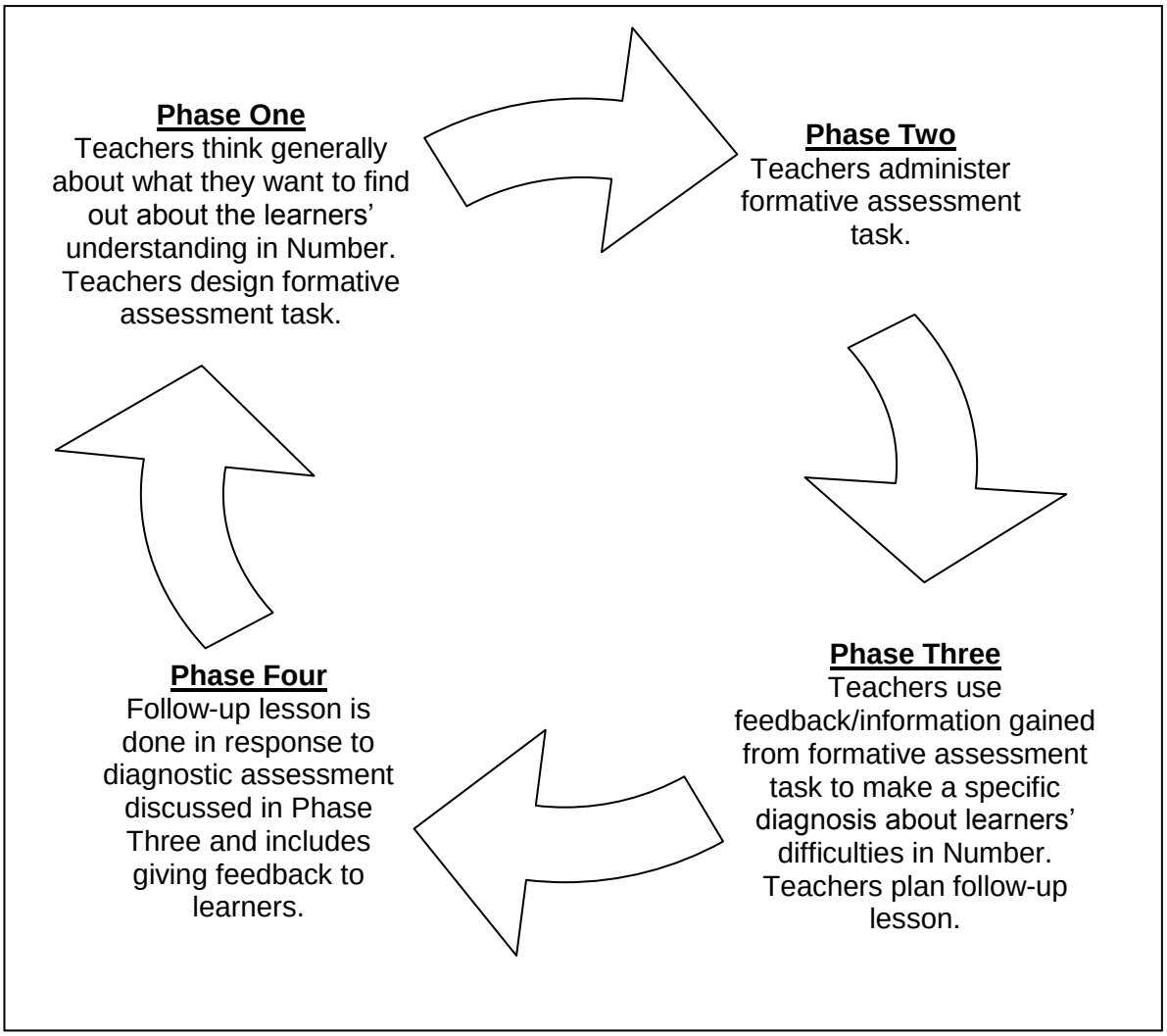
*The method, ways and pedagogical moves that are used by the teachers to 'scaffold' and enhance the formative interaction*

Lampert (2001) makes the point that teachers need to choose a strategy that will allow them to understand the learners' thinking and bring each learner to a deeper understanding of mathematics. If one applies this to using formative assessment diagnostically in the teaching of Number, the teachers choose strategies that enable them to understand the thinking of the learners and use the information gained to 'scaffold' the process of formative assessment. In the current study, pedagogical moves such as "probing questions and active interpretation," (PROBQAIN) "verbal demonstration," (VERB DEM) "concrete apparatus," (CA) "visual demonstration" (VIS DEM) and "evaluation" (EVAL) are carefully selected as part of the instructional practice of the teachers. In particular "probing questions and active interpretation" is used as a major pedagogical move and is used often, together with "evaluation," as a means to understand and diagnose the learner's thinking. It is also used as a means to attend to the diagnosis and bring each learner to a deeper understanding of the mathematics. Evidence of this can be seen throughout Phases Two and Three of the formative process. ("Probing questions and active interpretation" is discussed in further detail below).

To 'unpack' the pedagogical moves that are used in the 'scaffolded' formative process as the teachers work diagnostically, it is important to understand that the process is marked by a cycle of events (Refer to Figure 2).

**Phases of the 'scaffolded' formative assessment process**

**Figure 2**




In the initial designing of the formative task, the teachers think generally about what they would like to find out about learners' knowledge of Number. The formative task is designed and planned with this in mind. In this study, the teachers discussed what they hoped to find out about the learners' thinking, in Number, in their Phase One interviews. For example, Teacher A explained that she wanted to see how the learners work with concrete apparatus, write number sentences and what their level of counting is (Appendix A i, 1.4, paragraph 1-3, pp.5-6). After administering the task, the teachers used the feedback/information gained from the learners' response to the task to make a more specific diagnosis. For example, Teacher A said that based on the diagnosis she wanted to get the learners to "count in groups" (Appendix A iii, 3.2, paragraph 7, p.17).This diagnosis was discussed by the teachers in their interview in Phase Three. In this interview, the teachers also discussed how they would use the information gathered about the difficulties learners were experiencing to plan the follow-up lesson. In the initial planning of the assessment task and in the follow-up lesson, the teachers carefully planned the activities that were needed to evaluate the skills and concepts they thought were necessary for the learner to develop. This planning informed their feedback to learners during the lesson. In this way methods and ways that the teachers choose to use, when using formative

assessment diagnostically, are ‘scaffolded’ by a carefully planned cycle of events. In her interview, Teacher B refers to it as a “learning path.” Teachers A and C do not specifically mention the cycle of events of the formative process, but their careful planning is evident as they proceed through the phases of the research. The notion of careful planning and selecting appropriate activities with the greater vision of the skills, strategies, techniques and knowledge that the learners need to apply in mathematics reiterates the views of Murray et al (1992) and Askew et al (1997).

The “learning analysis” (Black and Wiliams, 2006, p.95) takes place as the teachers go through the carefully planned cycle of events. It is important to emphasise that the data shows clearly that the teachers’ learning analysis does not only occur at one particular point, for example, when the diagnosis is done, but rather forms what can be thought of as the background of the ‘scaffolded’ process. In other words: When the teachers plan the task, they think about what the learners have learnt and what they want to evaluate. When they analyse information gained from the task, they look at where the learners are at in their learning and what difficulties they are experiencing. In the follow-up lesson, the teachers work with the learners to construct knowledge and simultaneously, in the interaction, evaluate the learners’ learning. For example Teacher A designs the formative assessment task with the intention of evaluating the learners’ counting abilities. Based on the feedback/information gained from analysing learners’ responses to the task, she diagnoses that the learners’ are experiencing difficulty with counting in groups. Teacher A structures the follow-up lesson to encourage the learners’ learning of counting in groups. For example she sets word problems where the learners need to use counting in groups as a strategy. Using pedagogical moves such as “probing questions and active interpretation” and “evaluation” in the follow-up lesson, Teacher A not only encourages the learners to construct their mathematical understanding of counting in groups, but simultaneously evaluates the learners’ thinking.

The methods, ways and pedagogical moves used by the teachers are selected in relation to the learning analysis made. This analysis changes throughout the carefully planned cycle of events.

What does the analysis tell us about the teachers’ views on the nature of learning (Black and Williams, 2006)? In what follows, I examine how the teachers’ ideas influence the way they use formative assessment to diagnose their learners’ difficulties.

To address what the views and ideas on the nature of learning held by the three teachers in this study are, I focus on the most used pedagogical move in Phases Two and Four, i.e. “probing questions and active interpretation.” In these Phases, “probing questions and active interpretation,” as a pedagogical move, is used by the teachers to encourage the learners to construct mathematical understanding by applying and interpreting information. Newmann et al (1996) refer to this as “authentic construction.” An example of this can be seen when Teacher C asks questions such as, “I’ve got some numbers here, and I want to know which one you think I should start with? Why?” Or Teacher B says to the

learners, “Show me 4 groups of 7.” In both of these examples the learners are required to interpret and apply their knowledge of number. This view of learning where learners are encouraged to construct, apply and interpret knowledge in authentic experiences aligns to the constructivist view of learning (Shepard, 2000; James, 2006). The view of learning in turn influences the teachers’ approach to the analysis of learners’ learning (Black and Wiliams, 2006, p.94). In the instance of this study, the learning analysis takes place through the carefully planned cycle of events in the ‘scaffolded’ formative process.

The authenticity of “probing questions and active interpretation” in the formative and diagnostic process of this study lies in the teachers’ abilities to ask questions of a high cognitive level (Bennett, 1976; Galton and Simon, 1980, as cited by Askew et al, 1997). Examples of this can be seen in questions such as, “How can we write what we have done?” (Teacher A) or “How can we break up the 7 so that we can count how much there is altogether?” (Teacher B). The questions asked are not “intellectually shallow” (Newmann et al, 1996, p.281) or superficial (Biggs, 1999) and encourage the learners to interpret and articulate their own mathematical understandings. Haylock (1991) argues that learners’ articulating their own mathematical understanding is important for learners who are experiencing difficulty in mathematics. As the learners are encouraged to “demonstrate verbally” (James, 1986) what their thinking is, teachers not only get feedback/information on the learners’ constructions of old, previously taught mathematical knowledge and new mathematical knowledge of Number, but are able to gain an insight into the quality of learners’ mathematical constructions (Ball, 1993). Evidence of this in the pedagogical moves of the teachers can be seen, for example, when Teacher A asks a learner to explain the drawing that the learner used to solve a word problem as part of the formative assessment task. The learner responds by saying, “I drawed 7 rectangles in a line and 11 rectangles in a line and counted them all and got 18.” Teacher A, through the learner’s explanation, not only gets feedback on the learner’s previously taught mathematical knowledge (counting to reach an answer), but also gains an insight into the quality of the learner’s mathematical constructions (The learner counts ‘all’ and is not able to count in groups, which is a more sophisticated method of computation). Murray et al (1993) claim that learners’ having the opportunity to verbally demonstrate their understanding is imperative in the development of learners’ number concept. I propose that this is imperative as an act for describing the use of formative assessment tasks diagnostically.

The pedagogical move of “evaluation” is used in relation to “probing questions and active interpretation.” It is used by the teachers as another lens through which they can gain insight into the quality of the learners’ thinking (Shute, 2008), as the ‘scaffold’ of formative assessment is used diagnostically. There are only two occasions in the research process where “evaluation” is not used in relation to “probing questions and active interpretation” (see Section 4.3.1, pp.80-81). While one might expect it to be used more frequently when the formative task is being administered, it is used more frequently in Phase Four after the diagnosis of learning needs has taken place. The teachers use “evaluation” as a way to monitor and diagnose the learners’ thinking throughout the instructional

practice in Phase Four. For example, Teacher C says to the learners, “So what is the problem asking us to do?” She is using probing questions to encourage the learners to interpret the problem actively. As the learner “verbally demonstrates,” Teacher C “evaluates” the learners’ thinking. “Probing questions and active interpretation,” “evaluation” and “verbal demonstration” are all used in relation to one another, depending on the purpose for which they are intended.

Earlier in the discussion, “concrete apparatus” used as a means to recruit and work with “physical mathematical knowledge” was discussed. It is, however, also used in relation to “probing questions and active interpretation” as a means for the learners’ to “demonstrate visually” their mathematical thinking. As the learners “visually demonstrate” their thinking, they work with “concrete apparatus” and the teachers are able to “evaluate” and gain an insight into the learners’ thinking. For example, by Teacher B asking the learners to ‘show’ their thinking (“probing questions and active interpretation” and “evaluation”), she is able to see whether the learners are able to break the blocks up into groups (“concrete apparatus” and “visual demonstration”) that they can count in. The pedagogical move of “concrete apparatus” is integrated in the formative process with “probing questions and active interpretation,” “evaluation” and with “visual demonstration.” Once again we see evidence in the findings of the relation and integration between pedagogical moves.

An impression that could be gained from this discussion is that, in diagnosing and constructing the learners’ mathematical understandings’ of number, the teachers make use of very few explanations in the teaching, learning and assessment practice. This is true for Phase Two, but in Phase Four, “explicit explanations” is one of the most frequently used pedagogical moves. It is used by the teachers in relation to “probing questions and active interpretation,” and is focused on by the teachers to reiterate a solution, method or response. In most instances, it comes after the “probing questions and active interpretation” has taken place. Haylock (1991) makes the claim that “explicit explanations” are particularly important for learners experiencing difficulties in mathematics because they should not be left to make sense on their own. Evidence of this can be found in the data when, for example, after a learner responds to Teacher C and explains that the numberline they are working on will start at the number ‘9’, she asks the learner, “Why 9?” The learner responds and says, “Because there is no 1 in this number.” Teacher C then “explicitly explains” to the rest of the learners that their numberline will start at the number 9 because there are no numbers smaller than 9 in the pack. The learners’ understandings are first probed and they are given the opportunity to interpret and make sense on their own and then Teacher A provides an “explicit explanation.”

Biggs (1999), Shepard (2000), and Black (2003), in their studies on formative assessment, highlight the importance of making criteria explicit. Making “criteria explicit” is part of the pedagogical moves of the teachers in the study. In the activity system of Black and Wiliams (2006), it is aligned with the *outcomes,* which are related to making the teachers’ expectations clear to the learners. All three teachers use criteria to evaluate the learners’ understanding in their pedagogical moves. The criteria,

however, are not always made “explicit” to the learners. In Phase Two, all the teachers work with rubrics. Teacher B is the only teacher that gives the learners the rubric as they work with the formative assessment task, making the “criteria explicit.” It can be argued that the teachers use other pedagogical moves to transmit criteria. After the diagnosis, none of the teachers work with assessment rubrics, but in Phase Four, we see Teacher A in particular using “explicit instructions” more prominently as a pedagogical move. Through the “explicit instructions,” (INSTEXP) it can be said that the expectations are made “explicit” to the learners. For example Teacher A “explicitly instructs” the learners in Phase Two, on how she wants them to solve the word problems. She tells them to use the concrete apparatus, draw a picture and give a number sentence showing their answer. In so doing, Teacher A makes her “criteria explicit” to the learners. The moves of “visual demonstration,” (VIS DEM) “probing questions and active interpretation” (PROBQAIN) and “evaluation” (EVAL) could also be argued as a way that the teachers make the “criteria explicit” to the learners. Through the “visual demonstrations” and “probing questions” that require “active interpretation” and are used to “evaluate” the learners’ thinking, the criteria are made “explicit” to the learners. An example demonstrating this in the data would be when Teacher B says, “Now, I asked for 6 groups of 3, how many in each group? Can you show me your 6 groups please?” Through the “probing questions” the learners are “probed” to show (“visual demonstration”) their thinking. The learners’ “visual demonstrations” are used to “evaluate” their thinking and understanding. By asking the learners to do this, the criterion is made explicit to the learners i.e. to use the apparatus to visually show their understanding.

What is implied by the teachers using pedagogical moves such as “probing questions and active interpretation” “evaluation”, “verbal demonstration,” “visual demonstration” and “concrete apparatus” is that the teachers’ views of learning are aligned to a constructivist view of learning and consequentially instruction that is used to support the learners’ learning (Shepard, 2000; Gipps and Cumming, 2004). While two of the teachers did not provide the rubric content to their learners and to this extent, did not make their criteria “explicit,” (as discussed above) I proposed that during the learning process all three teachers used pedagogical moves such as “explicit instructions,” visual demonstrations,” “probing questions and active interpretation” and “evaluation” and transmitted criteria as an integrated form with their teaching. Arguably, none of these moves should be used instead of transmitting “criteria explicitly.” However, the idea that the views of learning implied by the teachers are aligned to assessment practices that are formative is supported by the fact that the teachers make “criteria explicit,” in whichever form (Biggs, 1999; Shepard, 2000; Black 2003). In the case of this study, the teachers select pedagogical moves that support the diagnostic use of formative assessment in a carefully planned cycle of events.

In summary, key aspects of formative assessment that promote the practice of diagnosis can be explicated from the analysis of the pedagogical moves and methods selected by the teachers in the instructional practice (Sub-question 1). These are: moves and methods that encourage learners to actively interpret (for example "probing questions and active interpretation" and "verbal demonstrations"), that allow the teachers to evaluate the learners' thinking ("evaluation") and make the criteria for learning explicit to the learners (for example "criteria explicit", "explicit explanations" and "visual demonstrations"). Furthermore, the pedagogical moves and methods selected by the teachers reveal that the teachers see the relationship between formative assessment and diagnostic assessment as part of a carefully constructed, 'scaffolded' process (Sub-question 2). The analysis of the pedagogical moves that the teachers use the most in the learning analysis suggests the teachers' views of learning (i.e. constructivist view). It also reveals how the teachers use the pedagogical moves as part of using formative assessment diagnostically, that is to understand their learners' difficulties and to improve their teaching (Sub-question 3).

In the final part of my discussion I reflect on the role of the teacher (Black and Williams, 2006) in the 'scaffolded' process of working diagnostically with formative assessment. I discuss the type of understanding required by the teacher, both mathematically and pedagogically. I also examine the roles that the teachers take on as they engage in the formative process.

*The role of the teacher in the 'scaffolded' process of working diagnostically with formative assessment*

What has been highlighted from the discussion on the planned cycle of events in the formative process is that for teachers to work productively with formative assessment in the activity system, they need to develop views on the nature of the subject, the nature of learning and the pedagogical content knowledge (Black and Wiliams, 1996). The quality and depth of their views and the pedagogical content knowledge (Ball, 2005; 2008; 2009) required for the act of working with formative assessment diagnostically (Cobb, 1991) are crucial. In the current study, the decisions that the teachers make about the recruitment of mathematical knowledge and the pedagogical moves which they recruit during instruction provide evidence of the depth and quality of the teachers' understandings and methods of teaching. This reinforces Ball's (1993) argument that the teacher in a reform mathematics curriculum needs to be guided by "deep disciplinary understandings" (p.337) and needs to have "mathematical knowledge for teaching" (Ball et al 2005, p.21). From the findings of this study, we are able to see that the quality and depth of understanding that the teachers have about the discipline relates to and is influenced by the view that the teachers have on the nature of the subject and the way in which it is taught (see pp.96-100). We are also able to see that the depth of the pedagogical content knowledge of the teachers or their mathematical knowledge for teaching (Ball et al, 2005) is related, firstly, to the views that the teachers have on learning and secondly, to carefully selected methods, ways and pedagogical moves that are used as part of a planned cycle of events (see pp.100-106).

The role of the teacher in the formative process changes as he/she works interactively and diagnostically with the various components in the system, using the three different *tools* specified by Black and Wiliams (2006). As the teacher makes decisions in the instructional practice about the mathematical knowledge that needs to be recruited, the appropriate pedagogical moves, the purpose of the mathematical knowledge being recruited and the purpose of the pedagogical moves, his/her role changes. For example, in Phase Two, when physical mathematical knowledge is being recruited to evaluate the learners' thinking on previously taught mathematical concepts, the teacher takes on the role of evaluator (Murray, 2000). In the same phase when the teacher works with the pedagogical move, "probing questions and active interpretation" in relation to "socialisation," she not only takes on the role of evaluator, but also takes on the role of mediator as she mediates the learners' learning of the mathematical terminology. When the teacher in Phase Four works with "probing questions and active interpretation" in relation to "verbal demonstration" or "visual demonstration," the teacher takes on the role of mediator in the learners' construction of knowledge (Cobb, 1991). In the same phase her role changes when she recruits previously taught mathematical knowledge in relation to new mathematical knowledge. Her role is now not only as an evaluator (as she evaluates the learners' previous mathematical constructions), but her role is also simultaneously as mediator (as she facilitates the construction of the learners' new mathematical knowledge). When the teacher provides the learners with "explicit explanations" in both Phases Two and Four she assumes the role of a knowledge transmitter as she carefully explains the mathematical concepts to the learners.

The role of the teacher in using formative assessment diagnostically changes not only as she makes decisions on pedagogical moves and the recruitment of knowledge in the instructional practice, but it also changes as she proceeds through each of the phases included in the research process. In Phase One, the teacher plans the formative assessment task. The role of the teacher in this phase is not only as designer, but also as evaluator. As she designs the task, she has to specifically think about what she wants to evaluate. In Phase Two, the teacher administers the task. As she administers the task, the teacher takes on the role of evaluator and facilitator. She is the evaluator because the teacher has designed the task to evaluate the learners' mathematical understandings, but the teacher is also the facilitator, because she facilitates the learners' thinking as they respond to and complete the assessment task through pedagogical moves such as "probing questions and active interpretation." In Phase Three, the teacher takes on the role of evaluator as she diagnoses the learners' thinking and the difficulties that they are experiencing in Number. In this phase, she also takes on the role of designer as she plans for the follow-up lesson based on the diagnosis made. In Phase Four, the teacher takes on the role not only of facilitator, as she facilitates the learning based on the diagnosis made, but also as evaluator as she evaluates the learners' mathematical constructions of, for example, the new mathematical knowledge being introduced.

In the findings, we see evidence of the alignment between the interviews, diagnosis discussed and what the teachers do as their roles change in each of the phases. The role that the teacher assumes

as part of the *subjects* (Black and Wiliams, 2006) in the activity system is complex as it is constantly changing at two levels. Generally, the teacher's role changes during each phase of the research process and more specifically, the teacher's role changes in the pedagogical moves and interactions that take place in the instructional practice.

In the concluding part of this discussion, I summarise and provide an overview of how the sub-questions of the research are answered by this study.

- What aspects of formative assessment promote the practice of diagnosis :

First and foremost, formative assessment that promotes diagnostic assessment is part of a carefully planned, 'scaffolded' cycle of events (re phases). Secondly, the teachers' views of learning and how the subject is taught influence the pedagogical decisions they make about firstly, *what* instructional practices to use to get feedback/information about learners' understanding of the work done, and secondly, *how* to scaffold the entire process of formative assessment This is evident in the way the teachers work with different types of mathematical knowledge, i.e. "physical", "social" and "logico-mathematical knowledge" in the formative process, as well as in the different forms of mathematical knowledge that the teachers recruit, i.e. previously taught mathematical knowledge, new mathematical knowledge, everyday and embedded mathematical knowledge. These different types and forms of mathematical knowledge are recruited in different frequencies and are used for different purposes throughout the formative process. Thirdly, it is evident in the way that the teachers work with and recruit different pedagogical moves, i.e. "probing questions and active interpretation," verbal demonstration," "visual demonstration," concrete apparatus," "evaluation" and "socialisation" at particular points (phases) throughout the 'scaffolded' process. These pedagogical moves are also carefully selected in the 'scaffolded' formative process and are also used by the teachers in varying frequencies and for different purposes. Lastly, an important aspect of the 'scaffolded' process are the various and complex roles that the teachers take in the cycle of events as they make the analysis of learning and as they use it to improve their teaching.

- What do the teachers understand as the relationship between formative assessment and diagnostic assessment?

The teachers explain what they understand as the relationship between formative assessment and diagnostic assessment with the following comments:

> [It's about] gathering information…and using this information to base the follow-up lesson on. (Appendix A iii, 3.1, paragraph 2, p.13).

> [It's part of the 'learning path'] [You] look at the results of the assessment and reflect on them, to set the basis for the next lesson. (Appendix B iii, 3.1, paragraph 1, p.13)

> The diagnosis of learning should be an integrated aspect of the assessment process. (Appendix C iii, 3.1, paragraph 4, p.13)

In summarising and combining the views of the teachers, diagnostic assessment is thought of as an integrated assessment practice. It is part of a process, or as Teacher B says, a 'learning path.' The results and the information gathered in the assessment process are reflected on and used to set the basis for the next lesson. This relates to formative and diagnostic studies done by Black (2003); Pryor and Crossouard, (2008) and Hodgen and Marshall, (2005). Drawing from the above analysis of the teachers' instructional practice, we see that the common understanding that they share is that diagnostic assessment is an integrated part of the 'scaffolded' process of formative assessment. Information about learning is gained both in the on- going feedback in the classroom as well as from the analysis of learners' responses to task and this information is used by the teachers to make pedagogical decisions. The ways the teachers enact this process (seen in the teachers' pedagogical moves) demonstrates their attempt to 'scaffold' the entire cycle of formative assessment. The teachers' understanding of the relationship between formative assessment and diagnostic assessment is also seen in the role/s that the teachers take in the various phases of the study, the views that they have on learning and the way in which the subject is taught. The enacting of this can once again be found in the pedagogical moves of the teachers.

- How do the teachers use diagnostic assessment to interpret the learners' difficulties and attend to/improve their teaching?

How the teachers use diagnostic assessment to interpret the learners' difficulties and improve their teaching, can be seen throughout the carefully 'scaffolded' cycle of events. Their learners' analysis of learners' responses to the formative assessment tasks enables the teachers to diagnose learners' difficulties and to use this diagnosis to improve their instructional practices by more carefully scaffolding the learning process through a series of pedagogic moves. A major pedagogical move that is used together with the other moves is "probing questions and active interpretation." Furthermore, the role/s that the teachers take up in specific moments during the formative process is evidence of how the teachers work with and use formative assessment diagnostically. The teachers' views of learning and the way in which the subject is taught (which can be seen in the pedagogical moves that the teachers enact) influence the decisions that they make as they 'scaffold' the cycle of planned events. By analysing learners' responses to the task, the teachers use formative assessment diagnostically and grow their understanding of their learners' difficulties.

## Chapter Six – Conclusion

The process involved in using assessment practice formatively in the teaching and learning programme is one that requires ongoing investigation and research, if the intricacies and subtleties are to be understood. While this study specifically investigates how Foundation Phase teachers use formative assessment tasks to diagnose learner difficulties and to improve their methods of instruction in the teaching of Number in Numeracy, it is important to bear in mind that this is a small scale case study and its findings are limited. The intention is not to present conclusions and recommendations in definitive terms or to draw generalisations for all South African classrooms and contexts, but rather the study is used as a means to gain some insight into what three 'strong' teachers do when they work with formative assessment to diagnose learners' difficulties and to respond to them, Furthermore, the study is used as a way to begin looking at the implications of using formative assessment diagnostically in the teaching and learning of Numeracy (and more specifically, in this study, Number) in the Foundation Phase.

### *Main findings and central claim*

The main finding of the study indicates that for the three teachers studied using formative assessment to diagnose difficulties learners are experiencing in Number and to improve the instructional practice is part of a carefully planned, 'scaffolded' cycle of events. Within this planned cycle of events six central claims emerge: Firstly, the "learning analysis" (Black and Wiliams, 2006, p.95) that takes place throughout the 'scaffolded' events involves careful planning by the teachers and does not only occur at one particular point, for example, when the diagnosis of learners' difficulties is done. It occurs in each phase of the 'scaffolded' process and is an integrated part of the diagnostic assessment that takes place in the four phases. Secondly, there is a strong correlation between what the teachers understand as the relationship between formative assessment and diagnostic assessment, and the ways in which the teachers interact with the learners as they work with a 'scaffolded' process of formative assessment to diagnose the learners' difficulties in the learning of number. Thirdly, the decisions that the teachers make about the methods or strategies that they use during instruction is most often related to a particular purpose in the 'scaffolded' process. Fourthly, the methods and strategies that the teachers use are not worked with in isolation. The methods are interrelated according to the purpose for which they are intended as the teachers work with the different types and forms of mathematical knowledge, and as they use formative assessment to support the diagnosis of learning needs and improve instruction. Fifthly, while the teachers use particular methods in their teaching practice in varying frequencies, this is not an indication of some teachers being more inclined to use one method over another. The number of times that the method or strategy is used in the teachers' classroom practice is also determined by the purpose to which it is related in the 'scaffolded' cycle of diagnosing the difficulties the learners are experiencing in Number.

Lastly, the views that the teachers have on learning and how the subject is taught are demonstrated in the role/s that the teachers take as they proceed through the phases of the 'scaffolded' process of working with formative assessment diagnostically, in the methods and strategies that the teachers use and in the types and forms of mathematical knowledge with which they work.

Based on the findings of this study, the central claim that this research makes, is that using formative assessment diagnostically involves a planned, 'scaffolded' process in which teachers carefully select ways of responding to learners and collect information about learners' mathematical understanding of the work done, which they then use to inform their decisions on teaching methods and strategies. These teaching methods and strategies include the recruiting of specific mathematical knowledge based on the diagnosis made in the formative process.

*Limitation and implications of the Research*

As mentioned in the introduction to this chapter, the current study is a small scale case study. The findings cannot be used to draw generalisations. However, based on the evidence, it highlights that using formative assessment diagnostically in the Numeracy Learning Programme is part of a carefully planned, 'scaffolded' cycle of events and needs to be considered in the instructional practice of the classroom. It provides a platform for further investigation and research to be done that not only looks at the 'scaffolded' cycle of events on a larger scale across various contexts, but investigates it in relation to various subjects. The formative assessment task was also administered to a small group of learners and a larger group may yield very different results.

While I am aware that in formative assessment practice the role of the learner is an important consideration, this study particularly focuses on the role of the teacher in the 'scaffolded' process of using formative assessment diagnostically in Numeracy. Further research might be done that more specifically looks at the role that the learner takes in this process. A comparative study might also be done on how the process of working diagnostically with formative assessment in Numeracy works with 'strong' learners.

*Reflection of growth and implication for the profession*

At the outset of the study, I was interested in the investigation based on my personal belief that while Foundation Phase teachers talk about formative assessment and working with it, it is not being used diagnostically, particularly in the Numeracy Learning Programme. A central claim that I found in the review of literature is that in order to diagnose the difficulties that learners' are experiencing in mathematics, understanding the quality of learners' thinking is important. The quality of learners' thinking is spoken about, in the literature, in relation to teachers' understanding the underlying process of learners' mathematical understanding. The findings of the study are consistent with this claim.

However, as I participated in the phases of the research and reflected, I realised that understanding the process of learners' thinking when working with formative assessment diagnostically was perhaps part of a more intricate process than what is described in the literature. It was more than giving out a task and seeing where the learners went wrong, but rather working with formative assessment diagnostically involved careful planning by the teachers that unfolded in a 'scaffolded' cycle of events. I realised that the word "process" had a far deeper meaning in the context of the study than I initially thought. In order for the teachers to understand the *"process"* of learners' mathematical thinking, they worked using a particular type of "*process,"* (re phases), in which they made decisions for their teaching practice as they worked diagnostically with formative assessment.

While the idea of 'feedback' was a familiar notion to me as part of formative assessment practices, I found this notion particularly helpful for the way that I am now thinking about using formative assessment diagnostically in Numeracy in the Foundation Phase. Not only is the feedback/information that the teacher gets from the formative task important for diagnosing the difficulties that the learners are experiencing, but the feedback/information that the teacher gains throughout the interactions in the 'scaffolded' process is equally important to understanding the learners' learning, and to improving the teachers' teaching, in diagnostic practices of formative assessment.

Based on the discussion above, there is a depth and level of expertise and knowledge that is required by the teacher, if working with formative assessment diagnostically is to be implemented successfully at the level of Foundation Phase schooling. It not only requires teachers who have a particular view on the subject (Numeracy),and the way in which it is taught, but it also requires teachers who have a deep understanding of assessment practice in the Foundation Phase. This is where I believe the challenge remains, namely ensuring that South African Foundation Phase teachers have not only been trained in, but are able to implement practically, the depth of thinking and assessment practice that is required.

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# Appendix A (Teacher A)

## Introduction

The Appendices (A, B and C) are aimed at presenting an account of the teachers' views, reflections and teaching practice in relation to their understanding of diagnostic assessment (with a specific focus on Number in the Numeracy Programme in the Foundation Phase). In an attempt to achieve this aim and capture what I would like to describe as the story of each teacher, a 'portrait' of each of the three teachers who participated in the study will be created. At this stage, key to the creation of these portraits is not to analyse the data, its consistencies or inconsistencies (this will be done in the Chapters Four and Five), but rather to try and represent the 'voice' of each of the teachers as they proceed through the four phases of the research process. The 'portrait' of each teacher will attempt to capture the teacher's understanding, shifts in understanding, her belief versus practice and more broadly, her struggles and the ambiguities she experiences when using formative assessment tasks diagnostically. In so doing, it will provide an insight into the process that is involved in transforming diagnostic assessment, using formative assessment tasks, into a new and improved teaching and learning experience.

The four phases of the research process will be used as the framing to structure the 'portrait' of each teacher.

### Teacher A

Teacher A is in her second year of teaching and is teaching at a government school in the East of Johannesburg.

## Appendix A i, Phase 1: Interview with Teacher A prior to the administration of the assessment task

1.1. *Teacher A's understanding of assessment, its different forms and its role in diagnosing learning*

1. Teacher A, at the outset of the interview, describes her understanding of assessment and different forms of assessment by very consciously dividing it into two main categories, i.e. formal and informal assessment. This is captured when she says:

> I use both formal and informal [assessment], so a lot of observation, well, recording but it doesn't always have to be a permanent record, so if I give a question and then you see them using apparatus and then recording their whole mental…what is the word?
> Interviewer: Thinking?
> Teacher A: Ya…

She goes on to explain what she sees as the purpose of these two forms of assessment:

> [Formal assessment] probably more towards like a summative task…but like the purpose of informal is so that it's a more ongoing thing, because you can't just assess the written work…
> Interviewer: …when you talk about ongoing, Teacher A, what do you mean?
> Teacher A: Like through my observations and things like that, you have to…watch them. It's not just about seeing what they've written. You have to watch and see how they put things together…

2. In the context of the school, however, she explains the dilemma with which she is faced. Teacher A explains that it is challenging when she is given an assessment task that has been structured as a reporting mechanism, and is of a summative nature, when in order to assess accurately, understanding what process the children have undertaken is important. This is the example that she provides when illustrating her point:

> …a lot of the time they'll say, ok, we're going to do bonds of 10 in our block books, write it up on the board, the children must do it. So it doesn't show the process, it just shows you the answer, which I don't agree with. I like seeing the process and that's why I do a lot of informal, like on white boards, watching them put the blocks, unifix cubes together…

3. Teacher A is then asked to elaborate on her understanding of formative assessment. She begins by saying that it is about "the little tasks…leading up to the bigger task." She elaborates and says that formative assessment is a tool for getting learners to try out first by constructing what they understand the task to be. This constructed knowledge is then assessed in a summative assessment task. This is captured in the following explanation:

> So, not just telling them something and then they must do it. It's about them constructing their own knowledge through the formative and then seeing whether they have finally constructed that knowledge and understanding through the summative.

Added to this, Teacher A says that formative assessment tasks provide the teacher with the opportunity to assess children's capabilities and difficulties. Once the formative assessment has been completed, the teacher is given the opportunity to compare the learners' development of knowledge construction, between the formative and summative stages of assessment.

1.2. *Teacher A's views on what guides her selection and design of a formative assessment task.*

1. When asked to describe what guides her selection and design of a formative assessment task as part of the Numeracy Learning Programme, Teacher A begins by describing the process as one which involves the Grade's teachers getting together and finding in the teaching preparation the topic/content that is being covered. Then based on the topic/content, Assessment Standards from the National Curriculum Statement (NCS) are chosen. Finally against these Assessment Standards, specific criteria will be chosen. Teacher A says:

> [We] see what it is that we are assessing…and then come up with some kind of criteria based on the Assessment [Standards]…so like all these things: can use concrete apparatus, can speak about their answers…so you're just finding a guideline according to the Assessment Standards.

2. However, she does highlight a challenge with which South African teachers are currently grappling in aligning formative assessment tasks to criteria. She describes this as being related to what is referred to as the Numeracy 'milestones'[1] in the Foundation Phase. Teacher A notes that each unit, as outlined in the milestones document, covers a variety of content across topics in mathematics, and that selecting the assessment criteria that are the most important for the unit and for the formative assessment task becomes increasingly difficult. This is captured in the following statement made by Teacher A:

> So there's so much that we're supposed to be following within one unit, that it is very, very difficult because you try to think which are the more like [important] assessment criteria…

What is expected by the intended curriculum creates a challenge for what can be realistically achieved in the classroom.

3. When Teacher A reflects on what specifically guided and influenced her designing of the formative assessment task that is to be administered for the project, there are three main areas that she emphasises repeatedly. Firstly, she mentions that she planned the criteria that she will use for framing the assessment task. Secondly, she considered how, through the activities in the task, she will get the learners to show their understanding, and finally she says that in order for the assessment task to allow for the construction of knowledge, "[the learners] have to have some kind of previous knowledge to build upon… [you need to make] sure you take into consideration their prior knowledge." Teacher A, therefore, feels that if the learners are going to construct knowledge through the assessment task, the learners' prior knowledge needs to be considered.

[1] Plots the sequence of mathematical learning for the various mathematical content in the Foundation Phase and was gazetted by the government in March 2008 (gazette number 30880).

4. When asked to comment on how she ensures the validity of the formative assessment task, Teacher A responded by associating the validity of the task to matching the activities in the assessment task to the Assessment Standards in the NCS. However, she says that although she matches her task to the Assessment Standards, she feels quite uncertain and is not always sure about how to interpret the Assessment Standards in the document and match it accordingly. She finds herself questioning whether she is assessing the intention of the Assessment Standard/s, and whether the specific criteria that in turn are set for the task are appropriately matched. She explains:

> Like if you're doing…if you're planning, we'll say right, we're doing…let's say the building up and breaking down of numbers. And then I'll sit there and think what is that? What do you actually mean? What Assessment Standards or criteria do you want?…so you don't know, well am I assessing the right thing, what I want the outcome of the lesson to really be?

5. She highlights, however, that although ensuring validity by matching the Assessment Standards to the formative assessment task is often challenging in the interpretation of the NCS, she sees it as crucial. Therefore, much time is spent on the interpretation of the Assessment Standards, and on deciding on the specific criteria that will be assessed in the task in an effort to achieve the Assessment Standard/s. Teacher A gives the following example in an effort to explain how she goes from the Assessment Standard to deciding upon specific criteria that will be assessed in the task:

> Can perform calculations using appropriate symbols to solve problems… [Assessment Standard]
> If we do word problems, then they have to be able to know whether it's addition or subtraction or multiplication, so you want to know if they can use those symbols correctly, because sometimes if you say, two cars, how many wheels? They'll say 2 + 4 instead of 2 x 4…So from the Assessment Standard I have just given you, then you can come up with more definitive criteria…

### *1.3. The mental processes with which Teacher A thinks learners need to engage, in order to have a sound sense of Number.*

Teacher A describes the mental processes that she views as important for learners in developing a sound number sense as the following:

1. Understanding (laughs) numbers, so seeing it in its concrete form…and having that idea and then moving towards a more abstract understanding. That's one, you don't have to see one to know it's one, kind of thing, and when they count, knowing… number patterns. If you're counting in 1s that you're adding one each time. If you're counting backwards in 2s, you're taking away two each time. Moving…that concrete understanding is very important for me.

What is important to Teacher A in encouraging this progression from the concrete to the abstract understanding of number is that the teaching and learning experience is not restricted to the physical only, but that learners have the opportunity to participate in what she refers to as "mental maths," i.e. working with number and number relations more abstractly. However, Teacher A reiterates her view that progression in the teaching of Number should initially lead from the physical "that helps [the learners] to construct the knowledge" to the abstract.

2. In order for the teacher to gain an insight into the development of the learners' mental processes related to number, Teacher A holds the view that the teacher has to provide an opportunity for the learners to verbalise their understanding. In so doing, the teacher is provided with valuable insight into the quality of the learners' number understanding that otherwise might be lost. The insight and information gained can in turn be used to inform following lessons. She says:

> The talk part of the Do-Talk-Record model[2] is so important because they are verbalising their understanding of what they have just done. So if you say to them, how did you get to that answer? And they say, well I drew pictures or whatever, and then counted the pictures […] then you have an understanding of what has happened inside their brain. Then in the next lesson, you can draw on that what they've told you and maybe…ya…everything is like an indication of their understanding. What they do, how they verbalise it.

Teacher A, therefore, has the opinion that in order for learners to construct knowledge of number, they need to engage in two important processes. Namely, the learners need to work concretely with number and they need to be given the opportunity to verbalise their thinking and understanding.

1.4. *The purpose of the designed task, and what Teacher A expects to be elicited by the task about learner difficulties in Number.*

1. When asked to respond to what she sees as the purpose of the designed task and what she expects will be elicited about learner difficulties in Number, Teacher A firstly explains that the formative assessment task to be administered will be given in the form of word problems. Based on the process that the learners use to solve the problems, the teacher will be able to identify learner difficulties with number. For example, Teacher A explains that one of the aspects at which she is looking is the way in which the learners work with or without concrete apparatus in the solution of the word problems.

> …a problem will be given to the group and then they have to solve the problem, I will look at how they use their concrete apparatus, whether they even use their concrete apparatus.

[2] The Do-Talk-Record model is a model that was developed by Nick James (1993), where learners first physically solve a mathematical problem using concrete apparatus, then they verbalise their solutions and finally they record a number sentence/algorithm for their solution.

Teacher A believes that observing their reliance or non-reliance on concrete apparatus may be very telling about their understanding of number and where they are at in the process of moving from the concrete to more abstract understanding of number. Teacher A explains this by saying that the learner who is not heavily reliant on concrete apparatus may be displaying a more abstract understanding of Number. However, there may also be a learner who does not use concrete apparatus but who should, because their physical understanding of number has not been sufficiently developed. Teacher A says, "Sometimes, you see those children who have misconceptions about something because they haven't been using the apparatus."

2. In the solution of the problems, Teacher A will also be looking at the way in which the numerical symbols of the four operations are used. That is, are the learners able to select the right symbol for the word problem that they are solving? (Appendix A i, 1.2, paragraph 5, p.4).

3. Finally, Teacher A explains that she is hoping that the task will elicit the learners' ability to count (at this level whether they are counting 'all' or 'on,' i.e. whether learners recount all numbers or are able to count on from a given number). She explains that this will give her an understanding of the learners' number sense. This example is given by Teacher A:

> If you say to them ten plus two […] and they first put across ten, then they put another two across to get twelve but then they have to recount all of the apparatus they have, you can pick up […] they count all of it. [If they] already have ten in their head and then they can count on 11, 12, with that extra 2, instead of counting all of them again, so you can pick up their counting ability.

If the learners 'count all,' Teacher A says that this could be an indication that the learners are "still very reliant on the concrete," but if they can store 10 and 'count on,' this will indicate that they are starting to develop a more abstract understanding of number.

4. In this first interview with Teacher A, she proposes that formative assessment consists of tasks that result in a summative assessment. She discusses the idea of observing what the learners are doing as important, in what she refers to as the "informal" (formative) assessment process. Teacher A notes the difficulties that she experiences when trying to align the Assessment Standards with the criteria that she has chosen for the formative assessment task. When reflecting on learner difficulties, Teacher A highlights the learners' ability to work with concrete apparatus and verbalise their strategies as important in gaining an insight into their understanding of number. In the formative assessment task that Teacher A will be conducting, the criteria that she has selected to look at are: the learners' counting levels, their ability to verbalise their solutions and the manner in which they record the number sentence, i.e. their understanding of the operation symbols.

**Appendix A ii, Phase Two: Coding of pedagogical moves used by Teacher A in the administration of the assessment task**

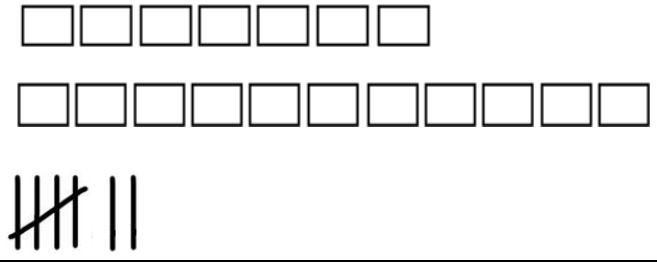
The following coding was used:

| Coding (pedagogical moves) | Abbreviation |
|---|---|
| Previously Taught Mathematical Knowledge | PTMK |
| New Mathematical Knowledge | NMK |
| Everyday Knowledge | ED |
| Embedded Mathematical Knowledge | EMBD |
| Socialisation | SOC |
| Verbal Demonstration | VERB DEM |
| Visual Demonstration | VIS DEM |
| Evaluation | EVAL |
| Validation | VAL |
| Instruction Explicit | INSTEXP |
| Instruction Implicit | INSTIMP |
| Explicit explanations | EXP |
| Criteria Explicit | CRITEXP |
| Criteria Implicit | CRITIMP |
| Concrete Apparatus | CA |
| Probing | PROB |
| Probing Questions and Active Interpretation | PROBQAIN |

*Setting*: Teacher A with her class of twenty nine learners. Seven of her weaker mathematical learners are on the mat, at the front of the classroom. She administers the formative assessment task to these learners, while the rest of the class are independently completing a written task.

*Focus*: Formative assessment task – Word Problems (Addition)

| | Pedagogical moves | Categorisation |
|---|---|---|
| 1. | Teacher A tells the group on the mat that they are going to do a word problem [INSTIMP]. She begins by setting a context. She tells them that they are going shopping at Woolworths to buy some items [ED]. | INSTIMP; ED: Teacher A tells the learners that they are going to solve a word problem. She does not give specific instructions on how the problem will be solved. The teacher uses an everyday context for the setting of the word problem. |

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| 2. | Teacher A states the first word problem as follows: "We buy 7 apples and then we buy 11 *more* apples, how many apples do we have altogether?" [EMBD; SOC]. | EMBD; SOC: Mathematical construct of addition is embedded in an everyday context. The learners are socialised into the mathematical language associated with addition in the phrasing of the word problem, i.e. "more." |
| 3. | Teacher A instructs the learners to show how they are going to solve the word problem using the concrete apparatus given (the learners are given unifix cubes). She then asks the learners to draw a 'picture' on the paper given and to show how they reached the solution. The teacher also instructs the learners to give a number sentence showing their answer on the piece of paper [CA; INSTEXP]. | CA; INSTEXP: The learners are given concrete apparatus to demonstrate their method and solution visually when solving the word problem. Explicit instructions are given on how the task needs to be completed. |
| 4. | Teacher A observes the manner in which the children work with the concrete apparatus and how they represent this in 2D [CA; EVAL]. (She has an assessment rubric with her [CRITIMP] and notes her observations as the learners work with the concrete apparatus and translate their method and answer to 2D, and finally to a number sentence).<br><br>All the learners set their concrete apparatus out in 1s, i.e. 7 unifix blocks in a straight line and then 11 unifix blocks in a straight line. When representing their method in 2D, six out of the seven learners draw 7 rectangles and then 11 rectangles and write 7 + 11 = 18 as the answer. One learner draws tally marks to represent the blocks and also writes 7 + 11 = 18 as the answer [PTMK].<br><br> | CA; EVAL: CRITIMP; PTMK: The learners need to use concrete apparatus to represent their solution. They need to apply previously taught maths knowledge, i.e. counting, value of a number, understanding number symbols and writing number sentences in solving the problem. Teacher A evaluates the learners' understanding as she observes their methods and solutions. She uses the criteria listed on her assessment rubric to guide her observations. The criteria are not explicitly explained to the learners. |

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| |  | |
| 5. | Once the learners have completed their 2D representation and number sentence to the word problem, Teacher A asks the seven learners to verbalise the strategies that they used to reach the answer [VERB DEM].<br>Teacher A asks questions such as, "What did you do?" "Tell me how you did this?" "Why did you do it this way?" [PROBQAIN; EVAL].<br>Teacher A encourages the learners to describe explicitly the strategy that they used to solve the word problem. This includes a description of how the concrete apparatus was used and a description of the 2D representation. For example:<br>Teacher A: "How did you draw that?" [PROBQAIN; EVAL].<br>Neha: "I drawed 7 rectangles in a line and 11 rectangles in a line and I counted them all and got 18."<br><br>Six out of the seven learners verbalise that in solving the problem they put out 7 blocks (counting in 1s), they then put out 11 blocks (counting in 1s) and finally counted that there were 18 blocks altogether (counting in 1s). These six learners 'counted all' the blocks (i.e. they went back and counted 1,2,3… →). They did not 'count on' or group the blocks in 2s, 5s, etc. (i.e. 7...→8, 9, 10, 11 or 2, 4, 6 →). Four out of the seven learners then represented this in the 2D form by drawing 7 rectangles and 11 rectangles, and by counting in 1s they reached the answer of 18. Two out of the seven learners could not translate the concrete to 2D representation.<br>One learner, Nondu, verbalises that she packed out the concrete apparatus in 1s but when she | VERB DEM; PROBQAIN (4); EVAL(4):<br>The learners verbalise the strategies that they used to solve the problems. The teacher asks probing questions to evaluate the learners' thinking. The learners are encouraged to interpret actively what they have done as they describe their strategies and representations to the teacher. |

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| | counted the apparatus, she counted in 5s.<br>Nondu explains it as follows: "I put my blocks in two lines."<br>Teacher A: "You mean 7 in one line and 11 in the other?" [PROBQAIN; EVAL].<br>Nondu: Yes. Then I counted 5…10 and the 3 left over.<br>Teacher A: "Ok, then how did you draw it?" [PROBQAIN; EVAL].<br>Nondu: "I made lines and counted in 5s and then counted the 3 left over."<br>*Nondu uses tally marks to represent her strategy*.<br> | |
| 6. | Teacher A asks the learners to verbalise their strategies [VERB DEM]. She encourages them to use the correct mathematical language.<br>For example, when Ash responds by saying, "I took the 7 apples and I put it together with the 11 apples," Teacher A responds and says, "So you *added* the 7 apples to the 11 apples?" [PROBQAIN; SOC].<br>Another learner, Daniel, says, "I put the bigger number with the smaller number and counted all of it."<br>Teacher A responds and says, "What is another word for 'put'?" "Can we say you *plussed*? A*dded*?" [PROBQAIN; SOC] | VERB DEM; PROBQAIN (2); SOC (2): Teacher A asks learners to verbalise their solutions. The learners are probed to interpret actively and use the mathematical language associated with addition as they verbalise their strategies. In so doing, the learners are explicitly socialised into the use of the mathematical language. |
| 7. | Teacher A validates the learners' responses as they verbalise their strategies. She makes comments such as, "Well done!" "Good!" "Listen again…now try." [VAL; EVAL]. | VAL; EVAL: Teacher A validates and evaluates the learners' responses. |
| 8. | As Teacher A asks the learners to verbalise their strategies [VERB DEM], she encourages them to reflect on and interpret their thinking and construction of the answer. Teacher A makes statements to the learners such as, | VERB DEM; PROBQAIN (3); EVAL (3); CRITIMP: The teacher asks the learners to verbalise their solutions. She uses probing questions to get the learners to think about the strategies they have |

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| | "Could you have done it differently?" "Do you think there might have been a quicker way? Why?" [PROBQAIN; EVAL]. As the learners verbalise their methods, the various strategies are assessed by Teacher A and the learners' understanding and difficulties are noted on the assessment rubric. [CRITIMP]. (Refer to Appendix A ii (R), p.28). For example, Teacher A says to one of the learners, "How did you count your blocks?" [PROBQAIN; EVAL]<br>Thando: "I counted them all."<br>Teacher A: "Is there a quicker way you could have counted?" [PROBQAIN; EVAL].<br>Thando: "I counted them all."<br>Teacher A notes on her assessment rubric that this particular learner is at the counting stage of 'counting all.' | chosen to solve the word problem. The learners need to interpret the strategies that they have chosen, actively. As the learners verbalise their strategies, the teacher evaluates the learners' understanding and thinking. Teacher A uses the criteria listed on her assessment rubric to guide her evaluation. |
| 9. | Following the verbalisation of strategies Teacher A discusses with the learners the number sentence that could be used to represent the solution, i.e. 7 + 11 = 18 [PTMK] or 11 + 7 = 18. [NMK].<br>Teacher A: "How can we write what we have done?" [PROBQAIN].<br>Neha: "We can write 7 + 11 = 18."<br>Teacher A: "Can we write it differently?" [PROBQAIN].<br>Learners: (no response)<br>Teacher A: "We can also write it as 11 + 7 = 18." [EXP; VIS DEM]. (Teacher A writes this up on a white board).<br>Teacher A: "Check to see if I am right by counting using your blocks." [CA]. | PTMK; PROBQAIN (2); NMK; EXP; VIS DEM; CA: The learners use previous maths knowledge on number symbols to write out the number sentence. They have not been introduced to the commutative property of addition, which is new maths knowledge. Teacher A probes the learners to think actively about a different way that the number sentence can be written. When the learners are unable to respond, the teacher explains and visually demonstrates the alternative. By using concrete apparatus, the teacher gets the learners to verify whether she is correct. |
| 10. | Teacher A revisits the learners' understanding of the (+) symbol. She explains, "Instead of writing '7 *plus* 11' or '7 *and* 11' to show what we did to get to the answer, a symbol (+) *(she writes this up on the white board)* [VIS DEM] is used to show that we are plussing or adding the | VIS DEM; EXP; SOC: Teacher A visually demonstrates, and explicitly explains and socialises the learners into the mathematical symbol used for plus/addition, i.e. (+). |

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| | numbers together." [EXP; SOC]. | |
| 11. | Once the discussion of the first word problem is complete, Teacher A follows the same pedagogical moves with two more word problems and concludes the lesson. | |
| 12. | At the end of the task, Teacher A takes in the papers that the learners are working on. This, together with her observation and discussion with the learners, is collated as the formative assessment task. She records and finalises the information on an assessment rubric. (See Appendix A ii (R), p.28). This rubric is not returned to the learners once the task has been finalised. [CRITIMP]. | CRITIMP: The learners do not see criteria used in the formative assessment rubric. |

*Summary*

In the administration of the task, there is evidence of the model that Teacher A speaks about in her first interview, The Do-Talk-Record Model. The learners have to solve the word problem using concrete apparatus, transfer their solution to a 2D form, talk about their strategies and finally they have to record a number sentence. The manner in which Teacher A administers the task also allows for the construction of knowledge which Teacher A highlights in her first interview as important as part of a formative assessment process. Evidence of this is to be found in the pedagogical moves that the teacher makes. Through the evaluation, probing, verbal demonstration and socialisation, the teacher is using her pedagogical moves as a strategy to identify learner difficulties. The learners are given an opportunity to think through the mathematical context of the question, the procedure they follow to get to the answer and the mathematical language they need to acquire.

Overall, there seems to be a strong correlation between what Teacher A discusses in the first interview and in the administration of the task.

**Appendix A iii, Phase Three: Follow-up interview with Teacher A after the administration of assessment task, where the diagnosis of learning is discussed**

3.1. *Teacher A's views on formative assessment and the diagnosis of learning*

1. In the opening of the post-interview, Teacher A is asked to reflect on what she sees the process of formative assessment consisting of now that she has administered the task and has made her assessment of learner difficulties in Number.

   Similarly to Interview One, Teacher A says that in the planning of formative assessment tasks in Numeracy, careful thought needs to be given to how the assessment criteria chosen by the teacher relates, in the designing of the task, to the Assessment Standards in the curriculum. Teacher A reflects and says that the selection or "narrowing down" of the criteria, together with observing the "children's behaviour," needs to be aligned to "see whether the children are achieving what you hoped according to your criteria." She highlights that the information gathered about the learners' learning, from the task, will be used in the designing of the follow-up lessons. In the follow-up lessons, the teacher is helping the learners to "gather more knowledge, based on previous knowledge, or you are helping them go back a step…" Teacher A has high expectations for her learners. She believes that this kind of pedagogical work "will help them reach their full potential."

2. Following the discussion on what Teacher A views the process of formative assessment consisting of, she is asked to comment on her understanding of the diagnosis of learning. Teacher A views the diagnosis of learning as "using formative assessments and gathering information…" The diagnosis of learning is, therefore, embedded in formative assessment tasks. She continues and says that "based on the behaviour and information that they [the learners] give you, follow-up lessons can be planned." In these follow-up lessons the information gathered in the diagnosis of learning in some way needs to be used productively in the teaching and learning experience to "help them [the learners] develop their number sense […]" or to "help them move forward." The diagnosis of learning is, therefore, a means to "expand on the learners' previous knowledge and to expand on the process."

3. Teacher A elaborates on the notion of diagnostic assessment by describing what she perceives to be the teacher's role and the learner's role, now having completed the first three phases of the research project. When describing the role of the teacher, Teacher A says that "initially, it is to make sure that you have criteria in place…then in administering the lesson you have to be very careful to guide them in an appropriate manner so…that they're not just sitting there." She argues that the teacher's questioning and the process that is used in eliciting the learners' responses in the formative assessment task is very important if the diagnosis of learning is to occur to its optimum. This is captured when she says, "…based on your questioning and the process, the entire process, [there needs to be] a two way interaction using, like language, correct terminology, showing the learners' understanding, not just

giving you an answer." The learners, therefore, need to have an opportunity to explain their thinking or demonstrate their understanding in some way through a carefully selected process. She adds to this and says that the teacher needs to be able to "look deeply" into his or her criteria and "have something to align" to what the learners are doing. The teacher, therefore, needs to be clear about what he/she is assessing (the criteria), and this must be aligned to what the learners do or say.

4. The idea of designing the formative assessment task to elicit explicit evidence of learners' learning, as part of diagnostic assessment, comes up in the thinking of Teacher A. The following example is given by Teacher A:

> Well, for example, if you use counting [as a criterion], you could narrow that counting down to counting in 1s or counting all or counting in 2s, or grouping them in 10 […]. You can pick up immediately who will put say, the 10s together, and then be able to count 10, 20, 30, if it's 3 groups of 10. But some will put those 3 groups of 10 together but still count all…So it immediately shows you their behaviour and their understanding and ya, that's diagnostic learning…

5. In the concluding part of this segment of the interview Teacher A is asked to comment on what she sees as the relationship, if any, between assessment in general and diagnostic assessment. She responds by saying:

> Well, I don't think they can work without one another, they work hand in hand. Because your assessment, so assessment in general, leads up to the summative assessment… and your diagnostic assessments, because the diagnostic learning is the process that's leading up to them (the learners) reaching an outcome. [Diagnostic assessment] is showing you all their (the learners) previous knowledge and how they build on that previous knowledge or assimilate or accommodate all the knowledge leading up to your general assessments, to a more summative task.

Therefore, Teacher A's belief is that the two assessments are linked in the sense that diagnostic assessments are part of "the process" that culminates in the learners "reaching an outcome." It is her view that diagnostic assessment "is the formative, the process." She explains that this process should not be made up of isolated formative assessment tasks, but rather that the tasks need to be a "…series of tasks integrating previous knowledge with new knowledge…" This needs to be done as part of a process leading towards the summative assessment. However, Teacher A admits that this is a conclusion that she has drawn as a result of her participation in the phases of the project. A more common practice in teaching is to treat formative assessment tasks as isolated tasks. She says this:

> I am guilty when I say that I have…taught lessons where I just, my mind has been on the final assessment and not on building the children up…I wish sometimes we could prep in advance so that we would know exactly all the little tasks and how we can manipulate those

tasks to help the children because they all have different needs, they never learn the same…"

3.2. *Information that Teacher A gained through the diagnostic assessment on learner difficulties in Number and how the diagnosis will be used to improve the teaching and learning experience of Number*

1. In discussing the information that Teacher A gained about the learners' difficulties in Number through diagnosis of the formative assessment task given, Teacher A starts by outlining the specific criteria that she looked for. Counting, the use of concrete apparatus and the representation of this pictorially, as well as the learners' verbalisation of their solutions and use of mathematical terminology, were the most important criteria. Teacher A notes that she had to define the criteria further when thinking about how exactly she would diagnose the learning:

> My criteria was counting, and then I narrowed that down to counting in 10s, counting in 1s…then what I did is that…if they were counting in 1s, then I'd tick counting in 1s and then I'd write a little comment…

2. Based on the criteria set, Teacher A makes the following diagnostic assessment about her learners' difficulties with Number. With regard to counting, Teacher A says:

> I would say five or six out of the seven children could not…they had to count all, they counted everything. So if there were 30 unifix cubes or 30 blocks on their picture, they would count from one to thirty. Even though in like discussions beforehand we would say there are 3 groups of 10. So they weren't quite understanding that a group of 10 you can count ten…

In terms of the learners' use of concrete apparatus and pictorial representation related to their understanding of Number, Teacher A notes:

> Two of them (learners) were very reliant on concrete apparatus and couldn't even get…what they had in front of them into pictorial form. So that shows me that they are very much on the concrete side, and aren't quite moving in the direction I would like them to, so I will have to help them do that in the future. …

Teacher A, when asked to elaborate on what she means by "the direction…," explains it as encouraging the learners to "stop being so reliant on the concrete moving more towards the abstract side" of understanding of number.

Teacher A continues by saying that there is, however, one learner in the group who is able to record her solution using tally marks, and groups these markings in either 5s or 10s, depending upon the number range.

> Another one […] is using tally marks and is grouping her pictures actually when she draws into 10s. When she was subtracting, she subtracted in 10s, and then in 1s like if it was 40 takes away 16, she took away… the ten and then the six, instead of counting them all.

3. In relation to the learners' verbalisation of solutions, Teacher A felt that "some children really experienced difficulty using their knowledge and the terminology and everything to explain their thinking." When asked why verbalisation of the solution is so important in diagnosing learners' difficulties, Teacher A felt that this is an important aspect in the concept development of number "because [it is a part of] the process of constructing knowledge and conceptualising a concept. …without that language, there's kind of no…reflection on their understanding." By the learners reflecting upon their understanding through verbalisation, the teacher is able to "tell what's going on in their (the learners) head."

4. Finally, Teacher A notes that although she did not specifically outline the learners' ability to use prior knowledge of number as a criteria, she was able to tell from the use of concrete apparatus and the pictorial representation those learners who were, for example, able to "use their understanding of, like, 2 and 8 to make 10, so that 18 and 2 could make 20." She felt that this now gave her an indication on how to further develop these learners.

5. Although Teacher A states in the first interview that a criterion is to look at the way in which the learners use the numerical symbols of the four operations, this was not, in the post-interview, named as an explicit criterion when discussing the actual criteria that she used when diagnosing learner difficulties.

6. When asked to comment on whether the designed formative assessment task elicited what she wanted it to elicit, Teacher A says:

> It did…you know I don't actually really know what I was expecting (laughs). It did give me a lot of information about the children. So thank goodness for that narrowed down criteria, because then you are able to look out for more things instead of just being based on one sort of thing.

At this point, Teacher A admits that she found it extremely challenging to be explicit enough with the criteria that she chose to assess the learners' understanding of number for the particular formative assessment task. She was not sure that her criteria would be accurate or rather, specific enough. This

is captured when she says, “It was very difficult for me in actually designing the task and in…align[ing] the criteria because I wasn’t even sure if what I put down in the criteria was accurate.”
For example, Teacher A says:

> I said (on the assessment rubric) ‘*Use of physical apparatus’* – uses with understanding or uses without understanding. And I wasn’t quite sure how to see whether they understand or they use it with understanding or not. Like what things show you, so I needed to like refine that a little better for myself…when they were doing it, I was thinking, actually I don’t know, are they just putting them together (unifix blocks) or must I ask them to verbalise more as they can explain?

Teacher A thought that she might have thought a little more carefully about this particular criterion and what exactly would show her the learners’ understanding of working with concrete apparatus.

7. In the final segment of this part of the interview, Teacher A is asked to elaborate on what she intends to do to improve the teaching and learning experience, now that she has elicited this information on her learners’ difficulties with Number. She responds by saying the following:

> I don’t think it’s possible to address everything in one session. I think that it’s a series of lessons that I’ll have to do…the thing that stands out for me the most is the counting, I really want to get them to start counting in groups, you know, to make their number concept better.

Teacher A explains that verbalisation of solutions will “come into play” and will, therefore, be incorporated naturally into the follow up lesson, as this is her approach to all Numeracy lessons. However, for the follow up lesson, “counting is going to be the explicit part,” i.e. getting the learners to group when counting, for example, in 2s, 5s, 10s, depending on the number range.

### 3.3. *What the cycle of activities that were included in the research process helped Teacher A to understand about formative assessment in the Numeracy Programme*

1. In response to what the cycle of activities helped Teacher A to understand about formative assessment, she firstly notes that it helped her to understand that you have to align your formative assessment with your diagnostic assessment. You furthermore need to match this to your “Outcomes and Assessment Standards and then narrow that down so that you’re really getting a true, true, reflection of your children, that you completely understand what they are giving you.” Teacher A states that the cycle of activities reinforced her belief that it’s “not just an answer, that they’re speaking (the learners), that you are guiding them, that there’s interaction taking place between the teacher and the learner, that you are not telling them what to do, that they are giving you the information just with your guidelines.” The learners are, therefore, given an opportunity to speak and there needs to be an

opportunity for interaction between the teacher and learners even in an assessment task. Importantly, Teacher A explains that:

> …you cannot base any results on one set of circumstances. There has to be a process where you're giving them opportunities and expanding on their opportunities and using their previous knowledge and just going beyond what…you know, kind of going beyond their abilities in a way because you want them to reach their full potential…and then using what you found out about them to help them in follow up lessons like for future lesson, scaffolding, structuring things according to their abilities…

*Summary*

In Phase Three, Teacher A places much emphasis on the alignment of criteria with the formative assessment task and what is expected to be elicited from the task. Furthermore, she discusses the notion of assessment in general and diagnosis of learning, and explains that in her opinion, the two cannot be treated as separate entities. Based on what is elicited about learner difficulties with regard to Number from the designed formative assessment task, Teacher A notes that Counting, and specifically the learners' ability to group quantities when counting, will be the focus of her follow-up lesson. In this interview, Teacher A also emphasises the idea that the design of the formative assessment task, and the information that is gathered about the learners' learning, should be directed towards designing follow-up lessons that focus on developing the individual learner's full potential.

**Appendix A iv, Phase Four: Coding of pedagogical moves used by Teacher A in the follow-up lesson in response to the diagnosis made in Phase Three**

The following coding was used:

| Coding (pedagogical moves) | Abbreviation |
|---|---|
| Previously Taught Mathematical Knowledge | PTMK |
| New Mathematical Knowledge | NMK |
| Everyday Knowledge | ED |
| Embedded Mathematical Knowledge | EMBD |
| Socialisation | SOC |
| Verbal Demonstration | VERB DEM |
| Visual Demonstration | VIS DEM |
| Evaluation | EVAL |
| Validation | VAL |
| Instruction Explicit | INSTEXP |
| Instruction Implicit | INSTIMP |
| Explicit explanations | EXP |
| Criteria Explicit | CRITEXP |
| Criteria Implicit | CRITIMP |
| Concrete Apparatus | CA |
| Probing | PROB |
| Probing Questions and Active Interpretation | PROBQAIN |

*Setting:* Teacher A is on the mat, at the front of the classroom, with the same group of seven weaker mathematical learners who did the formative assessment task. The rest of the class are completing a written task independently.

*Focus:* Teacher A, based on her diagnosis, from the formative assessment task of the difficulties that learners are experiencing with Number, focuses the follow-up lesson on developing the skill of counting in groups (e.g. 10, 20, 30, 40, …) rather than counting in 1s (e.g. 1, 2, 3, 4, 5, …)

| | Pedagogical moves | Categorisation |
|---|---|---|
| 1. | Teacher A, with the group on the mat, begins her lesson by setting a context for the lesson. She begins and says, "…at Easter time what usually happens?" [ED]. | ED; CA: The teacher uses an everyday context as a setting for the problem that will be introduced. |

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| | Christina: "You can take some eggs and decorate it."<br>Teacher A: "Yes…so we are going on an Easter egg hunt today. So we are each going to get a basket." (Teacher A hands each learner a container, i.e. bottom part of a 2 litre plastic Coke bottle that has been cut in half). [CA]. | |
| 2. | Teacher A continues setting the context by saying, "On our Easter egg hunt each child goes and we find two eggs each. Put them into your basket, we don't want them to get lost." (Each learner gets two little wooden cubed blocks to place inside the container) [EMBD; CA].<br>Teacher A continues and asks the learners, "How many children are in the group?"<br>Together with Teacher A, the learners count that there are seven learners in the group [PTMK]. | EMBD; CA; PTMK: Mathematical construct of grouping is embedded in an everyday context. The learners are given concrete apparatus to work with. They use their previous maths knowledge of counting in 1s to count how many learners there are in the group. |
| 3. | Teacher A says, "Now I don't want to know how many there are yet, I want somebody to try and tell me what we can do to try and find out how many eggs there are?" [PROBQAIN]. | PROBQAIN: The teacher probes the learners' thinking by asking them to interpret actively and think about ways in which they can work out how many eggs there are in the group. |
| 4. | Al responds and says, "We can count in 2s."<br>Teacher A: "Why would you want to do that?" [PROBQAIN; NMK]<br>Al: "Because it is a quicker way."<br>Teacher A: "Oh, very good, did you hear that?" [VAL]. | PROBQAIN; NMK; VAL: Teacher A probes the learner to think actively about the counting strategy that he has chosen. In so doing, the idea of counting in groups, as a more efficient strategy, is introduced to the learners. This is new maths knowledge. The learner's response is validated with praise. |
| 5. | Teacher A continues and asks, "Do you have any other ideas on ways in which we can work out how many eggs there are altogether?" [PROBQAIN; NMK]<br>Christina responds by saying, "You can also count in 3s."<br>Teacher A: "And how would you do that?" [PROBQAIN; EVAL]. | PROBQAIN (2); EVAL; NMK: The teacher probes the learners to think actively of other counting strategies (besides counting in 2s) that can be used as a method to reach the solution. This is new maths knowledge, i.e. grouping when counting. She probes the learner to think actively about how her suggestion of counting in 3s can be |

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| | Christina: "You take the one partner's other Easter egg and you join it." | practically achieved. In so doing, she evaluates the learner's understanding of counting in groups. |
| 6. | Before Teacher A asks both learners, who have suggested the methods of counting, to demonstrate what they mean (counting in 2s or 3s), she gets the learners to discuss the mathematical language associated with the problem. She says the following: "Can somebody remind me what's…like if we're putting things together, what another word for that is? *Putting together?*" [PROBQAIN; PTMK; SOC].<br>Thando: "Adding."<br>Teacher A: "Adding. Any other words?" [PROBQAIN].<br>Daniel: "Plussing."<br>Teacher A elaborates on the vocabulary given by the learners and relates it to one of the counting methods suggested by the two learners. She explains carefully, "So actually what we're doing by counting in 2s and putting those 2s together is we're actually plussing two each time, aren't we?" [EXP; PROBQAIN; NMK].<br>Teacher A then asks the learners to count with her as she touches each 'basket' using Al's method, i.e. counting in 2s. [VERB DEM; VIS DEM].<br>All the learners count: "2, 4, 6, 8, 10, 12, 14." | PROBQAIN (3); PTMK; SOC; EXP; NMK; VERB DEM; VIS DEM: The learners are probed to think actively of mathematical language that is associated with addition. In so doing, they are explicitly socialised into the language. The learners draw on their previously taught maths knowledge on the mathematical language related to addition. Teacher A uses the mathematical language related to addition to explain explicitly that as the learners count in 2s, what they are actually doing is adding two each time. Through the explanation the learners are probed to interpret actively and recognise the relationship between counting in groups and addition. This is new maths knowledge. The teacher verbally and visually demonstrates counting in 2s. |
| 7. | At this point in the lesson Teacher A tells the learners to put their 'baskets' behind them and to leave only their 'Easter eggs' (wooden cubes) on their page. She asks the learners, "Can you think of a way to write a number sentence for what we just worked out?" [PROB; NMK]. "7 children and they each have 2 Easter eggs, how many do they have altogether?" [EMBD].<br>Teacher A explains carefully, "So let's write, | PROB; NMK (2); EMBD; EXP (2); INSTEXP (2); EVAL (2); SOC (2); PROBQAIN (3); VIS DEM: Teacher A asks a question that probes the learners to think about a way to record what they just did. This is new maths knowledge as learners have not recorded a number sentence in this way before. Mathematical construct of grouping is embedded in an everyday context. The |

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| | Neha, she had 2, so write that first 2 down, or you can draw it, it's up to you" [EXP; INSTEXP].<br>"And then you said by putting them together what are we actually doing, Daniel?" [PROBQAIN, EVAL; SOC].<br>Daniel: "Adding, plussing them."<br>Teacher A: "And what sign can we use to show that? What is that mathematical symbol, what does that sign look like?" [PROBQAIN; SOC].<br>Teacher A asks one of the learners to draw the symbol on the board. (+) [VIS DEM].<br>She asks the learners: "So how many groups of 2 were there actually?" [PROBQAIN; EVAL; NMK].<br>Nondu: "7"<br>Teacher A: "7, right. So let's do 7 twos. So its 2 + 2 + 2 + 2 +...because we're just showing what we actually did." [EXP, INSTEXP].<br>Six out of the seven learners record the number sentence as 2 + 2 + 2 + 2 + 2 + 2 + 2 = 14<br>One learner, Neha, records the number sentence as 7 G 2 = 14 | teacher gives explicit instructions and explains how to start writing the number sentence to represent what they did. As the number sentence is being written, the teacher evaluates the learners' understanding of the mathematical language associated with addition. She probes the learners to think of the mathematical symbol associated with addition and gets them to interpret actively by visually demonstrating. In this way, the teacher socialises the learners into the addition symbol.<br>Teacher A evaluates the learners' thinking related to the new maths knowledge on counting in groups by asking a probing question that encourages the learners to think actively about how many groups of 2 they are adding up, i.e. 7 groups of 2. The teacher explains that by recording the number sentence, they are showing what they did. She gives explicit instructions on how to write the 7 groups of 2. |
| 8. | Teacher A asks Neha to explain her recording.<br>Teacher A: "Tell us a bit about that *G*. What does the *G* stand for? Can you just explain to me why you wrote it so that we can all understand?" [PROBQAIN; EVAL].<br>Neha: "7 children and each child has 2."<br>Teacher A: "Ok, so 7 children and each child has 2. Is that what you are trying to say? Ok, so you did it a much shorter way."[EXP]. "Ok, good." [VAL]. | PROBQAIN; EVAL; EXP; VAL: Teacher A probes the learner to think actively about the way in which the learner has chosen to write the number sentence. Through the active interpretation she is able to evaluate the learner's thinking. She explicitly explains that the way in which the learner has written the number sentence is a shorter way. Teacher A validates the learner's chosen method with praise. |
| 9. | Teacher A continues with the context of Easter and sets the next word problem. She tells the learners that she wants them to draw a circle on their page, and they are to pretend that this is their basket "because we are going on the treasure hunt and we are each going to get 5 | EMBD; CA; PTMK: Mathematical construct of grouping is embedded in an everyday context. Learners work with concrete apparatus as they place their 'eggs' in the basket. The learners draw on previous counting knowledge to count the 'eggs.' |

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| | Easter eggs." [EMBD]. The learners each add 3 wooden cubes to the 2 that they already have and place the 5 wooden cubes in their basket (circle) drawn. [CA] Teacher A asks the learners to count the eggs as they are placed in the basket [PTMK]. | |
| 10. | Once all the learners have 5 wooden cubes in their baskets, Teacher A says, "Now who would like to tell me how they would like to find out how many we have altogether?" [PROBQAIN; EVAL].<br>AI: "Count in 5s."<br>Teacher A: "You want to count in 5s. And what is the reason for that? Why would you like to count in 5s?" [PROBQAIN; EVAL; NMK]. "Listen to your friend."<br>AI: "Because it's quicker, you can just keep 5 in your head." | PROBQAIN (2); EVAL (2); NMK: Teacher A, through her questioning, probes the learners to think actively about ways in which the 'eggs' can be counted in order to work out how many there are altogether. As the learners respond, the teacher evaluates their understanding and thinking with regards to counting in groups. This is a concept that has been introduced earlier in the lesson. Once a learner verbalises a choice, the learner is probed to interpret actively and justify his choice. The teacher does this as a way of encouraging the learners to think about counting in groups as a more efficient manner, which is new maths knowledge. |
| 11. | Teacher A asks: "Is there anybody who perhaps preferred doing it another way?" [PROBQAIN; EVAL].<br>None of the learners respond.<br>Teacher A goes back to an earlier idea suggested by Christina to count in 3s. She demonstrates by saying, "We'll put 3 (wooden cubes), and then we've got only 2 here (teacher splits the group of 5 into 3 and 2), so where are we going to get another 1 from?" [VIS DEM; CA; PROBQAIN; EVAL].<br>Thando: "From Daniel."<br>Teacher A physically goes around the group and regroups each learner's group of 5 wooden cubes into groups of 3. When this is done, Teacher A asks the learners to count the groups of 3 with her [PTMK]. | PROBQAIN (2); VIS DEM; CA; EVAL (2); PTMK: Teacher A actively probes the learners to think of alternative ways of counting the cubes. The learners' responses will be used to evaluate their understanding and thinking. She probes the learners to think actively of how the concrete apparatus can be organised to facilitate counting in 3s, and uses this as a means to evaluate their understanding of grouping. Teacher A, using the concrete apparatus, visually demonstrates an alternative counting method, i.e. counting in 3s instead of 5s. As learners count in 3s, they need to draw on previously taught mathematical knowledge of counting in 3s. |

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| | Learners: “3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33…”<br>Teacher A: “And then we’ve got two more, so 33…”<br>Learners: “34, 35.” | |
| 12. | Teacher A now discusses with the learners the choice of either counting the ‘Easter eggs’ in 5s or in 3s. She explains to the learners that it took a really long time when they counted in 3s because they had to regroup the wooden cubes from a group of 5 to a group of 3. However, if they counted in 5s it would be much quicker, because it is already in a group of 5 and they can keep 5 in their head and simply count in 5s. Teacher A explains, “You see that you already have this 5 over here (wooden cubes in their drawn circle), so we don’t need to move this around because we already have 5, hey? Why don’t we try counting in 5s this time?” [EXP; PROBQAIN; NMK].<br>Learners: “5, 10, 15, 20, 25, 30, 35.”<br>Teacher A: “So how many do we have altogether?” [PROBQAIN; EVAL].<br>Learners: “35.”<br>Teacher A: “Do you see how we kept them in the basket and we counted them? We kept that number 5 in our heads to figure it out altogether.” | EXP; PROBQAIN (2); NMK; EVAL: Teacher A discusses the two different counting choices, i.e. 5s or 3s, and explicitly explains why, in relation to the particular word problem, counting in 5s is the more efficient choice. The teacher probes the learners to interpret actively that when they count in 5s they keep 5 in their ‘head’ and keep counting on in 5s until they reach the answer. This is new maths knowledge for the learners. Once the learners have counted in 5s, she evaluates whether they understand that by counting in groups they are able to reach a particular answer. |
| 13. | At this stage in the lesson Teacher A tells the learners that they are going to solve a little problem. The learners need to try solving the problem and then they will speak about what they did [INSTIMP].<br><br>She gives the learners the following word problem, “The Easter bunny comes into our garden, and he knows that in that garden he has to leave enough boxes of eggs for 4 children. There are 10 Easter eggs inside each | INSTIMP; EMBD: Teacher A instructs the learners that they are going to do a word problem. She does not give them specific instructions on how they need to solve it. Mathematical construct of grouping is embedded in an everyday context. |

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| | box. How many Easter eggs are there altogether?" [EMBD] | |
| 14. | Teacher A instructs the learners to draw their 4 boxes and to place 10 Easter eggs (wooden cubes) in each box. [INSTEXP; CA]. Once they have done this, she tells them that they need to use their "counting skills" to decide how many Easter eggs there are altogether. [INSTEXP]. | CA; INSTEXP (2): The teacher gives the learners explicit instructions on how to work with the concrete apparatus. She explicitly instructs the learners to think about the counting strategy that they will use to solve the problem. |
| 15. | As the learners are doing this, Teacher A works with one learner who is struggling.<br>Teacher A: "Ok, so how many do you need in each box, Nondu?" [PROBQAIN].<br>Nondu: "10."<br>Teacher A: "Here, I am just quickly going to give you a 10 card (which is a little card with the number 10 written on it), just to remind you that inside each box there are 10 Easter eggs." [CA].<br>Teacher A: "Now I want you to count how many there are altogether." [INSTEXP]. | PROBQAIN; CA; INSTEXP: Teacher A probes the learner to think actively about how many 'Easter eggs' are needed in each box. She gives the learner a card with the number 10 written on it to remind the learner of the value in each 'box.' The teacher gives the learner an explicit instruction to count the 'eggs' altogether in order to get to the solution. |
| 16. | Once all the learners have decided on the solution, Teacher A asks the learners to verbalise how they reached their solutions [VERB DEM]. For example, "… Neha, when you started off, how did you start counting your blocks?" [PROBQAIN; EVAL].<br>The learner battles to respond, so Teacher A asks her to demonstrate visually instead.<br>Teacher A: "Show me." [VIS DEM, EVAL].<br>The learner demonstrates that she first counted each of the wooden blocks in each box to check that there were 10 and then she counted each box in 10s.<br>Teacher A: "Okay, so [when] you knew each box had 10 so you counted like that (counted in 10s, i.e. 10, 20, 30, 40)." [EXP]. | VERB DEM; PROBQAIN; EVAL (2); VIS DEM; EXP: Teacher A asks the learners to verbalise their solutions. She probes the learners to think actively about the strategies that they used. The teacher uses the verbal demonstration to evaluate and understand the learner's thinking. When the learner cannot verbalise what she has done, the teacher asks her to demonstrate visually. Teacher A uses the visual demonstration to evaluate and understand the learner's thinking. She explicitly explains back to the learner how the learner has counted. |
| 17. | Teacher A: "Did anyone do it differently to Neha?" [PROBQAIN; EVAL].<br>Thando: "I counted in 5s."<br>Teacher A: "Okay, very clever." [VAL]. | PROBQAIN; EVAL; VAL: Teacher A probes learners to think actively of alternative strategies to the one demonstrated. The teacher evaluates and validates the |

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| | | alternative counting strategy chosen. |
| 18. | Teacher A goes back to a learner whom she observed had the solution to the problem very quickly and asks her, "Can you tell us a little bit more about how you did it so quickly?" [PROBQAIN; EVAL].<br>Christina: "I counted in 10s."<br>The learner did not first count and check that there were 10 in each box, she counted in groups of 10 straight away.<br>Teacher A explains to the learners, "Okay. So from now on I want you to remember that when you are grouping things, guys, and you know how many are in the group, you must use that number to count. Keep the number in your head." [EXP; NMK]. | PROBQAIN; EVAL; EXP; NMK: Teacher A questions and probes the learner to think actively about and explain the counting strategy that she chose. The teacher uses the learner's response to evaluate and understand her thinking. The learner's explanation is used by the teacher to explain explicitly to the learners that when you are counting in groups and you know how many are in each group, you count using that number so that you are more efficient. E.g. If there are 10 in a group, you would count "10, 20, 30…." This is new maths knowledge. |
| 19. | In the final part of the lesson, Teacher A very quickly consolidates and evaluates what she has taught them by handing each learner 5 ten blocks from a set of Diene's blocks.[3] [EVAL; CA].<br>Teacher A: "Pretend that the blocks are 5 bars of chocolate. How many little pieces of chocolate do you have altogether?" [EMBD].<br>Nondu shouts: "50!" This is the learner who initially was battling to count her wooden cubes in groups. | EVAL; CA; EMBD: As consolidation the teacher wants to evaluate the learners' understanding of counting in groups and gives them a word problem to solve. The learners are given concrete apparatus to work with. Mathematical construct of grouping is embedded in an everyday context. |
| 20. | Teacher A asks the learners to explain how they reached the solution. For example, with one learner she asks, "How did you count yours, Al? Can you show me?" [VERB DEM; PROBQAIN; EVAL].<br>Al: "10."<br>Teacher A: "So what were you actually doing?" [PROBQAIN; EVAL ].<br>Al: "Counting in 10s."<br>Teacher A: "Okay, so you knew that each one | VERB DEM; PROBQAIN (2); EVAL (2); EXP; NMK: Teacher A asks the learners to verbalise their strategies. As learners verbalise their strategies, the teacher evaluates their understanding and thinking. She uses 'open' questions to probe the learner to think actively about the strategy that he chose. When the learner responds with a one word answer, she asks a question that probes the learner to think more deeply |

[3] This is a mathematical set of apparatus that is used in the Foundation Phase to teach place value. Each ten block, in a set of Diene's blocks, is segmented into 10 which is representative of 10 units.

| | | |
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| | of these was ten and you were putting all the tens together. …so you knew that 5 groups of 10 would give you 50."<br>Teacher A then addresses the group of learners and says:<br>Okay, so children, can you see how easy that was, Imagine we had to go like this now, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and count every single piece of chocolate when we knew that there were 10, so you used your knowledge of 10 to count in tens. [EXP, NMK].<br>Therefore, Teacher A reinforces the concept that she has been trying to teach in this lesson. | about what he actually did. The teacher explicitly explains the strategy chosen by the learner to the group of learners. Teacher A concludes lesson by giving an explicit explanation of the efficiency of counting in groups as opposed to counting in 1s. Counting in groups is new maths knowledge that she has been trying to introduce in this lesson. |
| 21. | Finally Teacher A asks the learners, "How can we record what we did? [PROBQAIN; EVAL].<br>Daniel: "10 + 10 + 10 + 10 + 10 = 50."<br>Teacher A: "Yes!" [VAL].<br>She concludes the lesson by saying to the learners, "Well done. I am very proud of you all." [VAL]. | PROBQAIN; EVAL; VAL (2): Teacher A probes the learners to think actively about how they can record what they did as a number sentence. The teacher evaluates the learners' understanding of counting in groups to reach a solution. Teacher A validates the learners' responses with praise. |

*Summary*

In the follow-up lesson, Teacher A makes strong links in her pedagogical moves to what she has diagnosed as a difficulty that her learners are experiencing with Number, namely the ability to count quantities in groups (Phase Three). This focus remains the centre of the lesson throughout. She actively tries to engage the learners to reach the understanding of counting quantities in groups through both verbal and visual demonstration. The learners are also encouraged to reflect on their understanding or chosen strategies as they evaluate each others' strategies, as well as through responding to the questions posed by the teacher. The pedagogical moves taken by Teacher A show that there is a strong correlation between what she chooses as her central focus, based on the diagnoses from the formative assessment task, and the pedagogical moves in the follow-up lesson.

**Appendix A ii (R)**

**Teacher A**

Rubric

L.O. 1 – Numbers, Operations and Relationships

**Assessment Standards**

1. Counts forwards and backwards in twos, fives or tens.
2. Solves and explains solutions to practical problems that involve grouping.
3. Can perform calculations, using appropriate symbols, to solve problems involving addition (including repeated addition) and subtraction of whole numbers with at least 2 digits.
4. Uses following techniques: using concrete apparatus.
5. Explains own solutions to problems.

**CODE**

1=not achieved
2=partially achieved
3=good
4=excellent

**NAME:** _____ **DATE:** _____

| CRITERIA | Children's "Strategies" | Tick | Code | Comments |
|---|---|---|---|---|
| Counting | Grouping (2s, 5s or 10s) | | | |
| | Counts on | | | |
| | Counts all | | | |
| Use of physical apparatus | Uses with understanding | | | |
| | Uses without understanding | | | |
| | Doesn't use | | | |
| | Heavily reliant | | | |
| | Pictorial representation | | | |
| Verbalisation | Uses accurate terminology/language | | | |
| | Devises and explains own strategies to solve problems | | | |
| | Uses previous knowledge to explain new problem (I knew that….therefore…. | | | |

# Appendix B
# (Teacher B)

**Teacher B**

Teacher B is in her fifth year of teaching and is teaching at a middle-class, independent school in the North of Johannesburg.

**Appendix B i, Phase 1: Interview with Teacher B prior to the administration of the assessment task**

1.1 *Teacher B's understanding of assessment, its different forms, and its role in diagnosing learning*

1. When describing her understanding of assessment and its different forms, Teacher B outlines a carefully planned process that is followed by the Foundation Phase in her school with regard to assessment. She refers to this planned process as a "learning path." She describes the learning path as being a series of work plans which outline the concepts and the progression in which the concepts are taught and assessed in the Numeracy Programme. She elaborates on how this process is implemented as part of the different forms of assessment:

> First we would teach the [concept] to them, then the second time we will give them a formative [assessment], [with] a check list: was able to do it, or not able to do it, so we're starting with check lists now giving the children the criteria that we are looking for and then they either peer assess or self assess or teacher assess by either ticking the smiley face which shows they can do it, or the unhappy face.

Once the initial "formative" task, with a check list as described by Teacher B has been done, the learners write up their goals on a goal sheet and these become the skills on which learners need to work "in order to do the [formal] formative[assessment task], which is a set of many skills."

2. Following the formal formative assessment task, the teachers do "a formal rubric and [this] gets sent home to the parents where they have the opportunity to look at the assessment, comment on it, and if they have any queries, to come to [the teachers]."

3. The learning path as outlined by Teacher B consists of teaching a concept/s, learners doing an initial 'formative' task, re-teaching areas that the learners feel they need to work on and finally doing a formal formative assessment task, which involves a number of skills. This formal assessment task is assessed using a rubric and sent to the parents for comment.

4. Teacher B explains that summative assessment tasks are seldom incorporated into the learning path. She says that a summative assessment task would involve assessing many more skills than what is done in the formal formative assessment task. However, the school is:

> cutting down on that now, because [the school] found that it either took too long or there were too many skills in one assessment.

She notes that the focus has moved towards formative assessment tasks which are understood as being "smaller assessments that focus on the unit of work [learners] have already done."

5. As part of the learning path, Teacher B explains that the school is attempting to move away from teachers:

> doing something and then assessing it [straight away], towards making the decision on how many times we are going to have them do it, before we formally assess it? So we're working on a balance between the learning path and getting them assessed.

Therefore, the idea is that concepts are "revisited quite often and then the [formal] formative assessment [task] is based on the concepts that [were taught] in that unit." Teacher B continues and explains that the formal formative assessments, together with the check lists that are done with the learners, are what then get recorded in a formal mark book. This information is what is used for formal report purposes. The learning path is a construct in which the relationship between teaching, learning and assessment is understood at the school.

6. Teacher B explains the purpose of the forms of assessment that she has described:

> Well, the purpose is really to see if I have pitched my teaching at the right level as well as seeing what skills the children have achieved. Are they able to do it? But again, is it according to their number range. Are they working beyond that? Are they unable to do that level? So it is just to see the ability of the child so then I can say, okay, they need more emphasis on working with maybe grouping.

Teacher B continues and talks about how the purpose of the assessment that she does (which, in this instance, is primarily formative assessment) is to allow her to be "reflective." She explains:

> It (the formative assessment) gives me a reflection of what do I need to revise and go back on if I have not…if they haven't got the skills yet through the learning path and the assessment. If they're still struggling with the concept. So it's reflective. I want to see if it's…I want to reflect on my children's ability as well and see where they are in their own ability.

She describes it as "suiting my teaching for their learning." In response to this phrase, the interviewer asks Teacher B to sum up her understanding of formative assessment. She responds by saying, "Ok, formative, I would understand as a number of skills that are getting assessed over a period of teaching."

1.2 *Teacher B's views on what guides her selection and design of a formative assessment task.*

1. According to Teacher B, the guidelines, as set out by the National Curriculum, stipulate that at least five formative assessment tasks in Numeracy need to be done per term. This, Teacher B says, is:

> All good and well but it does limit the time that you get to teach. And we feel like we over assess sometimes and we would rather not but rather focus more on the learning path than assess, and not let the assessment be the be all and end all of everything.

When designing what she refers to as her "formal formative assessment task" in Numeracy (this being the task that incorporates the formal rubric that gets sent home to the parents to comment on), Teacher B explains that the assessment task usually takes place after two units of work have been covered. A unit will have incorporated a few concepts and the assessment task "will focus on key concepts that [the teachers have] pinpointed in those two units." It does not usually incorporate concepts that have been assessed previously in formal formative assessment tasks. However, Teacher B notes:

> If [the teachers] see that maybe there is a concept - like [the learners] are struggling with sharing of odd numbers, so we focused a lot on sharing of odd numbers, so we've given them an assessment with that and then the next assessment will also have that just to see if they are able to do it with input that we've given them after the first assessment that we've done.

2. Thus, consideration is given to concepts that the learners may be finding challenging, and after "input" is given "after the first assessment," the "next assessment" will reassess the concept to see if the learners are now able to do it after the input has been given.

Teacher B explains that as the formative assessment task is designed, consideration is given to how numerical concepts can be interrelated. Therefore, while the teacher assesses one concept, she is able to gain an insight into the learners' thinking on other concepts. She explains, "So with, just say, for graph work we'll also implement the identification of shapes, so they have to identify shapes and then use that data to do the graph work."

3. The numerical concepts that will be assessed as part of the formative assessment task are chosen from the NCS.

> We focus on the Learning Outcome…and the Learning Outcome will then dictate what activity we are going to do, and we also stipulate that to the children. So if it is graph work, we're going to say we're collecting data, we stipulate what we are going to do…we will tell

> them the criteria and we either say or write it up on the board…So we are setting…we're telling them what we expect from them. But we're not saying, you need to do it this way.

The NCS is used as a guide on what learners are expected to learn. However, although the Learning Outcome is clear and expectations are known to the learners, teachers work in response to the learners' thinking and progress and the "need to do it a [particular] way is not dictated."

4. From the Learning Outcome, Teacher B explains that Assessment Standards are chosen. The Assessment Standards are used in setting and designing the cognitive challenge of the formative assessment task. In the assessment task, achieving the Assessment Standards is seen as achieving the minimum understanding.

> Teacher B: When it comes to the rubric…we use what is in the NCS as our 3[1]
> Interviewer: Which is what? Is that the minimum?
> Teacher B: That's the minimum.

5. However, Teacher B explains that not only is the task designed to assess learners against the minimum understanding, but that it is designed to allow for the learner whose cognitive thinking and level goes beyond the minimum:

> a 1 is: unable to do a 3 (which is the Assessment Standard in the NCS), a 2 is: can do some but not all, 3 is: obviously can do it. And the 4 is: when we extend them within our assessment, where we allow for a 4.

Thus, in the designing of the task, consideration is given to the various cognitive levels of the learners. Teacher B explains the reasoning behind designing the task in this manner:

> So we provide for all of them and what's exciting is that then you do see, once you've given the child the input, the bottom children really do very well with even the higher numbers. So you can see that when you're teaching you can put up their number range a little bit.

6. Teacher B feels that by designing the task and taking cognitive levels into account, she is able to "[get] information and encourage [the learners] to grow in their own little ability." Teacher B is able to take the information that she gets from the assessment task about the learners' thinking and finds this "very good to base her teaching on."

[1] A key ranging from 1-4 is used on the assessment rubric to rate the learner's achievement of the selected Assessment Standard/s.

Therefore, in summary, Teacher B explains that the designing of the task is not only part of a carefully planned learning path, which involves order and procedure. In the designing, the NCS guidelines, cognitive challenge and a deeper need to understand and work with the learners' thinking are all carefully considered.

1.3. *The mental processes with which Teacher B thinks learners need to engage, in order to have a sound sense of Number*

1. Teacher B begins by saying that learners need to represent numerical concepts using concrete apparatus. She holds the view that much work needs to be done between the concrete and the symbolic representations. She explains:

> Initially I would say that the mental process is…learners need to have it concretely and represent, what does that representation mean in physical, actual things that I can manipulate, use, change?…it's not just 2D, it's…through experience. They need experience using real objects in order to understand what is written at an abstract level or representational level.

2. Following the learners' working with concrete apparatus, Teacher B says the learners will work with the 2D representation of the concrete. Teacher B describes the manner in which she encourages the learners to move from working with the mathematical representation in the concrete to working with the representation in 2D as follows:

> Once they've got the concrete…we work with concrete apparatus and then from [there]…we go through steps that they are going to use and then I ask them, ok, what's the first thing that we did with the concrete apparatus? Okay, we set out 36 beans. Right, now you are going to draw your 36 beans. So I always relate it to the experience that they just did.

Teacher B elaborates with an example:

> They are doing word problems and they need to work out how many biscuits John gives his dog in two weeks. We take yoghurt cups, we say okay, one week, there are 7 days and we put Monday, Tuesday, Wednesday to Sunday, and we do that again with another set of yoghurt cups. I give them a bag of dog biscuits (beans). On Monday how much does John give him every day, so they say 3 biscuits. So they take out the 3 beans they put it in the cup for Monday…So then they can see, okay, I've got 14 groups and in each group there's 3. So from the concrete then we go into the [2D] representational where they can draw their 14 days and then they can draw their 3 little biscuits in each. And that's either a circle or at that stage they want to write a 3 as a 2 and a 1, but it's purely up to them. I give them the option. If they feel comfortable with doing 3 little circles representing the 3 biscuits, that's fine, or they can use number, but at this stage they're still using 1s.

3. From the description and example given by Teacher B, a very carefully considered teaching process is followed in an attempt to encourage the learners to see the connection between the concrete representation and the 2D representation. According to Teacher B, following this understanding of the concrete and 2D representation will be an abstract understanding of number. This is where, for example, instead of learners representing a row of 10 using blocks (3D) or drawing 10 circles/sticks (2D), they will simply write the number 10. Teacher B says:

> So I've taken them from the concrete to the representational, now knowing that they know a row of 10, they can just write the number 10, so now they're starting to chunk in simple forms…you're breaking up the 1s into either a 5 or 1 or 2, or things like that. But at this stage, I'm just showing them that they know that a row of ten is number 10 represented by that.

4. When Teacher B is asked to discuss what mental processes the assessment task gives the learners the opportunity to exercise, she responds by saying that although the learners will be allowed to use concrete apparatus if they need to:

> I think most of this (the task) is based on the [2D] representational, because the two word problems they have to draw…they have to show me the method that they used, but again if they use concrete then they have to turn into representational.

She continues by saying that the "complexity of the representations," i.e. the strategy that the learners use to count, will elicit information about the learners' understanding of number. For example:

> If they can break it up into groups of 10 or like if this one's got the number 7 in, are they able to break up the number 7 into 5 or 2s, or 2, 2, 2, and 1. And from there I could see if they're still thinking in 1s or chunking their numbers up. So for counting strategies, in terms of can they count easily and quickly and accurately, or are they still resorting to 1s and making inaccurate solutions?

5. In an effort to understand and diagnose her learners' thinking and mental processes related to number, Teacher B focuses on the methods that the learners use to represent their solutions. She hopes that by diagnosing the "complexity of the representations" in both the concrete and in the 2D, she will be able to determine the manner in which the learners are counting and, therefore, their understanding of number.

1.4 *The purpose of the designed task, and what Teacher B expects to be elicited by the task about learner difficulties in Number*

1. Related to the mental processes that Teacher B hopes the assessment task will give the learners the opportunity to exercise, the underlying purpose to the designing of the task is to have activities that will allow her to see the counting methods with which the learners are working in their solutions. She explains that this will help her to understand the learners' "level of number concept" and consequently the difficulties that the learners are experiencing in number. For example, Teacher B says that by allowing the learners to work with concrete apparatus, she will be able to observe and see their level of number concept by assessing whether the learners are "working in 1s? Able to chunk[2] number, and [whether] they have the concepts of adding and subtracting." Using this information Teacher B explains that she will be able to give "input on strategies," for example, on how to "organise their concrete apparatus so that it is easier for them to count…" and, therefore, achieve a more in depth number concept level.

2. Teacher B explains that while she has included word problems on sharing in the designed assessment task, the purpose of this activity is not only to reveal the learners' ability to share into equal groups, but once again she hopes that it will elicit the learners' counting level and in turn "their level of number concept." Teacher B explains that she will be able to identify those learners who are unable to chunk number and are counting in 1s, as part of the concept of sharing, as these learners usually "count inaccurately or share inaccurately." In addition to this, Teacher B says that she will be able to identify whether the learners who can chunk, can only chunk in 10s or whether they "understand if they can't do it further in 10s they need to go into 5s. If they can't do it in 5s they need to go down to 2s. If they can't do it in 2s they need to go down to 1s."

3. In the activity that has been included on Money, Teacher B has designed this activity to serve a double purpose: 1- to gain information on the learners' ability to make decisions on the "least amount of [money]," and 2- to observe their ability to break up and chunk number, which is revealed when making these decisions. In so doing, the counting level of the learners will be elicited, which is the primary purpose in the designing of the assessment task.

4. In the Halving activity that has been designed as part of the assessment task, Teacher B expects to elicit the difficulties that learners are experiencing with regard to halving a number with a remainder:

> We have taught them the concept of half as two equal parts, smaller equal parts. And they do try but when you speak to them about it or tell them to explain it, they don't really know.

[2] Chunking is the idea of group counting – it is the method of counting that the learners use when solving the word problem.

In her explanation, Teacher B does not specifically say what she would like to understand about the learners' thinking or number sense when working with a remainder.

5. In this interview, it becomes evident that in the designing of the assessment task, Teacher B has chosen different numerical topics that have been previously covered as part of the learning path. While the rubric (See Appendix B ii (R), pp.26-27) that Teacher B uses as part of the assessment task shows various numerical concepts being assessed, the main purpose of the designed assessment task, as explained by Teacher B, is focused at eliciting the counting strategies that learners are using and, therefore, what Teacher B refers to as their "level of number."

*Summary*

In this first interview Teacher B discusses the notion of formative assessment as tasks that form part of what her school refers to as a "learning path." She explains that as part of the learning path there is no distinguishing specifically between summative and formative assessment tasks. She states that her school focuses more on formative assessment tasks, and this is used for reporting as well. Therefore, there are no separate summative tasks. According to Teacher B, the selection and design of the formative assessment tasks are usually based on key concepts that have been dealt with in the last two units of work covered, and are aligned to the Assessment Standards as set out in the NCS. She also notes that within the designing of the task, very specific consideration is given to the different mathematical abilities of the learners.

The mental processes that Teacher B believes are essential to the learners having a sound number sense involve working with number as a concrete representation (3D), then as a 2D representation and finally working with number in the abstract, as a symbol. In the formative assessment task that Teacher B has designed, she has selected concepts covered and taught in the "learning path." In the solutions of the assessment task, the learners will be given an opportunity to exercise what Teacher B has described as important mental processes for number sense. In an effort to diagnose her learners' "number level," she designed the task with the purpose of assessing number concepts taught, but she has also designed the activities with an underlying purpose and a carefully considered intention of assessing the counting methods used by the learners as they solve the problems. The information gained in the diagnosis will be used by Teacher B to give learners "input on strategies."

**Appendix B ii, Phase Two: Coding of pedagogical moves used by Teacher B in the administration of the assessment task**

The following coding was used:

| Coding (pedagogical moves) | Abbreviation |
|---|---|
| Previously Taught Mathematical Knowledge | PTMK |
| New Mathematical Knowledge | NMK |
| Everyday Knowledge | ED |
| Embedded Mathematical Knowledge | EMBD |
| Socialisation | SOC |
| Verbal Demonstration | VERB DEM |
| Visual Demonstration | VIS DEM |
| Evaluation | EVAL |
| Validation | VAL |
| Instruction Explicit | INSTEXP |
| Instruction Implicit | INSTIMP |
| Explicitly explanations | EXP |
| Criteria Explicit | CRITEXP |
| Criteria Implicit | CRITIMP |
| Concrete Apparatus | CA |
| Probing | PROB |
| Probing Questions and Active Interpretation | PROBQAIN |

*Setting*: Teacher B is with her class of twenty five learners. The six mathematically weaker learners come and sit at the front of the classroom (a row of desks has been prepared for these learners). Teacher B instructs the rest of the class to work independently on written tasks at their desks.

*Focus*: Formative assessment task – Doubling and Halving, More and Less, Decomposition of Number

| | Pedagogical Moves | Categorisation |
|---|---|---|
| 1. | Teacher B hands out the formative assessment task to the learners (Refer to Appendix B ii (R), pp.26-27). | |
| 2. | She tells them that it is an assessment task. Teacher B asks the learners to follow with her as she reads through and explains the instructions to them [INSTIMP]. | INSTIMP: Teacher B instructs the learners to follow with her as she explains the formative assessment task to them. |
| 3. | Teacher B goes through each section carefully. She reads the instructions with the learners. For example, she reads the instruction out as follows: "*Double the numbers, showing me how you reached your answer. Write the answer on the line*." [CRITEXP]. She proceeds by explaining each instruction carefully. For example, "You need to *show* me how you doubled the number and got to the answer. Then you write the answer on this line." (Teacher B points to the answer line) [INSTEXP]. | CRITEXP; INSTEXP: Expectations and criteria are made visible to the learners by the teacher ensuring that each instruction is explicitly explained. |
| 4. | Teacher B reads the instructions and simultaneously asks the learners questions about the concepts that are being covered in that section of the assessment task. She encourages them to verbalise and demonstrate their understanding, visually.<br><br>For example, with the 'Doubling and Halving' section of the assessment task, Teacher B asks the learners, "What do we do when we double? Please tell me what we do?" [PTMK; PROBQAIN; VERB DEM; EVAL]. The children respond saying, "Do it on an abacus. Draw how you did it." With the section on 'More' and 'Less,' Teacher B asks, "What do we mean by *more*?" [PTMK; PROBQAIN; SOC; EVAL]. The learners respond by saying things such as, "The number is getting bigger. We are adding." With | PTMK (3); PROBQAIN (2); VERB DEM; EVAL (3); SOC; VIS DEM: The teacher probes the learners' thinking and gets them to interpret the instructions and concepts actively by asking questions that draw on the learners' previously taught maths knowledge, i.e. doubling, halving, more, less, breaking up of number. Teacher B socialises the learners into the mathematical language associated with addition and subtraction. She uses probing questions, verbal and visual demonstrations to evaluate learners' understanding of instructions and concepts. |

| | | |
|---|---|---|
| | the section on 'Money' that involves an understanding of the breaking up of number, Teacher B says, "Show me how you break up the number 53." [PTMK; VIS DEM; EVAL]. The learners, on their white boards, break the number up as follows:<br>50 + 3 = __ | |
| 5. | Teacher B follows a similar line of questioning for each section as she reads and explains the instructions and concepts necessary for the formative assessment task. Once Teacher B has explicitly gone through the instructions and concepts, the learners complete the assessment task individually and independently. | |
| 6. | Teacher B sets out apparatus for the learners to use on the front mat, i.e. abaci, Diene's blocks, number charts and white boards. Teacher B asks the learners to select the apparatus that they feel will be the most useful in solving the particular problem that they are working on in the assessment task [CA]. For example, one of the questions in the assessment task reads as follows: *"Make the amounts of money. Cut and stick the coins that make the amounts in the purses."* In order to solve this problem, the learners need to be able to break up number. Most of the learners, therefore, choose to work with the Diene's blocks and take 5 longs (1 long = 10 singles) and 3 singles. The learners can also use their white boards to work out solutions. | CA: The learners are allowed to work with concrete apparatus and then translate the 3D solution to a 2D solution when solving the problems in the assessment task. |
| 7. | As the learners complete the assessment task, Teacher B observes and "assists" individual learners with their thinking where, in her opinion, the need seems to arise. She attempts to evoke the learners' thinking with comments and questions such as, "How are you going to draw this for me?" [PROBQAIN; EVAL]. "How are you going to do it?" [PROBQAIN; EVAL]. | PROBQAIN (3); EVAL (3); CA: Through questioning the teacher probes the learners to interpret actively and think as they attempt to complete the assessment task. She encourages the learners to interpret what they are doing and the solution that they have chosen. Teacher B uses the probing questions to evaluate the learners' thinking |

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| | "Use the blocks to show me how you are going to build the number. I need to see how you made it." [PROBQAIN; EVAL; CA]. | and understanding of concepts. She probes the learners to think about the way that they would represent the solution in a 2D form and/ or as a concrete representation (3D). |
| 8. | Teacher B interacts with the learners as they complete the task and affirms and praises them with comments such as, "You are superstars! You have done it many times before!" [VAL]. | VAL: Teacher B validates the learners' efforts with praise. |
| 9. | At the end of the task, Teacher B collects the tasks. She records and finalises the assessment on an assessment rubric. (See Appendix B ii (R), pp.26-27). This rubric is on the last page of the formative assessment task and is visible to the learners. The rubric is returned to the learners once it has been finalised [CRITEXP]. | CRITEXP: The learners are able to see the criteria chosen to assess each concept as they complete the formative assessment task. |

*Summary*

In the administration of the task, Teacher B ensures that the learners understand the instructions of the formative assessment task by explaining the instructions and by getting the learners to interpret the instructions actively. Active interpretation is encouraged through the open questioning that Teacher B uses. The open questioning used by Teacher B is not only to ensure the learners' understanding of instructions, but it is used by Teacher B to activate the learners' previous knowledge on the concepts that are being assessed in the task. Furthermore, Teacher B encourages active interpretation by asking the learners to interpret and translate their solutions into a 2D and 3D representation. Thus, through the pedagogical moves of Teacher B, there is evidence in the administration of the task, of the mental processes that Teacher B foregrounds as important in her initial interview when working with Number. Namely, working with number firstly in a 3D and 2D format and finally in the abstract. Although the learners need to work on the formative assessment task individually, Teacher B ensures that the learners are still given the opportunity to think through the mathematical concepts of the question and their approach to the solution.

**Appendix B iii, Phase Three: The follow-up interview with Teacher B after the administration of assessment task, where the diagnosis of learning is discussed**

3.1. *Teacher B's views on formative assessment and the diagnosis of learning*

1. Teacher B begins by reiterating the notion of formative assessment tasks forming a part of what her school refers to as a 'learning path.' However, she adds more specifically the formative aspects of these tasks; mainly from the teachers' reflective point of view:

> [The assessment task] really is [aimed at] success, so we should not really have problems in the assessment where they are struggling with something, but from the assessment we [the teachers] can pinpoint what areas we need to either consolidate, or recap or revise…so that it…can lead up to the next teaching phase or learning path.

Therefore, Teacher B highlights key aims of formative assessment tasks, firstly and most importantly, to be about success and secondly, to be about the assessment process that builds towards the learning path. Based on the learning needs of the learners as revealed by the assessment task, the teacher can then make decisions about the next learning path. Therefore, Teacher B's understanding of teacher diagnosis of learning is integrated with the idea that in order to make decisions about the learners' learning and the next learning path, she needs to "look at the results of the assessment and reflect on them, to set the basis for the next lesson."

2. This idea of being able to "reflect on" the learners' learning from the assessment task is similar to when, in the initial interview, Teacher B talks about the task "giv[ing] her information." The reflection or information gathered from the assessment is what Teacher B uses to make decisions about what and how to move forward in the learning path.

3. Teacher B explains that based on the "process of reflection" and in setting up the next learning path for the learners, each learner's goal for the next learning path is made explicit to them. Giving feedback to the learners is, therefore, an integral part of the learning path. She explains saying, "[I give] them feedback on the areas that they did well in, but also in the areas that they need to concentrate on." Thus, the learners are "aware of what they need to work on in the next learning path":

> Really, it is just a reflection of the areas that I feel that I need to either consolidate or revise. And go over concepts for those children who have not gotten it yet…or proficient yet. Or only achieved… showing them…more complex forms. The levels to go up and not always fall back on.

4. The idea of reflection, according to Teacher B, is an important aspect in the diagnosis of learning. It requires the teacher to be "reflective in terms of herself." Teacher B explains and says that the teacher cannot "just overlook things and say they'll (the learners) get it later." She elaborates and says that there needs to be a "process, and where there is a concern, [the teacher needs to] proactively put something in place…" Teacher B places emphasis on the role that the teacher's ability to reflect plays in both diagnosing the learners' learning and in altering the teaching programme or learning path accordingly. She demonstrates her point by giving an example from a previous formative assessment task that was done:

> Generally, we found that we just expected our children to know number patterns[3]…and we found that that was one of the areas that really needed work on, so now we've incorporated it that we do three number patterns a week, and we've also incorporated it into their homework and we have taught them how to tackle a number pattern…giving them the skills in order to complete it.

5. In Teacher B's opinion, assessment which is aimed at diagnosing learning and assessment in general are interrelated as part of the learning path. She describes the relationship between these forms of assessment in terms of the formal and the informal. Bearing in mind, from the initial interview, that what Teacher B refers to as formal and informal are not formal as in summative and informal as in formative, but rather that as part of the learning path the smaller, 'informal' formative assessment tasks build towards a 'formal' formative assessment. She says:

> So I think the informal assessment does relate to the formal assessment and that one really can't happen without the other because the assessment (informal), as you go along the learning path, will pitch how the formal (formative) assessment is done, but also from the formal assessment it shows you what needs to either be consolidated further or what skill they've really got well.

### 3.2. *Information that Teacher B gained through the diagnostic assessment on learner difficulties in Number and how the diagnosis will be used to improve the teaching and learning experience of Number*

1. The key criterion in the designing of the assessment task, as outlined by Teacher B in the first interview, was to diagnose the learners' "number concept in terms of the methods of counting that the learners used." More specifically, Teacher B says that she looked at the learners' ability to 'chunk' number in "either simple or complex forms." Therefore, in her reflection of the assessment task, Teacher B diagnosed the learners' conceptual understanding of number by reflecting on the simplicity or complexity of the counting method chosen by the learner.

[3] Learners needed to identify the patterning within the number pattern. For example, "2, 6, 8, 12…" The numbers are increasing by 2 and then by 4.

2. Although diagnosing the learners' counting methods was the key criterion, Teacher B explains that this was not set as an isolated skill, but was interrelated with other skills required when working with Number. Therefore, her diagnosis and reflection of the difficulties the learners were experiencing when working with Number involved more than looking at one main skill. For example, in the Doubling and Halving and Coin activities (Refer to Appendix B ii (R), pp.26-27), besides using counting methods to solve the problems, the learners needed to apply the skill of analysing number. Thus, the analysis of number was simultaneously diagnosed by Teacher B, as were the counting methods used. As the learners worked with concrete apparatus, not only did Teacher B diagnose the manner in which the apparatus was used to count, but also how the learners translated the concrete representation to their drawings and finally, to their number work.

3. Teacher B looked at the way in which the learners applied the integrated skills when working with the various number concepts, and based her diagnostic assessment on this. The following diagnostic assessment was made by Teacher B about the difficulties that the learners were experiencing with Number:

4. With regard to the Coin activity, Teacher B says that the "learners manage[d] to chunk in 10s and 50s and 20s using those coins." Teacher B was also pleased with the learners' ability to double and halve because she found that "those that had struggled with doubling and halving earlier [had] actually shown a huge improvement in the skill."

5. However, the most significant diagnosis about the difficulties that the learners were experiencing in Number, from the assessment task, was the learners' inability to count in groups independently from the teacher's mediation when working on the solution for word problems. The learners were unable to 'chunk' number and seemed to revert back to counting in 1s rather than counting in groups:

> The area they (the learners) really need to work on and where I was surprised, even though we do word problems every day, is that a lot of them resorted to using 1s when solving the word problems and they felt more comfortable and less anxious when doing so.

6. Teacher B explains and says what she realised is when the learners were working on the solutions to the word problems, that:

> When [she] mediates and facilitates the process or gives [the learners] scaffolding questions through the process, which [she] does when solving word problems with the groups on the carpet, [the learners] will use 'chunking.' Where [she] finds when leaving [the learners] independently, they seem to have to resort back to using 1s.

Although Teacher B mentions the learners' ability to work with concrete apparatus and represent their solutions in the 2D form as part of her criteria, she does not, in the discussion on the diagnosis of the task, specifically mention her findings on this.

7. The designed formative assessment task had elicited what Teacher B had designed it to elicit, namely to reveal the counting methods used by the learners. However, Teacher B had not expected the ability to count in groups or 'chunk' number to be a problem when working on the solutions for word problems. Teacher B explains:

> Um...it was fascinating because I think the areas that I thought they would do well in and use the chunking, like I said with the word problems…and that area wasn't the one… When it came to money they started using less coins than they normally do…I thought they would fall apart in the doubling and halving, but the doubling and halving is a skill that they really felt a lot more confident in. Actually the area that I found quite surprising was the word problems.

8. Having made the diagnosis that the primary difficulty that the learners were experiencing with Number was the ability to count in groups when working on the solutions to word problems, Teacher B explains how she intends to use this diagnosis to improve the teaching and learning:

> Ok, what I need to do with them, [is] just give them a little bit more of the grouping word problems. I want to give them a concrete opportunity to see what it actually means. I want them to see what 7 groups of 7 looks like, using matches or those little cubes...I want to try using the cuisinier[4] blocks, because for me I can say, well that's 7 and then they can show me different ways of making 7 and then putting it in groups.

9. Teacher B explains that she would like to give the learners the opportunity to work with word problems that, in the solutions, require them to count in groups. While working on these problems, Teacher B would like the learners to work concretely with counting in groups. She would like the learners to "see what 7 groups of 7 looks like," and to allow the learners to show her "different ways of making 7 and then putting it into groups."

10. In an attempt to demonstrate concretely to the learners how to count in groups or to 'chunk' number, Teacher B has chosen to use cuisnier blocks in the follow-up lesson. For example, if she wants the learners to show her "different ways of making 7 and then putting it into groups," she explains how the cuisinier blocks could be used:

[4] cuisinier - colour-coded maths blocks that are used to teach grouping of number. For example, red represents a group of 5, blue represents a group of 10).

> …Well all the red ones (cuisinier blocks) are 5s so they can say, okay, that's a 5 that's a 2. So I'm going to force them in some ways (laughs)…to not…well it sounds horrible to say force them, but I'm going to put them in a position where they're out of their comfort of [counting] using ones. They can show me ones but they can make it different…like if it was a rod of 7, you have the 7 ones but I'll ask them how they can make it a better way. They can count easier or more accurately. Because with the ones they can count inaccurately.

11. Using the information gathered from the formative assessment task, Teacher B wants to encourage the learners not to resort to counting in 1s, which she views as the learners' "comfort" zone and leads to them counting inaccurately. The information gathered about the difficulties learners are experiencing when counting in groups is what forms the basis for the follow-up lesson or for the next learning path.

### 3.3. *What the cycle of activities that were included in the research process helped Teacher B to understand about formative assessment in the Numeracy Programme*

1. Teacher B feels that the most significant aspect of the research cycle, or what her school refers to as the learning path cycle, is the information that is gained from the assessment task. More importantly though, is how this information is used to inform the next learning cycle. She explains, "[The information gathered from the assessment task] really has formed a basis of what's going to happen next, on what level we are going to pitch the next time we come to grouping, the next time we come to the analysis of number." Teacher B reiterates her point made earlier in the interview that the information gained from the assessment task enables the teacher to make decisions with regards to follow-up lessons or follow-up learning cycles about those "children that need to be extended, or go back for those children that need consolidation…"

*Summary*

In this interview, Teacher B places much emphasis on the notion of reflection and the role that it plays in teacher diagnosis of learning using formative assessment tasks. In particular, she discusses the idea that formative assessment tasks need to be reflected upon carefully and used as a means to gain information about learners' learning. Teacher B argues that this is dependent upon an ability to reflect on learners' learning and upon a teacher who is able to be reflective of self. The information gained is then used by the teacher to make decisions on the skills that the learners need extended or consolidated, and the teaching programme is altered accordingly. When discussing what the task that was administered elicited about learners' difficulty with Number, Teacher B explains that she was surprised to discover that the learners were unable to 'chunk' number when working on the solutions for the word problems independently in the given task. Therefore, Teacher B explains that in the follow-up lesson her intention is to attempt to get the learners to count in groups or to 'chunk' number when solving word problems, by getting the learners to "see" concretely what a number looks like when grouped. For example, 7 could be made up of a 5 and a 2.

**Appendix B iv, Phase Four: Coding of pedagogical moves used by Teacher B in the follow-up lesson in response to the diagnosis made in Phase Three**

The following coding was used:

| Coding (pedagogical moves) | Abbreviation |
|---|---|
| Previously Taught Mathematical Knowledge | PTMK |
| New Mathematical Knowledge | NMK |
| Everyday Knowledge | ED |
| Embedded Mathematical Knowledge | EMBD |
| Socialisation | SOC |
| Verbal Demonstration | VERB DEM |
| Visual Demonstration | VIS DEM |
| Evaluation | EVAL |
| Validation | VAL |
| Instruction Explicit | INSTEXP |
| Instruction Implicit | INSTIMP |
| Explicit Explanations | EXP |
| Criteria Explicit | CRITEXP |
| Criteria Implicit | CRITIMP |
| Concrete Apparatus | CA |
| Probing | PROB |
| Probing and Active Interpretation | PROBQAIN |

*Setting:* The same group of six mathematically weaker learners who did the formative assessment task are on the mat with Teacher B. The rest of the class work, independently completing a written task.

*Focus:* Teacher B chooses to focus the follow-up lesson on developing the skill of grouping quantities in the most efficient manner when counting (for example in 2s, 5s and 10s). Teacher B has diagnosed this as a difficulty that the learners are experiencing in Number, based on the formative assessment task.

| | Pedagogical Moves | Categorisation |
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| 1. | Teacher B is on the mat with the six mathematically weak learners. She tells the learners to sit in pairs. There are, therefore, 3 pairs. | |
| 2. | Teacher B begins the lesson and explains to the learners that each pair is going to get a set of paper plates. She says, "You know that we draw our groups normally on the board or in our word problem books, but instead of doing drawings today, we're going to use paper plates to have our groups." [INSTIMP]. She also tells the pairs that she is going to give them 70 unifix blocks [CA]. Teacher B says to the learners, "If the blocks are already in 10s, so you and your partner need to take?" [PROBQAIN; PTMK; EVAL].<br>Learners: "7."<br>Teacher B gives the learners the apparatus. | INSTIMP; CA; PROBQAIN; PTMK; EVAL: Teacher B explains to the learners what apparatus they are going to use. The learners are given the concrete apparatus with which they will work. She probes the learners' thinking as she hands out the apparatus, by asking them to think actively about how many groups of 10 unifix blocks will make 70. The learners need to draw on their previously taught maths knowledge of counting in 10s. The teacher evaluates learners' thinking and understanding of counting in groups of 10. |
| 3. | Teacher B explains to the learners that she is going to do the first example with them [EXP].<br>Teacher B: "Show me 4 groups of 7." [VIS DEM; CA]. "When I say 4 groups of 7, how many groups am I asking for?" [PROBQAIN].<br>Tristan: "7."<br>Teacher B: "4 groups of 7?"<br>Tristan: "4." | EXP; VIS DEM; CA; PROBQAIN: The teacher explicitly works through the first problem with the learners. She asks the learners to demonstrate visually the problem using concrete apparatus. Teacher B probes the learners' thinking of the visual representation by posing a question that asks them to interpret actively what '4 groups of 7' would mean. |
| 4. | Teacher B explicitly demonstrates and puts out 4 paper plates to represent 4 groups. [VIS DEM; CA]. | VIS DEM; CA: Teacher B concretely puts out the 4 paper plates to represent the 4 groups. |
| 5. | Teacher B proceeds and says, "…Now I need 4 groups of 7, how much is in group one?" [PROBQAIN].<br>Learners: "7."<br>Teacher B puts 7 blocks onto one paper plate (i.e. 7 blocks into one group). [VIS DEM; CA]. | PROBQAIN; VIS DEM; CA: Teacher B probes the learners' thinking by asking a question about the number of blocks in each group. The learners need to interpret actively. As the learners respond, Teacher B visually demonstrates. |

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| | Teacher B: "In group two?"<br>Learners: "7."<br>Teacher B continues with this line of questioning until she has put out 7 blocks on 4 paper plates. | |
| 6. | Teacher B proceeds (using her blocks and paper plates) [CA] and asks the learners: "Can we count in 7s?" [PROB].<br>Learners: "No."<br>Teacher B: "We're not able to count in 7s yet, so how can we break up the 7 so that we can count how much there is altogether?" [PROBQAIN; NMK; PTMK]<br>Brittney: "Break it up in 2s."<br>Victor: "2s, 5s." | CA; PROB; PROBQAIN; NMK; PTMK: Using the concrete apparatus, the teacher begins by probing the learners to think about whether they can count in 7s. She probes their thinking further and gets them to think actively of ways in which they can count the groups of 7, which is new maths knowledge. The learners need to think about their previously taught maths knowledge of counting in groups and apply it to counting in 7s. |
| 7. | Teacher B breaks the 7 blocks in each of the 4 groups into a group of 5 and a group of 2 [VIS DEM; CA]. Once Teacher B completes breaking the 7 blocks into groups, she says to the learners, "So let's count how much there is altogether?" [VERB DEM].<br>All the learners count: "5, 10, 15, 20… 22, 24, 26, 28."<br>The learners first count in 5s and then in 2s. | VIS DEM; CA; VERB DEM: Teacher B visually demonstrates the breaking up of the group of 7. All the learners verbally have to count the groups of blocks in 5s and 2s. |
| 8. | When the learners have completed counting the blocks in 5s and 2s, Teacher B goes back to Brittney's response that the blocks in each group could be broken up into 2s. She says, "Brittney had another way of doing it. Brittney can you share with the group how you would break it up?" [PROBQAIN; EVAL].<br>Brittney: "In 2s."<br>Teacher B: "Can you do it for me please?" [VIS DEM; EVAL; CA].<br>Brittney proceeds by breaking the 7 blocks in each of the 4 groups into 2s with 1 block remaining. | PROBQAIN; EVAL (2); VIS DEM; CA; EXP; NMK: Teacher B probes the learner to interpret actively and visually group the blocks in 2s as a way to demonstrate an alternative method of counting the blocks. The teacher evaluates the learner's thinking and understanding of grouping the blocks in 2s. Teacher B explicitly explains to the learners that there are different ways that the blocks can be grouped and counted. This is new maths knowledge for the learners. |

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| | As Brittney groups the 7 blocks in each of the 4 groups into 2s, Teacher B explicitly explains what has happened thus far in the lesson. She says, “Right. We can see that we have broken up 7 in two different ways, a 5 and a 2 and we can also break it up into three 2s, …one, two, three 2s , and one 1.” [EXP; NMK].<br>The learners then count the blocks in 2s and 1s.<br>All: “2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24.”<br>Teacher B: “24 plus 1?”<br>All: “25, 26, 27, 28.” | |
| 9. | Teacher B continues and tells the learners that she is going to give them a problem that they need to solve independently in their pairs [INSTIMP]. She gives the following problem: “Right I want to see 6 groups of 3.” | INSTIMP: Teacher B instructs the learners to solve problems independently in their pairs. She does not give them specific instructions on how they need to solve it. |
| 10. | As the learners work in pairs to place 3 blocks on 6 paper plates, Teacher B observes and probes the learners’ thinking with comments such as, “Listen, Brittney, *6* groups of 3. How many groups do you need?” “Now, I asked for 6 groups of 3, how many in *each* group?” [PROBQAIN]. “Can you show me your 6 groups please?” [PROBQAIN; VIS DEM; CA]. Teacher B also praises the learners for their efforts and makes comments such as, “Good, Ben, you’re checking. Right.” [VAL]. | PROBQAIN (2); VIS DEM; CA; VAL:<br>Teacher B probes the learners to interpret actively and think about what the problem is asking them to do, i.e. how many groups they need and how many blocks in each group. She asks them to demonstrate the problem visually, using concrete apparatus. She validates their efforts with praise. |
| 11. | When all the pairs have 3 blocks on 6 paper plates, Teacher B says, “Now, you’ve got 6 groups of 3 in front of you, now I want you to help each other and break up the number 3 into chunks that you can count in. What are you going to break up 3 into?” [PROBQAIN; NMK; PTMK; VIS DEM; CA].<br>Ben: “2 and 1”<br>Teacher B: “Show me…this is where you’re | PROBQAIN; NMK; PTMK; VIS DEM; CA:<br>Teacher B probes the learners to think actively about how they are going to group the 3 blocks into groups that they can count in. This is new maths knowledge as they have not been taught to count or group in 3s. In order to do this, the learners need to draw on previously taught maths knowledge, i.e. counting in 2s and 1s. The learners need |

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| | going to help each other. Now both of you check how many you have altogether. Talk with your partner and decide because your partner might have something different from you."<br>Learners count pointing to the blocks: 2, 4, 6, 8, 10, 12 (counting in 2s )… 13, 14, 15, 16, 17, 18 (counting in 1s) | to demonstrate their solution visually, using the blocks. |
| 12. | Teacher B continues the lesson following the same pedagogical moves with two other examples, i.e. 5 groups of 4 and 3 groups of 8. | |
| 13. | When the learners have completed grouping and counting 3 groups of 8, Teacher B asks the pairs to discuss the counting strategies that they chose to use. [VERB DEM]. She says, "Kabelo, can you describe to me how you broke up 8?" [PROBQAIN; EVAL].<br>Kabelo: "I decided to do it in 2s."<br>Teacher B: "Right, now…Pearl and Tristan, how did you break up your 8? Did you make it in 4s, 2s, and 1s?" [PROBQAIN; EVAL].<br>Tristan: "No, we did it in 1s, 2s and 5s."<br>Teacher B: "You did it in 1s, 2s and 5s. Because 5 plus 2 is 7 plus 1 is 8." [EXP.]<br>Teacher B asks Pearl and Tristan to count how many blocks there are in 3 groups of 8, using their chosen grouping. [VERB DEM; CA]. The learners count, pointing to the blocks. | VERB DEM (2); PROBQAIN (2); EVAL (2); EXP; CA: The teacher asks the learners to discuss how they have chosen to group the blocks in order to count them. She evaluates the learners' chosen strategy by using probing questions and asking them to interpret actively what they have done. Teacher B explicitly explains to the rest of the group a different strategy chosen by one pair in the group. The pair count pointing to the blocks. |
| 14. | However, Teacher B notices that when the learners count, although they have grouped the blocks in 5s, 2s and 1s, they revert back to counting the 2s in 1s. Teacher B says to the learners, "Why did you count in 1s, when you have got a group of 2s? [PROB, EVAL]. That was interesting [VAL]. You could break it up in 5s, 2s and 1s, but then you counted that as 1s instead of using it as a 2 [EXP]. | PROB; EVAL; VAL; EXP; VIS DEM; CA: Teacher B uses a probing question to get the learners to interpret and evaluate why they have counted differently to the way that they have grouped the blocks. However, the teacher does not allow for a response and does not allow the learners to interpret actively. Teacher B validates the learners' efforts and explicitly explains to them what |

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| | Okay, can we try and do it. 5…" [VIS DEM; CA].<br>The learners count pointing to the blocks: "…10, 15, 17, 19, 21, 22, 23, 24." | they have done. The teacher visually demonstrates to the learners how to count the blocks once they have been grouped. |
| 15. | Teacher B proceeds by explaining to the learners that she is going to give them a word problem [INSTIMP]. | INSTIMP: The teacher tells the learners that she is going to give them a word problem. She does not give them specific instructions on how they need to solve it. |
| 16. | The word problem she gives is as follows: "I feed my dog 4 biscuits every day. How many dog biscuits does she eat in 5 days?" [EMBD].<br>Teacher B continues and says to the learners, "How many days do I have?" [PROBQAIN; EVAL].<br>Learners: "7."<br>Teacher B: "*5* days." [EXP]<br>Teacher B: "Listen to my word problem. I feed my dog biscuits…4 dog biscuits every day. How many dog biscuits does she eat in 5 days? So how many days do I have? I have 5 days [EXP]. So how many groups am I going to have? If I have 5 days, how many groups am I going to have? Victor?" [PROBQAIN; EVAL].<br>Victor: "5."<br>Teacher B: "5 groups. [EXP]. Right. I feed my dog 4 biscuits every day. So how much will he get on the first day?" [PROBQAIN; EVAL].<br>Victor: "4."<br>Teacher B: "Show me the first day please." [VIS DEM; CA]. The learner places 4 unifix cubes onto a paper plate.<br>"How much will he get on the second day?"<br>Teacher B continues in a similar way until she gets to the fifth day. The learner places 4 unifix blocks on 5 paper plates. | EMBD; PROBQAIN (3); EVAL (3); EXP (3)<br>VIS DEM; CA: Mathematical construct of grouping is embedded in an everyday context. Teacher B probes the learners to interpret actively the number of days that the word problem refers to. When the incorrect answer is given, the teacher explicitly gives and explains the correct answer. She probes the learners to interpret actively and think about how many groups there are if they know how many days there are. She further probes the learner to think about how many biscuits the dog will get each day. Through the probing questions the teacher evaluates the learners' thinking and understanding of number of groups in relation to the number of days, as well as their thinking and understanding of the number of 'biscuits' that will go into each of the groups. The learner visually demonstrates, i.e. 4 unifix blocks on 1 paper plate. |

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| 17. | Teacher B: "I want to know *how many* biscuits does my dog eat in *5* days? So how am I going to find that out? What am I going to do?" [PROBQAIN; EVAL].<br>Victor: "You'll count them."<br>Teacher B: "Thank you, you're going to count them altogether to find out how many biscuits he eats altogether in 5 days." [EXP].<br><br>Teacher B: "Now I would like you to break your 4 into chunks that you can count in." [INSTEXP; NMK; VIS DEM; CA].<br>Victor breaks the 4 unifix cubes into a group of 2 and two separate 1s.<br>Teacher B: "Can you think of a quicker way than counting 2 plus 1 plus 1? [PROBQAIN; EVAL ]. What could you do with those two ones?" [NMK]. *This question she addresses to the rest of the group.*<br>Pearl: "You can put them together, so that you can count in 2s."<br>Teacher B: "Can I ask the rest of you to please count, how many dog biscuits he would eat altogether?" [VERB DEM].<br>Learners count the blocks in 2s.<br>Teacher B: "Thank you. Right. How many biscuits altogether in 5 groups of 4?" [PROBQAIN; EVAL].<br>Learners: "20." | PROBQAIN (3); EVAL (2); EXP; INSTEXP; NMK (2); VIS DEM; CA; VERB DEM: Teacher B probes the learner to think actively about how to find out how many blocks there are altogether once all the blocks have been grouped. The teacher evaluates the learner's understanding of how to find the value of the blocks once they have been grouped. She explicitly explains that the blocks will need to be counted altogether. Teacher B gives the learner explicit instructions to group the 4 blocks on each of the 5 paper plates into smaller 'chunks' so that they can be counted altogether. She probes the learners to think actively of quicker ways to count the blocks to what has been put out. Grouping or 'chunking' the blocks into groups for quicker counting is new maths knowledge for the learners. The learners count the blocks aloud in 2s. She probes the learners to interpret actively how many biscuits there would be altogether and evaluates whether the learners understand how many blocks there would be in 5 groups of 4. |
| 18. | Teacher B follows the same pedagogical moves with another word problem and concludes the lesson. | |

*Summary*

In the instructional practice of Teacher B in this follow-up lesson, there is evidence of the alignment between the pedagogical moves that she chooses and the diagnosis that she makes about the difficulties learners are experiencing in Number. In the Phase Three interview, Teacher B explained that she wants to encourage the learners to count in groups by getting the learners to "see what 7 groups of 7 looks like," and by allowing the learners to show her "different ways of making 7 and then

putting it into groups" (Appendix B iii, 3.1, paragraph 9, p.16). In this follow-up lesson, Teacher B frequently uses concrete apparatus and visual demonstrations in her pedagogical moves as a way to encourage the learners to "see" and "show" her what different groups (unifix blocks) would look like. As she uses the moves of concrete apparatus and visual demonstrations, she simultaneously uses probing questions and active interpretation to encourage the learners to apply, actively interpret and work with counting in groups. Throughout the instructional practice, Teacher B uses the move of evaluation to check the learners thinking and understanding in relation to the diagnosis made.

**Appendix B ii (R)**

**Teacher B**

| AS | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 2.1.10 | Unable to use the technique of doubling.<br>- unable to show appropriate methods of doubling<br>- solutions are inaccurate. | Uses the technique of doubling.<br>- able to show appropriate methods of doubling but solutions are inaccurate. | Uses the technique of doubling accurately.<br>- able to show methods of doubling using ones and/or twos accurately.<br>- solutions are accurate. | Uses the technique of doubling accurately.<br>- able to show methods of doubling using ones, twos, fives and tens accurately.<br>- solutions are accurate. |
| 2.1.10 | Unable to use the technique of halving.<br>- unable to show methods of halving appropriately.<br>- solutions are inaccurate. | Uses the technique of halving.<br>- able to show appropriate methods of halving but solutions are inaccurate. | Uses the technique of halving accurately.<br>- able to show methods of doubling using ones and/or twos accurately.<br>- solutions are accurate. | Uses the technique of halving accurately.<br>- able to show methods of halving using ones, twos, fives and tens accurately.<br>- solutions are accurate.<br>- able to write the correct notation for half. |
| 2.1.4 | Unable to compare whole numbers to at least 2-digit numbers.<br>- unable to identify numbers before and after a given number. | | Able to compare whole numbers to at least 2-digit numbers.<br>- able to identify numbers before and after a given number. | |
| 2.1.8 | Unable to perform calculations to solve problems involving addition. | Performs calculations using appropriate symbols but adds inaccurately. | Can perform calculations, using appropriate symbols, to solve problems involving addition of whole numbers. | Can perform calculations, using appropriate symbols, to solve problems involving addition with solutions beyond 50. |
| 2.1.8 | Unable to perform calculations to solve problems involving subtraction. | Performs calculations using appropriate symbols but subtracts inaccurately. | Can perform calculations, using appropriate symbols, to solve problems involving subtraction of whole numbers. | Can perform calculations, using appropriate symbols, to solve problems involving subtraction with solutions beyond 50. |
| 2.1.10 | Unable to use the technique of building up and breaking down number.<br>- unable to use the correct coins to make the amount of money | | Able to use the technique of building up and breaking down number.<br>- uses the 1c, 2c, 5c and 10c coins to make the amount of money accurately. | Able to use the technique of building up and breaking down number.<br>- uses the 1c, 2c, 5c, 10c, 20c and 50c coins to make the amount of money accurately. |
| 2.1.8<br>2.1.11 | Unable to perform calculations to solve problems involving addition.<br><br>Explains own solutions to problem:<br>• Applies inappropriate methods to repeated addition problems and solutions are inaccurate. | Performs calculations using appropriate symbols but adds inaccurately.<br><br>Explains own solutions to problem:<br>• Applies appropriate methods to repeated addition problems but solutions are inaccurate. | Can perform calculations, using appropriate symbols, to solve problems involving addition.<br><br>Explains own solutions to problem:<br>• Applies appropriate methods to repeated addition problems and solutions are accurate.<br>• Writes a matching number sentence for repeated addition problems. | Can perform calculations, using appropriate symbols, to solve problems involving addition.<br><br>Explains own solutions to problem:<br>• Reaches accurate solutions for repeated addition problems by chunking numbers in twos, fives and tens.<br>• Writes a matching multiplication number sentence for repeated addition problems. |
| 2.1.7<br>2.1.11 | Unable to solve solutions to problems that involve equal sharing and that lead to solutions that also include unitary fractions.<br><br>Explains own solutions to problem:<br>• Applies inappropriate methods of solutions to sharing problems.<br>• solutions are inaccurate. | Solves solutions to problems that involve equal sharing and that lead to solutions that also include unitary fractions.<br><br>Explains own solutions to problem:<br>• Applies appropriate methods of solution to sharing problems but solutions are inaccurate. | Solves solutions to problems that involve equal sharing and that lead to solutions that also include unitary fractions.<br><br>Explains own solutions to problem:<br>• Reaches accurate solutions and writes a matching number sentence for sharing problems. | Solves solutions to problems that involve equal sharing and that lead to solutions that also include unitary fractions.<br><br>Explains own solutions to problem:<br>• Reaches accurate solutions for sharing problems by chunking numbers in twos, fives and tens.<br>• Writes a matching number sentence for sharing problems. |

I did well in:

| | | | |
|---|---|---|---|
| Showing how to double numbers. | | Showing how to halve numbers. | |
| Finding the number before the given number. | | Finding the number after the given number. | |
| Adding numbers accurately. | | Subtracting numbers accurately. | |
| Making the amounts of money using coins. | | Solving repeated addition problems. | |
| Solving sharing problems. | | | |

One thing I can improve is:

| | | | |
|---|---|---|---|
| Showing how to double numbers. | | Showing how to halve numbers. | |
| Finding the number before the given number. | | Finding the number after the given number. | |
| Adding numbers accurately. | | Subtracting numbers accurately. | |
| Making the amounts of money using coins. | | Solving repeated addition problems. | |
| Solving sharing problems. | | | |

Teacher's Comment:

Teacher's Signature: _____

Parent's Comment:

Parent's Signature: _____

# Appendix C
# (Teacher C)

**Teacher C**

Teacher C is in her 2nd year of teaching and is teaching at a middle-class, government school in the East of Johannesburg.

**Appendix C i, Phase 1: Interview with Teacher C prior to the administration of the assessment task**

1.1. *Teacher C's understanding of assessment, its different forms and its role in diagnosing learning*

1. Teacher C, at the outset of the interview, explains that the understanding of assessment and its different forms, and the implementation thereof in the Foundation Phase of her school, is currently under revision. She explains that in the Foundation Phase they were previously mainly using "formal assessments," and these assessments were mainly based on the written work that the learners produced. She explains this as being a result of teachers trying to "cram a lot in," in an attempt to implement the new Foundations for Learning Milestones, as well as Work Schedules[1] that need to be completed by the teachers for the Department of Education. The teachers "found that [they] were assessing more than teaching and it was too much for [them] and for the children." As a result, the teachers have changed to doing "formal assessment for some of the things in a task," but have added what's called a "silent assessment." A silent assessment is an observational assessment where the teacher will give a tick and a cross (a tick being that the learner *has* achieved what is being assessed, and a cross being that the learner *has not*). Teacher C explains that a silent assessment is "not necessarily [based] on a written task in a book." For example, Teacher C says if she is assessing the "[learners'] ability to communicate their solutions, it will either be a tick or a cross for a silent assessment." However, a "formal assessment" is structured around a 1-4 scale that is based on descriptors that range in level of achievement of task (1- being not yet achieved (the lowest in the scale) and 4- being excellent (the highest in the scale)).

2. In explaining the purpose of "formal assessments" and "silent assessments," Teacher C says that for her "formal assessments," she takes the Assessment Standard on which she is focusing and assesses this Assessment Standard more than once using the 1-4 descriptor scale. The average 'mark' that she gets from the assessment then becomes the final 'mark' for that particular Assessment Standard. The following is an example she uses to illustrate this:

[1] This Schedule highlights for the Department of Education the Assessment Standards that will be covered in a particular term.

> What I do is for one Assessment Standard, I would maybe have assessed 3 or 4 times the same [Assessment Standard], so if it's counting patterns, for example, I would have assessed the same range 3 or 4 times before I got my final mark. So I would see, maybe they got a 4 for the first one [assessment task], a 2 for the second one, a 3 and a 1 for the last two tasks, then they would get a 2.

Teacher C says that because she would have done more than one assessment task per Assessment Standard, that the "formal assessment would or should have influenced the learner support that would come, [but it] didn't always happen."

3. In her explanation of the purpose of a "silent assessment" task, Teacher C explains that the Grade is still in the process of figuring out the exact purpose, but that the idea is that:

> It (the silent assessment task) should then affect how we're going to deal with it (the concept/concepts) because each silent assessment will be formally assessed in a later assessment task. So it should influence then how we would deal with that concept or subject matter."

Teacher C implies that current thought on the purpose of silent assessments is that it should influence the teaching and learning process.

4. When asked to comment on her understanding of formative assessment, Teacher C responds by saying:

> I thought that's what I was doing, (explaining) where it's more than one assessment on the same concepts or same Assessment Standard. So that you're getting 3 or 4 different marks, if you want to call it, or ratings on 1-4.

It is what Teacher C described earlier as her "formal assessment." She elaborates, however, and explains that not only is the same Assessment Standard assessed more than once, but that the same format is not necessarily used each time. For example, with number patterns:

> I do number patterns in the book where I give them the first three, so it's 1, 2, 3, and then they have to fill in 4, 5, 6, 7, 8, 9, but then they also have other little number charts where there's numbers missing. Like three consecutive numbers on the chart missing and then they would have to fill it in. Then, on a Friday, I might test a number pattern.

Teacher C's idea of formative assessment is constructed around the notion that firstly, it involves a number of assessment tasks based on the same Assessment Standard or concept, and secondly, that these assessment tasks will appear in different formats although assessing the same concept.

1.2. *Teacher C's views on what guides her selection and design of a formative assessment task*

1. Teacher C explains that the designing of formative assessment tasks in the Grade is largely driven by curriculum documents and assessment requirements as outlined by the Department of Education. There is a very particular process that the teachers follow in attempting to ensure that Department requirements are met. The Milestones document is looked at by the teachers in the Grade, and these milestones are then "grouped" or linked to the Assessment Standard/s that the teachers feel are being referred to by the milestone/s. This, in turn, is linked to the assessment tasks that are given by the Department on the content or concepts that should be covered in a particular term, and in a particular assessment task. This process is explained by Teacher C as follows:

> We took all of those Milestones and Assessment Standards and we tried to sort of group or link which Milestone refers to which Assessment Standard, and then we basically put it on a huge grid of what would be…done during which term in the year and you know, the assessment tasks it does give you what should be done in assessment task one, assessment task two. But what we also had to deal with was work schedules which were given to us by the Department. So we also had to take what the Department gave us and what they needed us to cover in term one, link it to the Foundations for Learning and those Milestones as well as the Assessment Standards, and try and fit it in.

2. According to Teacher C, the designing of assessment tasks is largely driven by having to meet Department requirements. She explains that as a consequence, little has actually changed in the manner in which the teachers in her Grade are thinking about the designing of assessment tasks. She says:

> What we're basically having is exactly what we did before…so, we're just looking at what has been told we have to get done in a term and breaking it up into weeks and seeing how we can fit it into assessment tasks.

She explains that skills are mainly assessed in isolation in the Grade, and are very seldom carried through to another assessment task. Skills are not integrated, "For example, last term we did 2D and 3D shapes. This was in Task One. Ordinal number…the assessment was for Task Three."

3. However, as mentioned earlier in the interview, Teacher C reiterates that she, as an individual in the context of her own classroom, for formative assessment practices, tries to assess content/concepts more than once before making the decision on a final 'mark.' She explains that for her, the validity of this final 'mark' is achieved through making use of the 1-4 descriptor scale:

> If a child's getting a 4 for all four of the times that I've assessed them, then obviously it's a 4. Whereas if they're getting a 4 for the first time I've assessed it, but one every other time, it's not going to be a 4.

4. In conjunction with the 1-4 descriptors, Teacher C explains that she has an assessment grid," which she uses to make brief observational notes of what the learners are doing as they complete the tasks. Later on, she uses the information from these observational notes to formulate, in her mind, where the learners fall on the 1-4 scale with regard to the particular Assessment Standard being assessed. This assists with her making a decision on the final 'mark,' and with the validity of this final 'mark.'

5. However, Teacher C explains that in the designing of the assessment task that will be administered to the learners as part of the research process, she was less bound by Department regulations and designed and structured her task somewhat differently to what was earlier described in the interview as the Grade norm. She explains:

> I took problem solving as a topic and looked at my own NCS documents and saw what I think goes into problem solving, so calculation would be important in problem solving. Their ability to count would be important in problem solving. Their ability to verbalise their solution would be important.

6. Therefore, Teacher C took the topic first and aligned it to possible Assessment Standards. This is as opposed to taking the Assessment Standards first and aligning them to topics/concepts/content. Once she had decided on the Assessment Standards that could be aligned to the topic, she explains that she narrowed her focus further and decided that, because she was working with the weak group, her main focus would be on counting. She felt that:

> [Her] weak group were battling with grouping and skip counting, and they were basically rote counting and they [were] not really at a point where they [could] understand how their counting [could] help them to solve problems.

7. Once Teacher C's specific focus for the assessment task has been established, she explains that she then designs a rubric where she more intentionally tries to 'break up' what skills she will be assessing as the learners complete their solutions. For example, "1[2]- they cannot calculate even when assisted. A 2- battles to know which calculation…a 3- they can calculate but there might be small errors, a 4- is perfect calculation." From Teacher C's explanation of the process that she undertook in the designing of the task to be administered, it is apparent that Teacher C follows a very particular process in moving from the broad to the more specific. That is, from a general topic to designing and aligning the task to specific skills to be assessed. Although Teacher C works with the NCS when designing the task, it is not the

[2] A key ranging from 1-4 is used on the assessment rubric to rate the learner's achievement of the selected Assessment Standard/s.

sole driving force, as she intentionally considers the skills of the learners to be assessed. She does, however, talk little about the diagnostic use of this assessment.

### 1.3. *The mental processes which with Teacher C thinks learners need to engage, in order to have a sound sense of Number*

1. When asked to comment on the mental processes with which, in Teacher C's opinion, learners need to engage in order to have a sound number concept, she explains it by relating it to three types of knowledge that she has included in the design of her assessment task.

Firstly, physical knowledge:

> Looking at my weak group, the first would be physical understanding. So what I've done in my assessment task is I've given them physical, concrete apparatus. If the story problems are on pens, they'll have physical pens to work with.

Secondly, social knowledge:

> Then there'll be a sort of opportunity for them to talk about it, get information from their peers…or me as the educator would step in and give them the social knowledge to actually just clarify their thinking. So the social knowledge will come in from the talking and the actual language being used during that talking period, the terms they're using – "add," "subtract."

Thirdly, logico-mathematical knowledge:

> That leads into their actual ability to calculate - their logico-mathematical knowledge. I think that will be the highest form of understanding that they'll reach, and that is just to calculate and to understand and verbalise their calculation, explain their solution and just to have clarified it in their minds.

2. In the explanation that Teacher C gives, she has deliberately designed the assessment task to incorporate what she believes are important mental processes (which she explains in relation to three types of knowledge). She believes that these are what learners need to be exposed to, to encourage the development of a sound number concept. She also highlights that the decision to incorporate the particular types of knowledge in the assessment task is taken after she has carefully considered the ability group with which she is working. She explains this by saying the following, "In my top group, I have [learners] who wouldn't even look at the concrete apparatus, [they] would just mentally work through the problem and finished." She would, therefore, not necessarily include the use of concrete apparatus, as a mental process, in an assessment task designed for this particular group. However, when working with the weaker ability group she has chosen to incorporate it.

*1.4.* *The purpose of the designed task and what Teacher C expects to be elicited by the task about learner difficulties in Number*

1. Earlier in the interview, Teacher C describes the design of her assessment task, and explains that she has designed the task with the intention of assessing particular skills. However, at this point in the interview, she is asked to reflect more specifically on what she sees as the intention of the assessment, namely, the purpose behind assessing the chosen skills. What is it that Teacher C would like to learn about the difficulties that the learners are experiencing in Number from the skills that she has chosen to assess?

2. Teacher C starts off by saying that because she will be using problem solving as her topic, a *central* purpose of the designed task will be to look at the learners' "ability to calculate." In her opinion, the "ability to calculate," when solving a "story problem," is taken to "just a little bit of a higher level." This "higher level" she links to the idea that, in order to calculate, the learners need to process information. Teacher C says, "So once they've processed the information in the story sum, can they put it into 3 + 2 = 5." Teacher C explains that besides assessing the learners' ability to calculate, an embedded purpose of the designed task will be to assess the learners' ability to process information. Not only will the learners' ability to calculate be influenced by their ability to process information, but Teacher C explains that it will be influenced by the strategies or methods that the learners use to count. For example, "Are they grouping, are they counting in 5s?" Assessing the strategies or methods that the learners are using to count is, therefore, also explained as a purpose of the task. Finally, linked to calculation and as a purpose of the task, Teacher C explains that she will be looking at "how they actually display it (their solutions)." This will include the manner in which they display their solutions using concrete apparatus, as well as the manner in which they display their solutions using pictorial representation.

3. Teacher C explains the purpose of the assessment task by relating it to the skills being assessed. She appears to have designed the task bearing these skills in mind, but does not explicitly explain what will be done with the information gained about these skills from the assessment task. She does not explain exactly what it is that she is trying to learn about the learners' numerical understanding, or the difficulties that they are experiencing in Number from the skills being assessed. For example, what diagnostic information she will gain from the manner in which they work with concrete apparatus.

*Summary*

In this first interview, Teacher C advocates that formative assessment tasks are what she refers to as her "formal assessments." For Teacher C, a "formal assessment" task is where a particular Assessment Standard is assessed a few times using a 1-4 descriptor scale. From these assessments, a final 'mark' is decided upon. Teacher C does not talk diagnostically about these "formal

assessments," but rather on how the average 'mark' obtained from these assessments help her decide on the final 'mark.'

The design of assessment tasks, she notes, are primarily driven by Department requirements and skills are often assessed in isolation. However, for the purposes of the research, the designed assessment task is planned from the broader topic, i.e. Problem Solving is matched to what Teacher C has selected as appropriate Assessment Standards and finally, is related to the chosen skills to be assessed. The skills that Teacher C has chosen to assess are: the learners' ability to calculate and process information, counting strategies used and the learners' use of concrete apparatus and pictorial representation. Within the design of the task, Teacher C has included the three types of knowledge that she sees as important in order to have a sound sense of Number, i.e. physical, social and logico-mathematical knowledge. The careful designing of the task is particularly foregrounded by Teacher C in this interview.

**Appendix C ii, Phase Two: Coding of pedagogical moves used by Teacher C in the administration of the assessment task**

The following coding was used:

| Coding (pedagogical moves) | Abbreviation |
|---|---|
| Previously Taught Mathematical Knowledge | PTMK |
| New Mathematical Knowledge | NMK |
| Everyday Knowledge | ED |
| Embedded Mathematical Knowledge | EMBD |
| Socialisation | SOC |
| Verbal Demonstration | VERB DEM |
| Visual Demonstration | VIS DEM |
| Evaluation | EVAL |
| Validation | VAL |
| Instruction Explicit | INSTEXP |
| Instruction Implicit | INSTIMP |
| Explicit explanations | EXP |
| Criteria Explicit | CRITEXP |
| Criteria Implicit | CRITIMP |
| Concrete Apparatus | CA |
| Probing | PROB |
| Probing Questions and Active Interpretation | PROBQAIN |

*Setting*: Teacher C is with her class of twenty eight learners. The seven mathematically weaker learners come and sit at the front of the classroom on the mat with Teacher C. Teacher C instructs the rest of the class to work independently on practical and written tasks within their differentiated groups.

*Focus*: Formative assessment task – Word Problems (Addition and Subtraction)

| | **Pedagogical Moves** | **Categorisation** |
|---|---|---|
| 1. | Teacher C tells the group on the mat that they are going to do a word problem. She explains to them that she is going to work through the word problem with them [INSTIMP]. | INSTIMP: Teacher C explains to the learners that they are going to solve a word problem. She does not give them specific instructions on how to solve it. |
| 2. | She states the word problem as follows: "James has 8 cars. Thando has 4 *less.* How many cars does Thando have?" [EMBD; SOC]. | EMBD; SOC: Mathematical construct of subtraction is embedded in an everyday context. The learners are socialised into the mathematical language associated with subtraction in the phrasing of the word problem, i.e. "less." |
| 3. | Teacher C asks the learners to try solving the problem on their white boards independently before she goes through the steps with them [INSTIMP; PTMK]. | INSTIMP; PTMK: The teacher tells the learners that they are going to solve a word problem. She does not give them specific instructions on how they need to solve it. The learners need to apply previously taught maths knowledge (counting, value of a number, number symbols and number operations) in the solving of the problem. |
| 4. | Teacher C observes as the learners solve the word problems. | |
| 5. | Once all the learners have attempted solving the problem, Teacher C selects a learner who has not managed to solve the problem correctly and asks him to verbalise the strategy that he used [VERB DEM].<br>She asks the learner, "How did you work it out?" [PROBQAIN; EVAL]. (The learner has solved the problem as 8 + 4 = 11).<br>Chesney explains and says, "I took the 8 cars and I plussed it to the 4 cars and I got 11 cars." | VERB DEM; PROBQAIN; EVAL: Teacher C probes the learner to think actively about how he has solved the problem and in so doing, evaluates the learner's thinking. |

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|---|---|---|
| 6. | Teacher C: "How did you plus?" [PROBQAIN; EVAL].<br>Chesney: "I said 8, 9, 10, 11."<br>Teacher C: "I want you to check your counting…put 8 in your head, now count…8… (pause) 9, 10, 11, 12." [INSTEXP; VERB DEM].<br>(Teacher C and learner count together).<br>Teacher C: "Right, so the answer is 12."<br>Teacher C: "But was it a plus sum?" (She directs this question to the group) [PROBQAIN].<br>(Four of the seven learners shake their heads to indicate: 'No,' it was not a plus sum). | PROBQAIN (2); EVAL; INSTEXP; VERB DEM: The teacher probes the learner to think actively about how he counted. Using probing questions, the teacher evaluates the learner's thinking. Teacher C gives the learner explicit instructions and verbally models, with the learner, the counting strategy that should have been used. She probes the learners (this time focussing on the group) to decide actively whether addition was the correct operation. |
| 7. | Teacher C then reads the word problem again, and this time emphasises the word *less.* She asks the learners to give words that mean the same as "less" [SOC]. The learners respond and say, "fewer," "take away" and "minus." | SOC: The learners are explicitly socialised into the mathematical language associated with the word "less." |
| 8. | Teacher C then asks the learners, "So what is the problem asking us to do?" [PROBQAIN; EVAL].<br>One of the learners, "To take away." | PROBQAIN; EVAL: Teacher C probes the learners to think actively about what operation the word problem is asking them to perform. She evaluates whether learners' understand the relationship between the mathematical language in the word problem and the operation to be performed. |
| 9. | Teacher C writes the number sentence on her white board as she says, "8 – 4 = 4" [VIS DEM]. | VIS DEM: The teacher demonstrates the writing of the correct number sentence. |
| 10. | Teacher C then gives each of the seven learners a word problem on a workcard. This is given with the matching concrete apparatus [CA]. For example, if the problem has potatoes in the word problem, the learners receive a container with potatoes in it [EMBD]. The learners are instructed to complete the problem that they have been given and then to swap it for another word problem. They are instructed to continue swapping until they have completed all seven word problems [INSTIMP].<br>(These seven word problems are what make up | CA; EMBD; INSTIMP: The learners are given concrete apparatus to use in the solving of problems. Mathematical constructs are embedded in an everyday context within the word problems. Teacher C explains to the learners what needs to be done. |

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| | their formative assessment task). | |
| 11. | Teacher C gives the learners a recording sheet. She explains to them that they need to record a number sentence and a picture for each of the seven word problems on the recording sheet [CRITEXP; INSTEXP] (Refer to Appendix C ii (R), p.25). | CRITEXP; INSTEXP: Expectations and criteria are made visible to learners by the explanation and instructions that are given by the teacher. |
| 12. | The word problems that the learners need to solve either require addition or subtraction as the operation to be performed in the solution of the problem [PTMK]. The word problems also make specific use of mathematical language associated with addition and subtraction. For example, "more," "less" or "fewer" [SOC]. For example, "Mom has 5 cups, she buys 7 *more* cups. How many cups does she have altogether?" or "Jim read 20 books, Lebo read 5 *less*. How many books did Lebo read?" [EMBD]. | PTMK; SOC; EMBD: In the solution of the word problems, the learners are expected to use previously taught maths knowledge to perform the correct calculation, (+ or -). The learners are socialised into the mathematical language associated with addition and subtraction, i.e. "more" and "less," through the wording of the word problems. Mathematical constructs of addition and subtraction are embedded in an everyday context. |
| 13. | Learners proceed and complete the assessment task. | |
| 14. | As the learners solve the word problems, Teacher C observes their solutions. She interacts with the learners by making statements and asking questions. For example, she says, "Tell me what you think you must do." "Why are you plussing?" [PROBQAIN; EVAL]. "What word tells you this in the word problem?" [PROBQAIN; EVAL; SOC]. "You know what to do, how can you work it out?" [PROBQAIN; EVAL]. | PROBQAIN (3); EVAL (3); SOC: Teacher C asks questions to probe the learners' thinking as they solve the problems. The learners need to interpret actively and reflect on what they are doing and their chosen strategy. In so doing, the teacher evaluates the learners' thinking. Teacher C socialises the learners into the mathematical thinking required in the solution of the problems by drawing attention to the mathematical language used in the wording of the problem. |
| 15. | Teacher C affirms the learners with comments such as, "Well done, I can see that you are on the right track!" "Keep trying." "Think about what I have taught you." [VAL; EVAL]. | VAL; EVAL: The teacher validates and evaluates the learners' responses. |
| 16. | The task ends once most of the learners have | |

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| | completed the word problems. Those who have not completed will be given an opportunity to do so in the next group session. | |
| 17. | At the end of the task, Teacher C takes in the papers that the learners are working on. This, together with her observation and questioning of learners as they solve the problems, is collated as the formative assessment task and recorded and finalised on an assessment rubric and observation sheet. This rubric is not returned to the learners once the task has been finalised [CRITIMP]. (Refer to Appendix C ii (R), p.25). | CRITIMP: The learners do not see criteria used in formative assessment rubric. |

*Summary*

In the pedagogical moves that Teacher C makes when administering the task, she actively encourages the learners to process the information given in the word problems. In the initial interview with Teacher C, the ability to process information is highlighted as a key skill to be assessed. The strategy that Teacher C uses to encourage this ability is to ask probing questions and to get the learners to evaluate their responses and solutions. By using probing questions and getting the learners to evaluate their responses, Teacher C attempts to promote the learners' socialisation into the mathematical language of number and how this may relate to the calculation to be performed.

Teacher C, in the initial interview on the design of the task, does not seem to place much emphasis on mathematical language. However, in the administering of the task, there seems to be a focused effort on this area and the language that the learners need to acquire for the solving of the word problems.

In the pedagogical moves of Teacher C, the three types of knowledge which she discusses in the initial interview are evident, i.e. "physical knowledge" (working with concrete apparatus), "social knowledge" (working with the mathematical language of "more" and "less") and "logico-mathematical knowledge" (working with number sentences).

The teaching strategy employed by Teacher C in the administering of the task, seems to have a greater diagnostic emphasis than what is alluded to in the initial interview, where the emphasis is placed on design (and the learners' acquisition of concepts, with less emphasis being placed on their reasoning). In the pedagogical moves made by Teacher C, the diagnostic emphasis is to be found in the probing questions and in the evaluation and active interpretation that is required by the learners.

**Appendix C iii, Phase Three: The follow-up interview with Teacher C after the administration of assessment task, where the diagnosis of learning is discussed**

3.1 *Teacher C's views on formative assessment and the diagnosis of learning*

1. Teacher C begins by explaining her understanding of formative assessment tasks in the same way as she does in Interview One. This is based on the idea that for one Assessment Standard there will be a number of assessments, and the average 'mark' gained from these assessments will make up the final assessment 'mark.' In Interview 1, the idea of using the formative assessment tasks as a means to achieve a final assessment mark is foregrounded. However, in Interview 2, Teacher C, in her explanation, shifts the discussion from the sole idea of using formative assessment tasks as a means to gather 'marks' to the idea of selecting and assessing specific criteria within the formative assessment tasks.

> Ok, my idea about [formative assessment] is still basically that for one Assessment Standard you'll have a number of assessments that you've done. And those combined marks will then form your final mark or what's going to go in the reports. But now I also see that within the different assessments that you're doing, as your formative assessments, you can be watching specifically for different criteria.

She explains and says:

> For my formative assessment I need a number of marks making up my final mark, but I could have broken up what I did more, so maybe this week look specifically at how they count. I am still assessing story sums but what I'm looking specifically within that may vary from assessment to assessment.

Although Teacher C would still be assessing the broad Assessment Standard, i.e. Word Problems, she proposes that within the different formative assessment tasks leading up to the final 'mark,' she could select and assess specific criteria as opposed to simply assessing the broad Assessment Standard.

2. Selecting criteria to assess within a formative assessment task is described by Teacher C as an important aspect for teacher diagnosis of learning. Teacher C explains teacher diagnosis of learning by saying that it is, "Teaching and assessing, but within that the teacher is looking at where the breakdown is happening." She elaborates and says:

> Your assessment is not just, they got a 1 because they can't do it and they got a 4 because they can do it. Your diagnosis would come in; they got 1, why did they get 1? They got a 4, where are the strengths that are enabling them to get a 4, and how can I harness that and how can I use it to better each learner's situation?

3. In this conversation with Teacher C in the second interview, although she does not discard marks in formative assessment, she seems to place a greater emphasis on selecting criteria and using this diagnostically to understand 'marks' attained. She says:

> [By setting] out in your mind beforehand to watch for specific criteria, you know what you are supposed to be looking for. In your own mind you need those specific things or else it makes diagnosis very difficult.

Teacher C, therefore, proposes that selecting criteria provides the focus needed for the diagnosis of learning.

4. Apart from selecting criteria for the diagnosis of learning, Teacher C suggests that the diagnosis of learning should be an integrated aspect of the assessment process. She explains:

> Before [I] did this task, I was thinking, I've got all these broad Assessment Standards and I need to get through my assessment. By my reports I need to have assessed A, B, and C. Then I was going back and seeing, okay, Child X is battling, now how can I help them, what additional support can I give them, and then I was trying to diagnose.

Thus, Teacher C explains that for her, the diagnosis of learning was something that came after all assessments for a particular Assessment Standard were completed. However, she says that now having engaged in the research task, she feels:

> I am (Teacher C) putting the cart before the horse and then trying to go back and see where a breakdown is happening. Where if I was diagnosing when I was actually assessing, I would have made my job a lot easier.

She proposes that by diagnosing learning as you are assessing, the teacher can "see what to address to achieve the broader Assessment Standard." Therefore, assessment is "not driven by: is it a 1, 2, 3, or 4, just to get to the end of reports, it is about diagnosing all the time to make your learner support meaningful."

### 3.2. *Information that Teacher C gained through the diagnostic assessment on learner difficulties in Number and how the diagnosis will be used to improve the teaching and learning experience of Number*

1. In diagnosing the learners' difficulties in Number as part of the research assessment task, Teacher C notes that many of the learners seemed unable to process the information given in the word problem. "They (the learners) were unable to break it down in their own minds and see, do I add? Do I subtract?" The learners did not seem to understand the concepts of more and less. This inability affected their end

answer because the learners “were either subtracting when they should be plussing or plussing when they should be subtracting.”

2. An interesting diagnosis, according to Teacher C, was the unexpected realisation that although the learners were able to work with concrete apparatus and count, they were ‘counting all’ rather than ‘counting on.’ Teacher C also observed that while one of the little girls “was touching and moving each object over as she counted, she still counted incorrectly.” The learner was unable to count accurately even when ‘counting all.’

3. Pictorially, Teacher C also diagnosed that for some learners the pictorial representation did not match the symbolic. Teacher C was not sure whether this meant that the learners were still more concrete bound rather than symbolic, or whether the idea of drawing a picture had become tedious.

4. Based on the diagnosis of difficulties the learners were experiencing in Number, Teacher C comments that while the assessment task for the most part had elicited what she expected, she had not expected the level of conceptual difficulty that the learners were experiencing. Based on the diagnosis of learning, Teacher C felt that although she knew that her weak group were weak, “they were actually quite a lot weaker than what I thought.”

5. She elaborates and says that although she had chosen the learners’ ability to process information as a criterion, and expected them to have difficulty with this, she had expected the learners’ conceptual understanding of “more and less to be a little better because [it] had been done in class before.” Teacher C says:

> It was prior knowledge which I thought had been developed and what I didn’t realise was that I’m also isolating…I’ve boxed things. They have done more and less on their grid charts but not as a word problem. The learners are not taking prior knowledge and using it for something else.

Teacher C admits, “I also thought that the counting would be a lot better and that they’d be able to count at least accurately even if it’s counting all.”

6. Using the diagnosis of the difficulties that the learners are experiencing with Number, Teacher C explains that the focus of her follow-up lesson will be on developing the learners’ conceptual understanding of more and less. The lesson will be structured to develop within the learners a sense of, “What makes a number more than another number? What makes it less?” Once this conceptual understanding is developed, Teacher C believes that the learners should then be able to process the information given in the word problem.

> I am hoping that if they've got that concept of more or less it will make the whole processing of the problem easier, because they'll know what to do when they see more, and know what's expected of them when it's less. So I'm hoping the two will link to each other.

The difficulties that the learners are experiencing with counting will not be specifically addressed in this follow-up lesson.

7. In the follow-up lesson, Teacher C explains that the learners will physically build a number line. As the numbers are built on the number line, there will be a discussion about each number, i.e. whether it is more than? Less than? And why? Following this the learners will solve, "Word problems [that] will be linked to the number line so they (the learners) can actually go to the number line and see what's more and what's less."

### 3.4. *What the cycle of activities that were included in the research process helped Teacher C to understand about formative assessment in the Numeracy Programme*

1. In Teacher C's concluding comments on what the cycle of activities included in the research process helped her understand about formative assessment, she discusses three specific areas, i.e. the idea of criteria, the role of diagnosis and the notion of using one task to assess different Assessment Standards.

2. As discussed in the opening of the interview, she explains that prior to the cycle she would assess one Assessment Standard a number of times, and this constituted what she considered to be her formative assessment practice. However, she now suggests that criteria are selected within the different tasks, and that a few specifics are assessed within the broader Assessment Standard.

> My biggest understanding of formative assessment has been changed. It was just an Assessment Standard that we were assessing over and over again. What I think needs to be done is, specific criteria needs to be set and be looked at within each different task. So the first time I'm assessing, I'll look at one specific thing. The next time I'm assessing it will be another specific thing. Each time you're assessing, you may be looking at different specifics within the broader Assessment Standard.

3. Teacher C proposes that the selected criteria for the formative assessment task should then be used diagnostically:

> I think that the formative assessment needs to be diagnostic, so that's what I am saying with the criterion, that's going to help with that. Because it's not just at the end of the day what needs to go in their report, it's how you're actually going to support the learners through.

4. Teacher C explains that amidst her initial feelings of pride at having acquired four or five different marks (her formative assessment tasks), the question was raised as to whether these marks were as significant as she originally believed because they were not being used to address the learners' needs or difficulties:

> I was quite proud of myself of having 4 or 5 different marks and saying, Ooh look at me, I can base it on this. But what did it mean? I was assessing the same thing without having addressed what needed to be addressed before assessing it again.

5. Finally, Teacher C notes that, in her opinion, through her participation in the cycle of activities, formative assessment tasks can be used to assess different Assessment Standards in one task rather than in separate tasks. She says:

> Another thing about formative assessment, different things can be linked in different Assessment Standards, different things that we are now assessing separately can be linked in one task. The understanding and the concepts are linked…assessing them together, instead of having all these separate things that you need to assess all the time.

*Summary*

In the second interview, Teacher C seems to shift from the notion that formative assessment is the idea that a number of tasks are done, to which 'marks' are allocated, in order to assess a specific Assessment Standard. She places a greater emphasis on the role of criteria and the diagnosis of learning using formative assessment tasks. By using the criteria selected for a task, Teacher C proposes that learners' learning can be diagnosed. Using this diagnosis, the teacher is able to provide support that addresses the learners' needs or difficulties. In this interview, Teacher C also suggests that formative assessment tasks can be used to assess a number of Assessment Standards rather than one Assessment Standard at a time.

She explains that while the task administered elicited what she had expected it to, the level at which the learners were experiencing difficulty was not expected, i.e. their understanding of the mathematical concepts of more and less. Therefore, in the follow-up lesson, Teacher C plans to develop this understanding by concretely building a number-line and discussing with the learners what makes a number more or less. Learners will then be asked to apply this knowledge to solving word problems that will use the mathematical language of 'more' and 'less.'

**Appendix C iv, Phase Four: Coding of pedagogical moves used by Teacher C in the follow-up lesson in response to the diagnosis made in Phase Three**

The following coding was used:

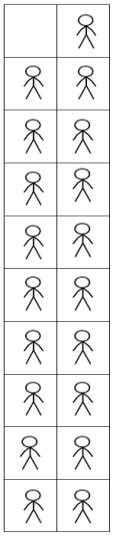
| Coding (pedagogical moves) | Abbreviation |
|---|---|
| Previously Taught Mathematical Knowledge | PTMK |
| New Mathematical Knowledge | NMK |
| Everyday Knowledge | ED |
| Embedded Mathematical Knowledge | EMBD |
| Socialisation | SOC |
| Verbal Demonstration | VERB DEM |
| Visual Demonstration | VIS DEM |
| Evaluation | EVAL |
| Validation | VAL |
| Instruction Explicit | INSTEXP |
| Instruction Implicit | INSTIMP |
| Explicit Explanations | EXP |
| Criteria Explicit | CRITEXP |
| Criteria Implicit | CRITIMP |
| Concrete Apparatus | CA |
| Probing | PROB |
| Probing Questions and Active Interpretation | PROBQAIN |

*Setting:* Teacher C calls the same seven learners who did the assessment task in Phase Two to the mat. The rest of the class work independently, completing a written task.

*Focus:* Teacher C chooses to focus the follow-up lesson on reinforcing the learners' conceptual understanding of 'more' and 'less.' Teacher C has diagnosed this as a difficulty that the learners are experiencing in Number, based on the formative assessment task.

| | Pedagogical moves | Categorisation |
|---|---|---|
| 1. | Teacher C starts the lesson and asks the learners to name things that they can use to count [PTMK]. The learners respond and say, “Abacus, hands, beans, number chart and a numberline.” She explains to the learners she needs them to help her make a number line [INSTIMP]. | PTMK; INSTIMP: Teacher C draws on learners’ previously taught maths knowledge on concrete apparatus that is used for counting. She explains to the learners that she needs them to help her make a numberline. She does not give specific instructions on how she would like them to do this. |
| 2. | Teacher C says, “Now, I have got some numbers here, and I want to know which one you think I should start with? What do you think?” [PROBQAIN; EVAL]. (She shows the learners six cards with the numbers 9, 10, 14, 12, 11, and 13 printed on them) [CA; PTMK].<br>Susan: “9.”<br>Teacher C: “Why 9?” [PROBQAIN; EVAL].<br>Susan” “Because there is no 1 in this number.”<br>Teacher C: “Okay, so there’s no numbers smaller than 9 in our pack.” [EXP; PTMK]. | PROBQAIN (2); EVAL (2); CA; PTMK (2); EXP: The teacher draws on previously taught maths knowledge related to the value and order of Number. She probes the learners’ thinking by posing a question that encourages them to think actively about which number would come first in the given series of numbers. When a learner responds with the answer, she poses another question to encourage the learner to think more deeply about the value of the number 9 in relation to other numbers, and why it would be at the start of this particular series of numbers. Using probing questions, the teacher evaluates the learner’s thinking and understanding on the value and order of number. Teacher C explains to the learner that there are no numbers smaller than 9 in the pack and draws on previously taught maths knowledge. The teacher uses concrete apparatus as a visual stimulus to encourage the learner’s thinking on number and number relations. |
| 3. | Teacher C explains to the learners that they are going to build a numberline and even though they know that there are numbers that come before 9 [PTMK], for today their number line is going to start with the number 9 [NMK; EXP]. She places the card with the number 9 on it [CA] at the start of a numberline. She has drawn this on the board prior to the lesson [VIS DEM]. | PTMK; NMK; EXP; CA; VIS DEM: Teacher C draws on previously taught maths knowledge on the value and order of number. She introduces and explains to the learners that a number line can start at any number (for the purposes of this lesson at the number 9). She visually demonstrates to the learners what they are going to do using concrete apparatus. |

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| 4. | Teacher C proceeds and explains to the learners that their lesson is going to be about school children [ED]. She says, "I've got some school children. If I want to put the same number of children as what this number is showing me, what do I need to do? How many do I need to put?" [NMK; PROBQAIN] (She shows them the number 9 on the number line and has cards with school children printed on them) [VIS DEM; CA].<br>Vusi: "9."<br>Teacher C: "Let's count together." [VERB DEM].<br>The learners count together. Teacher C puts down the cards as the children count. She does this until 9 cards are placed in front of the learners (Cards are placed in a vertical row) [CA; VIS DEM]. | ED; NMK; PROBQAIN; CA (2); VERB DEM; VIS DEM (2): Teacher C uses an everyday context to introduce the learners to new maths knowledge, i.e. matching the numbers (in this instance 9) to its value. She probes the learners' thinking by asking them to interpret actively what needs to be done. The teacher gets the learners to count with her. She visually demonstrates where the number 9 is situated on the number line and uses concrete apparatus to demonstrate its value. |
| 5. | Teacher C continues and asks the learners, "Now, what number on our number line would come after 9?" [PROBQAIN; EVAL; PTMK].<br>Gordon: "10."<br>Teacher C: "Is it this one?" (Shows a card with the number 12 on it) [PROBQAIN; EVAL; CA; PTMK].<br>Gordon: "No."<br>Teacher C: "Do you think that it's this one?" [PROBQAIN; EVAL; CA; PTMK]. (Shows a card with the number 10 on it).<br>Gordon: "Yes." | PROBQAIN (3); PTMK (3); EVAL (3); CA (2): The teacher probes the learner to think actively about what number comes after 9 by drawing on the learner's previously taught maths knowledge on the value and order of number. Teacher C uses probing questions to evaluate whether the learner can match the verbal to the written representation (concrete apparatus) of the number. |

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| 6. | As she places the card on the number line after the number 9 [CA; VIS DEM], Teacher C asks the learners, "Now what can you tell me about the number 10? Anything that you know about the number 10" [PROBQAIN; PTMK].<br>Natasha: It's almost like 9, but you have to get one more to make it 10."<br>Teacher C: "Well done!" [VAL].<br>Teacher C: "So, it's nearly the same amount as 9, but if I add one *more*, it's going to be?" [EXP PROBQAIN; SOC].<br>Learners: "10."<br>Teacher C puts down a vertical row of 10 cards with children printed on them next to the vertical column of 9 cards [CA; VIS DEM].<br> | PROBQAIN (2); PTMK; VIS DEM (2); VAL; EXP; SOC; CA (2): Teacher C visually demonstrates where the number 10 will come on the number line using concrete apparatus. The learners are probed to think actively about previously taught maths knowledge that they have related to the number 10. The teacher validates the learner's response with praise. She socialises the learners into the mathematical language associated with addition, i.e. "more," through an explicit explanation and encourages the learners to interpret actively that 10 is *one more* than 9. Concrete apparatus is used to demonstrate visually the difference in value between the number 9 and 10. |
| 7. | Teacher C continues and asks, "Lebo, which number do you think will come after the number 10?" (She holds up cards with the numbers 12, 11, 13 and 14 printed on them) [PROBQAIN; EVAL; PTMK; CA].<br>Lebo: "11."<br>Teacher C: "Why did you choose this number, Lebo?" [PROBQAIN; EVAL]. "Are we counting backwards or are we counting forwards?" [PROBQAIN; EVAL].<br>Lebo: "Forwards."<br>Teacher C: "Are the numbers getting bigger | PROBQAIN (4); EVAL (4); PTMK; CA: Teacher C probes the learner to think actively about what number comes after 10 by drawing on the learner's previously taught maths knowledge on the value and order of number. She uses concrete apparatus to encourage the learner's thinking on number and number relations. Through probing questions, the learner is encouraged to consider why she has chosen the specific response. Teacher C evaluates the learner's thinking and understanding of the value and order of number. The learner is |

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| | or smaller?" [PROBQAIN; EVAL].<br>Learners: "Bigger." | probed to interpret her response actively by thinking about the number 11 and its relations to other numbers. |
| 8. | Teacher C: "Okay, what can you tell me about the number 11?" (She places the number 11 card on the number line after the number 10) [PROBQAIN; PTMK; VIS DEM; CA].<br>Lebo: "It's like, you take 10 and you put one more and it makes 11."<br>Teacher C: "You have 10 and you put one *more* and it makes 11" [EXP; SOC]. "Okay. So if I have 11 what do I need to get to 10 then?" [PROBQAIN].<br>Lebo: "You must take one away."<br>Teacher C: "It's one *less*." [EXP; SOC].<br>Teacher C: "Let's count 11 cards together."<br>Learners count: "1,2,3,4,5,6,…" (Teacher C places 11 cards with school children printed on them in a vertical row) [CA; VIS DEM]. | PROBQAIN (2); PTMK; VIS DEM (2); EXP (2); SOC (2); CA (2): The learners are probed to think actively about the mathematical knowledge that they have related to the number 11. Teacher C visually demonstrates where the number 11 card will come on the numberline using concrete apparatus. Through probing the learner to think carefully about the relationship between the number 10 and 11, and through the explicit explanations given by the teacher, the learners are socialised into the mathematical language associated with addition and subtraction, i.e. "more" and "less." Teacher C visually demonstrates the value of the number 11 using concrete apparatus. |
| 9. | Pointing to the three different columns of children, Teacher C asks the learners questions such as, "Is this row the same as this row?" [PROBQAIN; EVAL]. (Pointing to the row of 9 cards and the row of 11 cards) [VIS DEM; CA].<br>Learners: "No."<br>Teacher C: "Why?" [PROBQAIN; EVAL].<br>Masego: "It's two more."<br>Teacher C: "Or?" [PROBQAIN; EVAL].<br>Masego: "It's two less." | PROBQAIN (3); EVAL (3); VIS DEM; CA: Using concrete apparatus to demonstrate visually, the teacher probes the learners to interpret actively the value of the numbers in relation to each other. In so doing, she evaluates and encourages their conceptual understanding of more and less. |
| 10. | Teacher C continues the lesson in a similar manner with the numbers 12, 13 and 14. As each number is introduced, it is discussed by asking the learners questions. For example:<br>Teacher C: "What is one less than 12?" [PROBQAIN; EVAL].<br>Susan: "11."<br>Teacher C: "11. Why? Would it be bigger or | PROBQAIN (5); EVAL (5); SOC: Teacher C evaluates the learners' thinking by using probing questions to get them to interpret actively the relationship that exists between numbers, i.e. whether they are 'more than,' 'less than,' 'bigger than' or 'smaller than' another number. Through probing, the teacher socialises the learners into the mathematical language of "more" and "less." |

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| | smaller?" [PROBQAIN; EVAL].<br>Susan: "Smaller."<br>Teacher C: "What is one more than 12? What do you think?" [PROBQAIN; EVAL].<br>Vusi: "13."<br>Teacher C: "Would it be bigger or smaller?" [PROBQAIN; EVAL ].<br>Vusi: "Bigger."<br>Teacher C: "So does it make it *more* or *less*?" [PROBQAIN; EVAL; SOC].<br>Vusi: "More." | |
| 11. | After the number line and the rows of children have been built to the number 14, Teacher C tells the learners that she has some word problems that she would like them to complete [INSTIMP].<br><br>She reads the following word problem to them, "There are 9 children in Mrs. Rabbit's class. There are 2 *more* children than this in Mrs. Hare's class. How many children are there in Mrs. Hare's class?" [EMBD; SOC]. | INSTIMP; EMBD; SOC: Teacher C tells the learners that they are going to do some word problems. She does not give them specific instructions on how they need to solve it. Mathematical constructs of addition are embedded within an everyday context. The learners are socialised into the mathematical language associated with addition, i.e. "more." |
| 12. | Teacher C instructs the learners to draw on their white boards and to use the number line or an abacus to help them with their solutions [INSTEXP; PTMK; CA]. | INSTEXP; PTMK; CA: Teacher C explicitly instructs the learners on the process that they need to follow in order to solve the problem. They are to use concrete apparatus and draw on previously taught mathematical knowledge. |
| 13. | When they have completed the word problem, Teacher C selects a learner and asks him to explain his solution. She says, "Wandi, do you want to tell me what you have written?" [VERB DEM].<br>Wandi: "Uh…9. 9 plus 2 equals 11."<br>Teacher C: "Okay, what in your mind told you…where to start?" [PROBQAIN; EVAL].<br>Wandi: "From 9."<br>Teacher C: "From 9, and then what did you do, you *added*..?" [PROBQAIN; EVAL; SOC]. | VERB DEM; PROBQAIN (3); EVAL (3); SOC (2):<br>A learner is chosen and asked to verbalise his solution. Teacher C probes the learner to interpret actively the solution he has given. In so doing, the teacher evaluates the learner's thinking and understanding. As the teacher probes the learner further, she evaluates whether the learner is able to make the link between the wording "more" and the operation of addition in the statement of the problem. |

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| | Wandi: “2 more.”<br>Teacher C: “What wording told me if I must plus or minus?” [SOC; PROBQAIN; EVAL].<br>Wandi: “More.” | |
| 14. | Teacher C continues the lesson by giving another word problem. She says, “There are 13 children in Mrs Flamingo’s class, if there are 3 *less* in Mrs Swan’s class, how many children are there in Mrs Swan’s class?” [EMBD; SOC].<br>When they have completed the word problem, Teacher C selects a learner and asks her to explain her solution. She says, “Kristen, I want you to tell me about your sum.” [VERB DEM].<br>Kristen: “It equals 10.”<br>Teacher C: “It does equal 10, but how did you know? What in the sum told you to take away?” [PROBQAIN; SOC].<br>Kristen: “3.”<br>Teacher C: “Ya, there is a 3, but what *word* tells me to take away?” [PROBQAIN; SOC].<br>Kristen: “Less.”<br>Teacher C: “Okay, now can you tell me, if it is less, if the answer is less, must it be bigger or smaller than 13?” [PROBQAIN; EVAL].<br>Kristen: “Smaller.”<br>Teacher C: “So then do we know we’re on the right track?”<br>Kristen: “Yes.”<br>Teacher C: “Well done!” [VAL]. | EMBD; VERB DEM; PROBQAIN (3); SOC (3); EVAL; VAL: Mathematical construct of subtraction is embedded in an everyday context. The learner is asked to verbalise her solution. She is probed to think actively about what mathematical language used in the setting of the word problem suggested that she should subtract. Through probing, the teacher evaluates whether the learner understands that if the answer is less, the number needs to be smaller. Teacher C validates the learner’s response with praise. |
| 15. | Following a similar pattern Teacher C gives the learners two more word problems and concludes the lesson. | |

*Summary*

In this follow-up lesson there is a strong correlation between the diagnostic assessment made by Teacher C and her pedagogical moves. In the second interview she identifies that the learners are experiencing difficulty with the conceptual understanding of more and less. They are also unable to relate the terminology of “more” to addition and “less” to subtraction within a word problem. Thus, she develops, in her pedagogical moves in this lesson, the learners’ conceptual understanding as well as their socialisation into the language by probing their thinking and getting the learners to demonstrate their understanding verbally. Teacher C makes use of visual demonstrations and encourages the learners to work with concrete apparatus throughout the lesson. Teacher C’s pedagogical moves in this lesson are reflective of her diagnosis made and chosen focus in the second interview.

# Assessment Task / Problem Solving

| | **Ability to count** | **Stage** | | | | **Ability to calculate** | | | | **Written** |
|---|---|---|---|---|---|---|---|---|---|---|
| | Counting strategy -counting on/back -skip counting | Pre operational | Operational<br><br>Concrete / iconic | Symbolic | Post operational | 1 Cannot calculate even when assisted | 2 battles to know which calculation | 3 can calculate – small error | 4 perfect calculation | 1 7 x<br>2 5-6 x<br>3 2-4 x<br>4 1 x |
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# Appendix D

**Interview Schedule: before assessment task is administered – Phase One**

**Questions**

1. What forms of assessment do you use in your classroom?
2. What do you see as the purpose of each of these forms of assessment?
3. What do you understand by formative assessment? (Thinking of asking this in case it doesn't come out in the first question)
4. In the new guidelines on assessment in the Foundation Phase, it emphasises using formative assessment as part of your work programme. How do you implement formative assessment in your Numeracy Learning Programme?
5. How do you select/design a task as part of your formative assessment plan and what guides your selection/design?
6. How do you ensure that the assessment you make is accurate and valid?
7. How do you align your assessment standards with the task you select/design?
8. What do you see as the purpose of this task that you have selected or designed on 'Number'?
9. Comment on your understanding of the mental processes that you think learners need to go through to develop sound number concept.
10. What specific parts of that mental process does this task give the learners an opportunity to exercise? Please explain in detail.
11. What difficulties in 'Number' do you expect to be elicited from this task?

# Appendix E

**Interview Schedule: after assessment task is administered – Phase Three**

**Questions**

1. What does the process of formative assessment consist of?
2. What do you understand by teacher diagnosis of learning?
3. What aspects do you think are involved in this kind of learning?
4. What do you see as the relationship between assessment in general and assessment which is aimed at diagnosing learning?
5. What did you look for when diagnosing learner difficulties in this task?
6. What have you diagnosed about your learners difficulties in 'Number' from this task? (mental process, prior knowledge, specific skill that is missing etc.)
7. Did the task elicit what you wanted it to elicit? How close was your diagnosis of learner's difficulties to what you initially thought would be elicited from the task you designed or selected?
8. What does this diagnosis tell you (about what) you need to address with your learners when you see them next time?
9. Comment on how you think you will use the information gathered in the diagnosis to address learner difficulties in the follow-up lesson/s.
10. What did the cycle of activities that were included in this research process help you understand about formative assessment?