

The importance's of the physical analogue clock in mediating learning of analogue clock time in Grade 4 learners.

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DEDICATION

I dedicate my work to the late Mr Nelson R. Mandela for his passion towards education in our country South Africa.

I especially dedicate this work to my loving parents who passed on while I was doing my studies. In remembrance of the high value they attributed to my schooling career. I thank you (Mummy & Daddy) for believing in me.

Lastly, to my wife De-Ann and my two children Alec and Alexis for encouraging me to study further.

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Thirdly, I thank the teacher and four learners for having voluntarily participated in sharing their perspectives pertaining to analogue clock time mediation using the physical clock. If it were not for their participation, data generation would not have been possible.

Fourthly, I thank my late parents Charles and Ester for instilling me the importance of a good education. I began to understand “good” as a hill of another hill in my own learning.

Fifthly, I thank my wife De-Ann and children Alec and Alexis for their support that enhanced my persistence and commitment to my studies. I appreciate the “time” you sacrificed to enable me to focus on my studies.

Finally, I thank God the Almighty for once more blessing me with the opportunity to gain experience as a researcher and eventually greatly expanding my knowledge base upon which my teaching practice is now founded.

ABSTRACT

My research topic concerns how learners use the analogue clock (as a human tool) to make meaning of clock time. This study is informed by a Vygotskian socio-cultural framework to learning and development based on the concept that human activities take place in cultural contexts and is mediated by tools. In this qualitative study I report on the learners meaning making of analogue clock time using the physical clock. This study was carried out at a South African primary school through an intervention programme after school.

The research employed a case study method. It involved a purposeful sample of 4 learners ($n=38$) from the grade four class group based on their response to a baseline assessment task. The selected sample of learners included learners across the ability spectrum to gain rich insight into how learners make meaning of analogue clock time.

Data collection and analysis was done through an interpretive approach. The video-taped interviews and intervention programme was my main instrument of data collection. Other research instruments included document analysis of responses to baseline assessment tasks. These research tools yielded the data collected and also allowed for triangulation.

My research topic explored how the learners make meaning of analogue clock time. In particular the two-way movement of how the learners use the physical tool namely the analogue clock to develop meaning and how the clock mediates clock knowledge in return.

The findings of the study suggest that learners' find it difficult to conceptualise analogue clock symbols and signs, in particular, in Afrikaans the half hour concept, in relation to the two hands. The physical analogue clock is also important to support and extend clock knowledge in solving time-related problems. This shows the power of the analogue clock to mediate meaning making of clock time in young learners.

Because of its potential to improve teaching and learning analogue clock time in primary school it is therefore recommended that the analogue clock time be further researched in South Africa.

DECLARATION OF ORIGINALITY

I, ROGER GREGORY METELERKAMP declare that this assignment is my own work written in my own words. Where I have drawn on the words or ideas of others, these have been acknowledged using complete references according to Departmental Guidelines.

A handwritten signature in black ink, appearing to read 'R. Metelerkamp', written in a cursive style.

15 December 2013

(Signature and Date)

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CHAPTER 1 - INTRODUCTION

1.1 INTRODUCTION

In this study I explore how a sample of grade 4 learners make meaning when reading, telling and writing analogue clock time and how they interpret and make meaning of the passing of analogue time.

Literature points to the evidence that learners between the ages of 8 years to 10 years (Grade 3 to Grade 4 level) have difficulty in understanding time and the representation as well as the measurement of time (Piaget, 1969; Long & Kamii, 2001; Kamii & Russell, 2012). Further that learner's only fully acquire time knowledge and skills at the age of 12 years (Grade 6 level in South Africa). For example, a European study described that learners in year 7 (11-12 years) did not know some rudimentary vocabulary and conventions for measuring time and ordering the past (Haydn, 1995 cited in Cockburn, 1999). My own teaching experience bore out difficulties encountered by this age in grasping analogue clock time.

Previous studies tended to look at the problem from a Piagetian cognitive perspective such as laboratory type approach (Kamii & Russell, 2012) while more recent studies argue for an 'educative' perspective in researching learners understanding of analogue clock time (Burny, 2012). This study will pursue a Vygotskian educative perspective that involves participatory interaction processes with the less knowledgeable learners. Thus I, the teacher, intentionally teach a sample of learners through continual collaboration with them and with their social milieu, with the children's desires and readiness to act together on the clock activity (Davydov & Kerr, 1995; Rogoff, 2008).

Because little research has been done on this problem using this perspective there is scope for research contribution here and there is no published current research in South Africa on this. Literature suggests that digital and analogue clock tasks involve substantially different processes. Unlike the analogue clock the digital clock reading only requires the retrieval of number names, whereas the analogue clock demands complex mental procedural sequences (Friedman & Laycock, 1989; Burny, 2012). Studies done suggests that learners were more successful in reading digital clock time such as 06: 30 because the learner essentially read the numerals separated by a colon as 6 hours and 30 minutes (Boulton-Lewis, Wilss & Mutch, 1997).

The study will be located in my own primary school in a semi-rural agricultural environment in the Eastern Cape in a small town called Alexandria which is some 70 kilometres from Grahamstown.

1.2. THE CONTEXT OF THE STUDY

1.2.1 THE SOUTH AFRICAN CURRICULUM AND ASSESSMENT POLICY STATEMENT (CAPS)

Both the Revised National Curriculum Statement (RNCS) (Department of Basic Education (DBE), 2002) and the new National Curriculum Statement (NCS) also referred to as the Curriculum and Assessment Policy Statement (CAPS) document within the mathematics curriculum in the intermediate phase, i.e. grade 4 to 6 (DBE, 2012) states that teaching and learning of mathematics should enable the learner to acquire the specific knowledge and skills necessary for the application of mathematics to physical, social and mathematical problems (DBE, 2011). Moreover learners should display mental, algorithmic and technological confidence and accuracy in constructing new insights and meaning.

The CAPS curriculum document for the intermediate phase mathematics says what content of time should be taught in the area of measurement. In the general content focus of measurement in CAPS (DBE, 2011, p.11) the focus is on “the selection and use of appropriate units, instruments and formulae to quantify events, shapes, objects and the environment”. It relates directly to the learner’s scientific, technological and economic worlds, enabling the learners to:

- make sensible estimates
- be alert to the reasonableness of measurements and results

The general content focus seems to direct teaching and learning towards the use of instruments to quantify time events, shapes, objects and the environment.

Furthermore the intermediate phase specific content focus suggests that learner’s use standardised units of measurement and appropriate instruments for measuring. Herein the measurement of angles, area, perimeter and capacity/volume is presented with no mention of time. Onwards in CAPS (DBE, 2011, p. 27) the phase overview of measurement of time says what content must be covered and the concepts and skills namely:

- reading time and time instruments (include clocks and watches)
 - read, tell and write time in 12-hour and 24-hour formats on both analogue and digital instruments
- calculations and problem solving time include
 - time intervals in minutes and hours

Seemingly CAPS (DBE, 2011) does not explain how it should be taught in the content area of measurement.

Turning back to when time must be taught the CAPS say that it should take place during the first term for a 6 hour duration on an ad hoc basis (DBE, 2011) while the Foundation for Learning document (DBE, 2010) sets it for the third term. The CAPS then recommends that learner's activities of read, tell and write clock time continue at frequent intervals during the entire year. It suggests that teachers teach clock time during the mental mathematics time, just before or after break time, before learners go home, or when they come in from a class in another venue. It seems that the concept of telling time and interval of time are to be taught in a less formal structured teaching and learning approach.

Although the CAPS description of what needs to be learned for time measurement is clear and direct, it provides few strategies of how to teach the measurement of time. For example it only mentions that measurement instruments such as clocks and watches are to be used to measure time. In contrast to this, a number of strategies and suggestions are presented on how to teach the concept of length and the measurement of length.

The main point argued here is that CAPS (DBE, 2011) being silent on any possible strategy to teach the topic time and also only allocating 6 hours in the whole year (which my own anecdotal experience and those of fellow teachers suggest is inadequate) is thus unhelpful and perhaps is creating an obstacle for teachers to tackle this matter effectively.

1.2.2 LITERATURE ON THIS PROBLEM

In essence the literature points that time telling is a complex and important cognitive skill that is required on a daily basis (Friedman & Laycock, 1989; Bock, Irwin, Davidson & Levelt, 2003; Burny, 2012). According to Friedman & Laycock (1989) the ability to understand

analogue clock time requires knowledge of several unique features such as reading displays, transforming times, and understanding times temporal referents (Friedman & Laycock, 1989).

Friedman & Laycock's (1989) study highlights the complex nature of clock reading that involves both the storage of associative time names for each confirmation and the use of retrieval processes to read the display. Herein underlies the bi-dimensional nature of the thought needed to simultaneously calculate the movement of hour and minutes hands in motion.

Kamii & Russell (2012) further point that learners construct time logically through reflective (constructive) abstraction of the coordination of hours and minutes. Herein they argue that the logical mathematical nature of time is overlooked. Moreover they make suggestions about how teaching practice can encourage conceptual thinking, by using the child's daily experience to think about duration of time. Importantly, they recommend allowing learners to do their own thinking about the elapsed time, hence enabling children's construction of logic-mathematical relationships.

In summary international literature seems to point to the difficulty of teaching and learning the concept of analogue clock time and the measurement of analogue clock time.

1.2.3 MY OWN EXPERIENCE

Looking at my own context of teaching and learning in grade 4 mathematics classes, I recognise similar difficulties mentioned in the literature.

Our South African mathematics curriculum promotes that learners should display confidence and accuracy when telling, reading and writing analogue clock time and calculating the passing of time (DBE, 2002). In contrast more often than not, grade 4 learners in my classroom struggle to display knowledge and skills for telling, reading and writing analogue clock time.

I concur with the curriculum that foundational knowledge (DBE, 2002) of the concept of measurement should be developed by working practically with different concrete objects (in this case, clocks). Additionally activities relating to time should be structured with the awareness that the understanding of the passing of time should be developed before learners read and write time (DBE, 2002, p.11). An international study portrayed that teachers' more

often use rote learning to teach the concepts of time, measurement of time and analogue clock time (Burny, Valcke & Desoete, 2009). This suggests that teaching time can become an obstacle without the necessary pedagogical content knowledge (Shulman, 1987) for instructional purpose to teach analogue clock time to learners.

The grade three teachers at my school and colleagues in other schools expressed frustration at teaching analogue clock time, saying that learners find it difficult to grasp and understand. More often, they shift teaching clock time from the first term to a later term because they feel frustrated with the learners' slow grasp of analogue clock time knowledge and skills. This would suggest that additional learning opportunities are needed to develop a deep conceptual understanding of the concept of analogue time for grade 4 learners.

1.2.4 THE PROVINCIAL ANNUAL NATIONAL ASSESSMENT (ANA) RESULTS

Reflecting on my school's mathematics departmental meetings at which the foundation (grade 1 to 3) and intermediate phase (grade 4 to 6) presented task analysis it pointed that learners in general did not perform well in time-related questions during the formal assessment tasks.

Similarly these performances were present in the ANA (Provincial Department of Basic Education (DBE, 2012) results regarding time-related questions. There were no formal reports on the grade 4 learners' time-related competency provincially for 2012; a formal report for grade 3 learners was available. The Eastern Cape Provincial Annual National Assessment (ANA) result for mathematics of grade 3 of 2012 reports the learners did not perform well in time questions. It should be recognised that the ANA test conditions occurred over a limited period and covered limited content of the content measurement of time to which learner may have engaged at school. Furthermore the type of the question and style of the questioning could have an influence on the overall result in Eastern Cape Province and elsewhere.

The Provincial Department of Education report illustrates that 38.3 % (see figure 1) of the grade 3 learners' in the Eastern Cape Province were able to answer time-related questions correctly (DBE, 2012). The report thus reflects that 61.7 % of the Eastern Cape grade 3 learners of 2012 were not able to correctly answer time-related questions. If the above mentioned report serves as a barometer then the current grade 4 class groups could be expected to perform roughly the same as in 2012. The report also supports my own and the grade 3 teacher's sense that learners have difficulties telling time in general.

Provincial ANA Analysis Question by Question Mathematics Grade 3 2012

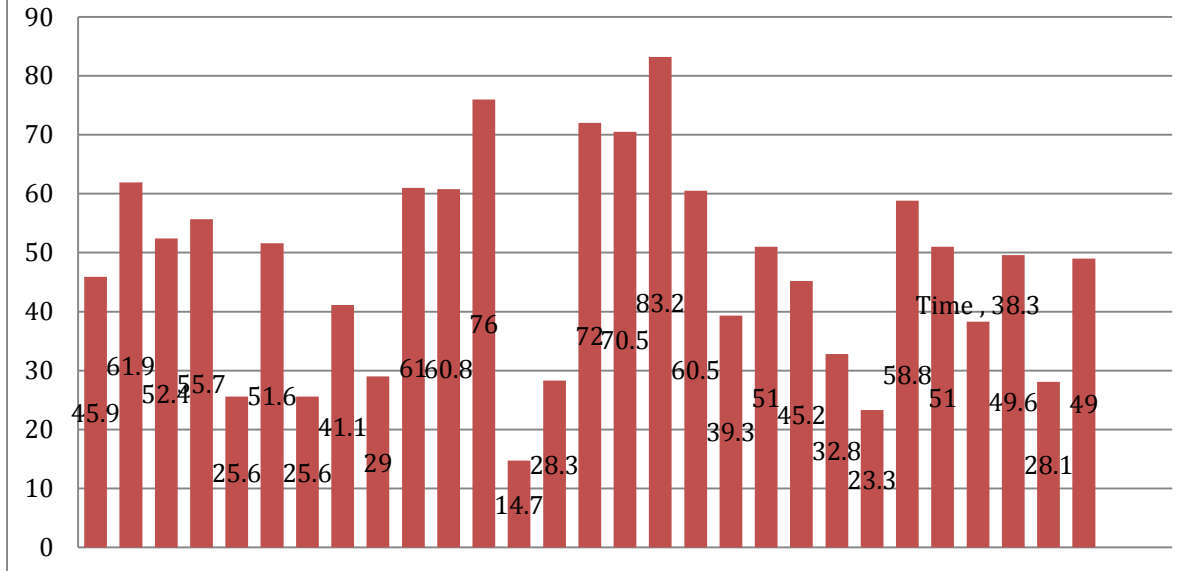


Figure 1: Eastern Cape Provincial ANA analysis of grade 3 (DBE, 2012) performance. In the graph above the fourth last bar indicates 38.3 learners could answer the question about time correctly.

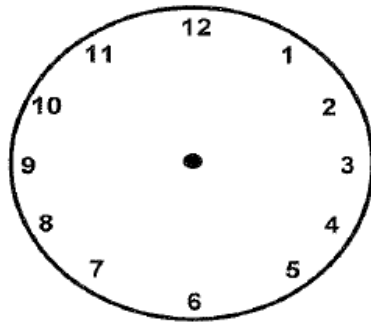
I present the type of the analogue clock time questions grade 3 learners had to do as taken from the ANA Mathematics paper for grade 3 of 2012. Three questions related to time were present in the examination. These are given below.

- a. Circle the letter which is in front of the correct answer.

We read 8.15 a.m. on an analogue clock as:

- A quarter past eight in the evening
- B quarter past eight in the morning
- C quarter too eight in the evening
- D quarter too eight in the morning

- b. Draw the hands on the hands plate of the clock in to show 11.30 p.m.



c. One and a half hour is the same as _____ minutes

(DBE, 2012, p. 11)

For the purpose of this study I limit the focus only to the ANA analysis for grade 3 of the Province of the Eastern Cape to provide a glimpse of the challenge learners might experience with analogue questions. While significant international studies show that low understanding and performance is prevalent in many countries for example United Kingdom and United States (Siegler & McGilly, 1989; Cockburn, 1999). It therefore suggests that this is not a case of a South African “maths crisis” (Fleisch, 2008) but rather a wide spread challenge of the difficulties of teaching and learning analogue clock time.

I conclude from this that this problem with reading, telling, writing and making meaning of analogue clock time is not a product of the well-known “maths crisis” of South Africa but a more profound and widespread aspect of difficulty in its own right.

1.2.5 SOUTH AFRICAN NUMERACY CHAIRS

The South African Numeracy Chair at Rhodes University is one of two national numeracy Chairs. A key Chair imperative is to research sustainable ways to improve the quality of teaching of in-service mathematics teachers at primary level and improve learner performance in primary schools as a result of quality teaching and learning (Graven, 2011). Within this Chair project there is a growing research community of both full time and part time doctoral and masters students. I am a part time Masters student conducting my research within the broader research aims of the Chair.

As a life-long learner and member of the research community at the SA Numeracy Chair at Rhodes University I see this as an opportunity to gain a better understanding of how grade four learners learn to tell, read and write analogue clock time.

1.2.6 PURPOSE OF THE STUDY

It is my intention to use the insight gained to contribute to the improvement of teaching and learning of the topic measurement of time particularly in my school, with the broader Numeracy Inquiry Community of Leader Educators (NICLE) of the South African Numeracy Chair community and with others through conference presentations.

My interest is to understand how grade 4 learners make meaning when learning to read, tell and write analogue clock time and the passing of analogue time. My study will focus on three aspects:

- First, I will seek to gain insight into how learners make meaning of time using the analogue clock.
- Second, I will explore how the physical analogue clock mediates the meaning making process in an afterschool intervention programme.
- Last, I will seek to gain insight into how the physical representation impacts on how learners' think and ways of thinking.

The two main research questions I will attempt to explore to gain insight and understanding are:

- a. How does the grade 4 child interpret the analogue clock time representation?
- b. How does an analogue clock mediate meaning making of analogue clock time?

2. OVERVIEW OF THE THESIS

This section provides an outline of the thesis which comprises six chapters.

Chapter 1 describes the context of the research, provides reasons for conducting the research and presents the purpose of my research.

Chapter 2 gives an overview of the relevant literature which addresses key concepts and principles of emergent analogue clock knowledge and skills. Firstly a glimpse of the history of the concept time towards the use of the mechanical clock is given. Secondly I look at the multifaceted nature of mechanical time and particularly how learners make meaning of time mediated by the analogue clock. Lastly I interpret the learners' meaning making using a conceptual framework of time-related competence.

Chapter 3 provides an outline of the research methodology selected for this study and the rationale for the choices made. Aspects dealt with in this chapter include the selection of the sample, the design of instruments and the research site. The approach used to analyse and interpret data, limitations and ethical considerations have also been described in detail.

Chapter 4 reports about the data collected through instruments mentioned in Chapter 3 that was analysed and interpreted. The analysis and interpretations of findings were categorised according to the theoretical framework in terms of what emerged through the interviews and intervention programme tasks.

Chapter 5 provides a discussion of the findings in the light of the literature reviewed. Particular attention is given to the central themes and constructs, namely how the physical analogue clock mediates meaning making to grade four learners understanding and gaining insight in the meaning making of time using the physical clock. Lastly insight on how this physical clock impacts on the learners thinking and ways of thinking is discussed.

Chapter 6 presents possible recommendations, implications and avenues for future research. I also point to the limitations of this research and my own learning as a researcher through this process.

CHAPTER 2 - LITERATURE REVIEW AND THEORETICAL FRAMEWORK

LITERATURE REVIEW

2.1. INTRODUCTION

The purpose of this chapter is to provide a contextual background to the study and also to review literature to find out what was previously researched in the field of telling time. In reviewing the literature I would briefly trace the development of the awareness of time as a human activity while focusing on the historical cognitive development of the clock.

The research draws on literature that primarily addresses how learners experience learning clock time using the analogue clock in the mathematics classroom. The research will review local and international research studies in mathematics education that reports how learners learn clock time and use the physical analogue clock to mediate meaning making. Especially how the learners in grade four (year 4) of formal schooling learn analogue clock time. Thus how learners make meaning when measuring time to tell time.

I also endeavour to establish whether any South African research has been done regarding the above-mentioned purpose. Importantly to the research would be to review the current South African mathematics curriculum for grade four learners as structured by the Department of Basic Education (DBE) with regard to how learners learn analogue clock time in year four.

2.2 HISTORICAL PERSPECTIVE OF TIME

This section provides a glimpse into how time awareness developed as an important human activity and why time became a powerful and important daily phenomenon in society. I chose to look at human beings' meaning making of telling time using cultural artifacts primarily the mechanical clock. Furthermore I provide a brief historical significance of the clock as it developed as a cultural tool to keep the time and also to measure the passing of time in a more precise way.

2.2.1 MEANING AND INTERPRETATION OF TIME

Literature more often described time as multi-facet with different meanings and interpretation with related function (Lakoff & Johnson, 1980; Burny, 2012). The awareness of time has been described as a fundamental human characteristic of human experience by reflecting on our

continuous experience. Whitrow (1988) suggests that although we as humans tend not to access the physical presence of time the “sense of time” involves some feeling or awareness of duration” that depends on our attentional interest of such events we experience (p. 5).

The gradual acquisition of time sense in learners can be closely correlated with the development of his/ her use of language as a thought articulator. Wallis (1966) as cited in Whitrow (1988) highlights that human awareness of the idea of the time is a product of human evolution that is neither innate nor automatically learned.

The product of time awareness involves an intellectual process of construction resulting from individual experience and action (Fraisie, 1984). The intellectual capacity in which language gradually develops increases both the child’s ability to understand and communicate time experience and action. Although awareness of the temporal phenomena seems inherent in personal experience it involves an abstract conceptual framework which humans gradually learn to construct (Piaget, 1969).

The awareness of time develops through a process of associative experience of the individual with events in the history of his / her social group (see also Siegler & McGilly, 1989). This awareness becomes possible through the development of memory. Thus an individual’s conscious realisation that things bear a relationship in different orders and function in relation to each constructs a sense of time.

Similar to Piaget’s (1969) ideas Whitrow (1988) found that very few learners at the age of 10 seems to grasp the abstract concept of time independent of actual clocks. Therefore he suggests that the grasp of the time concept depends on the rate of development of the child’s intelligence. I surmise that young children’s time knowledge and skills depend on the use of the actual physical clock because of the abstract nature of time.

Although pointing towards intelligence Whitrow (1988) acknowledge that attentional interest of a particular culture may influence whether time is seen as important or whether time dominates their lives or not. This suggests that certain cultural groups may find it difficult to associate or relate to actual clock time or time. It seems inconceivable for many to imagine life without the sense of time. It has however been claimed that certain human beings do manage very well without time.

The classic example is the Hopi of Arizona, whose language contains no words, grammatical forms, constructions, or expressions that refer to time or any of its aspects (Whitrow, 1988; Cockburn, 1999). The Hopi language prefers verbs rather than nouns and do not use terms that refer to space and time. The point made is that although for the Hopi group, time sense is different from the European view, they successfully developed agricultural and ceremonial time sense. Similarly, Evans-Pritchard as cited in Whitrow (1988), pointed that time has a different significance for the Azande of Southern Sudan.

In comparison to the Hopi group which recognise only two temporal states such as the present and past that is accessible or has been accessible to the sense, the Azande see the present and future as already existing (example here and now). Another Sudanese tribe the Nuer have no word similar in meaning for time and use social activities as reference to time sense such as cultural historical events such as spiritual, natural, agricultural and social experience and actions (Whitrow, 1988; Cockburn, 1999).

It seems that the construction of time sense develops closely with social activities which determines the relevance and need hereof. I will further engage with some aspects that perhaps necessitate clock time and thus leading to the invention of the mechanical analogue clock.

2.2.2 TIME TELLING DEVELOPMENT

This section explains why time telling became important as human development happened. Herein I also highlight some cultural contributions in the process of time telling such as the day consisting of a total of 24 hours as we know it today.

Literature shows that the temporal concept of instant time and duration of time was a contentious topic during the eighteen century. The arguments concerned reality as a thing completed (instant) or being to becoming (duration). According to Whitrow (1988) our experience of time is dualistic: intensity of sensation is associated with the instant, but the awareness of multiplicity of sensation depends on duration.

As mentioned the nature of time telling would be to locate experience and actions in space. Over centuries people have become fixated to know when, where and how long events took place. Williams (2004) puts that humans seem to be fixed by some absolute position in space-time (here and now idea) but points that our position or location in space time is always relative.

It seems to indicate that the position or location in space is fixed relative to objects while time is fixed relative to events.

Likewise the point in time can be fixed relative to prominent natural events such as sunrise or sunset. According to a cultural system the telling of time serves as a measuring object by reference of events. Changes in time telling systems over the centuries have moved from natural reference events to a system of measurement with less natural objects as reference.

The development of time telling was solved with the aid of the shadow sticks, sundials, and clocks of various kinds (Williams, 2004). The practical challenges the above presented to record the actual and relative time of events (here-and-now and also future) necessitated a device that could measure durations of time with two fixed points relative to each other.

The natural systems became impractical because of the non-standard scale used and change in the time position of the object being measured. For example if the location has a long winter or short summer then natural systems to measure time and duration become less accurate. Furthermore the sun's apparent motion produces three distinct reference points: sunrise, apex, and sunset. The above seem to point to the need to develop a measuring tool that could not be influenced by natural changes.

Although different cultural groups had contributed significantly towards time telling it seems that the Egyptians developed a specialised artifact known as a T-stick (Williams, 2004). The significance is that it divided the period of daylight into temporal parts. The T-stick used six reference lines to divide the day into twelve equal parts. Other cultural contributions worth mentioning are the Greek, Romans, and Arabs who used water clocks and sundials that divided the day into twelve parts because it became a key structuring element for the system of time measurement used today. Through this means the twelve hours for daytime were joined to twelve hours for night-time, producing a total of twenty-four hours in the period from one sunrise to the next (Williams, 2004). The cultural artifacts of water clocks, sundial and t-sticks highlight the fortitude of humans to tell and measure time of events.

2.2.3 THE MECHANICAL CLOCK

This section looks at the incentive of a time measuring device that could consistently tell time orderly which became the next benchmark in telling time. I look at the development of

mechanical clock as device to tell and measure time without interruption presented of a natural nature.

According to literature the mechanical clock developed during the middle ages in Europe from water clocks rigged to ring small bells at night, alerting monks when it was time to ring the monastery bells to ensure punctuality to prayer time. This bell-ringing function of the water clock prepared for the invention of the mechanical clock (Whitrow, 1988; Williams, 2004).

The English history of the word 'clock' relates to the Medieval Latin word *clocca* and the French word *cloche*, meaning bell (Dutch *klok*). As mentioned before the sundial was already mathematically divided into twelve segments, which is similar to the face of the mechanical clock. Significantly the mechanical clock device enabled us to measure daytime and night time hours through a second revolution of the indicator around the dial. Noticeable was bringing the daytime and night time hours together in a single device, thus clock time is displayed as a continuous process.

2.2.4 THE SOCIAL INFLUENCE OF THE MECHANICAL CLOCK

The reason for telling time seems to shift from religious to agricultural and more recently to an industrial motive. I briefly discuss the apparent shift in the purpose of telling time.

The clock included a special invention of the pendulum by Huygens (Williams, 2004) that made the clock more accurate and allowed the hours to be divided into smaller parts called "minutes" The shorter hand indicates the number of hours while the long hand indicates the number minutes. The two dials are read separately, in one or the other sequence, to construct a time reading that includes both hour and minute components.

With this back drop I expand on the importance of the hours and minutes with regard to our social existence in space. Williams (2004) presents that the temporal framework namely secular time created pressure for the development of the clock hour hence creating a standard unit of time. The development came about with the rise of industry. The textile industry in medieval Europe used the clock hour to measure labour. The socio-economic power of the hour clock increased in power throughout the world. More advancement in the hour clock made them more accurate, reliable, and affordable to the general public.

The practice of time telling and their associated artifacts were shaped by the cultural activities of particular social groups and their shifting power relations. Whitrow (1988, p. 112) eloquently describe the “economic power of the public clock in medieval time to open and close markets, to signal the start and end of work and to move people around”. The popular complaint of Jean in the Gargantua (1535) of Rabelais that applies even today was that “the hours are made for man and not man for the hours!” (Whitrow, 1988, p. 114)

Lakoff & Johnson (1980) underscore that our conceptualization of time seems to be grounded by a conceptual metaphor in which time is understood as unidirectional motion through space. Thus conceptualization of time in units such as days, hours, and minutes are culturally orientated ideas and meanings. More importantly is our interaction with the culturally developed artifact; the clock unifies different meanings and functions of time.

The historical development of time is continuously evolving in and with human development. More often time directs our daily experience and actions in a systematised and structured fashion may it be spiritual, agricultural, economic and socially.

2.3 MULTIFACETED PERSPECTIVE OF CLOCK TIME

This section presents literature on the notion of time in primary school focusing on grade four (year 4) learners’ cognitive acquisition hereof. My aim is to provide an educative perspective on how learners’ make meaning of time in particular the analogue clock.

Many studies address the child’s temporal concept of time concluding that the concept of time is complex and difficult to teach learners (Friedman & Laycock, 1989; Burny et al., 2009). According to Burny (2012) learners need to acquire time-related competences to enable meaning making of time and clock time. Thus I engage with Burny’s (2012) interpretation of Friedman’s (1978) (see also Friedman & Laycock, 1989) conceptual time-related model which includes the relative impact of mathematics, language and visual spatial competence.

Similar to Burny’s (2012) study Boulton-Lewis, Wilss and Mutch (1997) show that the time-related competences are basically mathematical activities that build upon children’s mathematical knowledge. Figure 2 below shows Friedman’s (1978) framework.

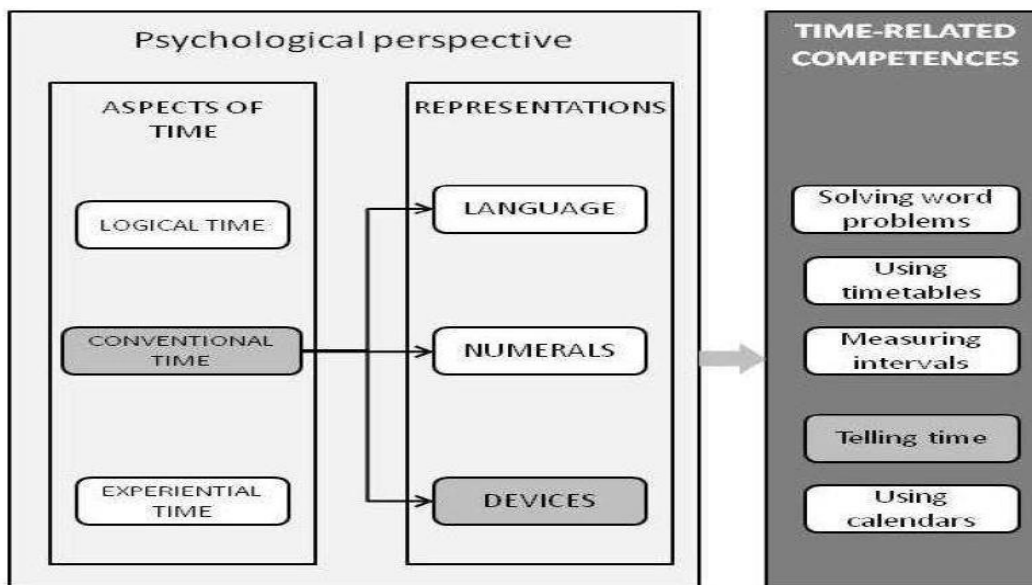


Figure 2: Time- related competence within framework of Friedman (1978) cited in Burny (2012, p.9)

2.3.1 PIAGET’S COGNITIVE MODEL

Essentially researchers use Piaget’s cognitive model as a theoretical position for understanding the child’s general perceptual and cognitive skills. This cognitive theoretical framework explains the developmental stages at which learners acquire the concept of time (Piaget, 1969; Friedman & Laycock, 1989; Block & Zakay, 1997; Long & Kamii, 2001; Kamii & Russell, 2012).

In Piaget’s (1969) view, the development of temporal cognition involves the gradual learning of coordinative relationships between spatial information and temporal information. Hence, Piaget’s research on logical mathematical knowledge suggests that learners in the operational development stage (grade 4) are able to judge that both objects had moved for the same duration. Kamii & Russell (2012) point that Piaget’s empirical research involved primarily qualitative quantification in which learners had to give verbal reasons using only three categories to classify a series of events. Thus they argue that numerical quantification is more precise but develops later than what Piaget proposed.

The emphasis is strongly about the internal mental structure involving attention and memory of temporal information. Piaget (1969) also seemed to have underestimated individual difference and neglected social and cultural differences between learners and the importance of a child’s interaction with the environment (Burny et al., 2009).

2.3.2 COMPLEXITY OF TIME

Time is a complex and multifaceted concept that has shown to be difficult for learners to understand due to its abstract nature and the absence of concrete representations (Lakoff & Johnson, 1980; Siegler & McGilly, 1989; Burny et al., 2009, Burny, 2012).

Although time is such an integral part of life, people ceased to think about it as a mathematical issue. Time has become a vital structuring element in today's society. Time varieties determine the planned nature of economics, politics, culture, communication and more. Cockburn's (1999) research highlights that lots of language has been learned from the time concept. Time is studied from different perspectives such as history, geography, language and mathematics that it seems ever present without a definite definition of it.

Time taught in the school curriculum, as a component of measurement, is far more elusive than measurement of length, volume, mass and money. Cockburn (1999) suggests that because of the elusive nature of time learners experience time as something abstract that cannot be seen or touched. So anything that represents actual and passing is instantaneous and disappears with the action experienced. The argument made therefore is that the passing of time is more elusive an experience than counting because it is difficult to go back to check the time event.

According to Williams (2004, p.86) learners find it difficult to understand that the motion of each hand on the clock face "starts" at the top (the 12) and proceeds in a particular direction (clockwise), completing a cycle when it reaches the top again—even though the motion of the hands is actually continuous, neither starting nor stopping at any point, and is so slow that the hands appear stationary.

Furthermore Block & Zakay (1997) give insight about the cognitive processes involved for a person to remember past events and anticipate future events. The complexity to estimate durations requires a person to encode temporal properties of events, construct cognitive representations, and use those representations for actions. Although meta-cognitive ideas remain useful to look at children's development it presents an incomplete picture as it only focuses on the logical aspect and did not look at experiential and social aspects (Burny et al., 2009).

Acknowledging the recognized complexity of the time concept and the difficulties learners experience in acquiring time-related competences, research about the development and learning of the time concept in learners has mainly remained descriptive and reflects few attempts to disentangle the complexity of children's acquisition of time related competences (Piaget, 1969; Fraisse, 1984; Block & Zakay, 1997).

2.3.3 MEASUREMENT OF TIME

According to Clements & Bright (2003) the measurement of time cannot be taught to learners by simply teaching them to read clocks because it involves a social convention (conventional). Thus alerting that the measurement of time also requires experiential (individual's subjective impression) and logical (knowing about succession and duration) convention knowledge (Burny, 2012).

A study by Haydn (1995) as cited in Cockburn (1999) underscores that many learners in year 7 (11-12 years) in the United Kingdom do not know some of the rudimentary vocabulary and conventions for measuring time and ordering the past. The conceptual understanding of the measurement of time or telling time seems not to be fully developed.

Long & Kamii (2001) distinguish measurement of time as different from reading clocks. Additionally time is one aspect of measurement that has not gone metric, so the relationships between the units, for example, 24 hours in one day; 60 minutes in an hour, and 60 seconds in a minute, seems to make converting units challenging. For example, the learners use a subtraction algorithm for finding the time intervals from one time to another presents various problems.

Haylock (2001) recommends that such challenges be done on an ad hoc process of adding-on. He suggests that learners use a number-line to find the time-interval from example 10.45 a.m. to 1.30 p.m. and avoid using a circle to represent it. Haylock (2001) puts that the conventional dial-clock is complicated by the fact that the hands go round twice in a day. Thus the use of the number-line can assist and make adding and subtracting of time-intervals easier for learners to calculate.

On the other hand Long & Kamii (2001) found that grade fours could construct units without relating their own action to time measurement instruments. More over by grade 6 learners

make logical sense of the measurement of time. I surmise that Long & Kamii (2001) were content to limit time conception to three kinds of logic-mathematical knowledge (transitive, unit iteration and conservation of speed) which seems relevant.

Recently Kamii & Russell (2012) describe Piaget's theory of logic-mathematical knowledge as consisting of mental relationships that each individual creates in his or her mind about elapsed time. The thinking required to coordinate hours and minutes simultaneously is logic-mathematical knowledge. Similar to Piaget (1969) Kamii & Russell (2012) view that the domain of mathematics requires logical reasoning and thought processes for learners to form time structures.

2.3.4 ANALOGUE CLOCK TIME

Time telling is a complex and important cognitive skill that is required on a daily basis (Friedman & Laycock, 1989; Bock et al., 2003). Available studies have shown that the ability to tell time from analogue clocks develops in a particular order. In short literature suggests the different orders such as beginning with the whole hours, half and quarter hours and then 5's and 1's minute units. I would promote that the aforementioned connect with the child's experiential, conventional and mathematical time related knowledge and skills.

Friedman and Laycock's (1989) conventional time (symbols and symbol systems) reading approach provides some fundamental insights into children's natural developmental acquisition of clock knowledge. They highlight the complex nature of clock reading that involves both the storage of associative time names for each configuration and the use of retrieval processes to read the display. Further they underline the bi-dimensional nature of the thought needed to simultaneously calculate the movement of hour and minutes hands in motion.

For now I briefly discuss the complex cyclic nature of the analogue clock. According to Williams (2004, p. 50) learners should learn that the "cyclic structure involve labels 1-12 and that the number labels are associated with the hours and the tick marks between the numbers with the minutes". Thus individuals must recognise that not all of the scales have explicit numeric labels. The hour scale has labels, but the labels for the minute scale and quarter-hour scale need to be filled in from imagination.

According to Williams (2004) the label '12' has many associations:

(1) in terms of order, it stands for the number between 11 and 1 in the repeating cycle; (2) in terms of quantity, it stands for twelve, zero, sixty, no quarters, and four quarters (or a whole); (3) in terms of the scales, it marks the origin and upper bound; (4) in terms of the indicators, it marks the starting point and endpoint of motion around the dial; (5) in terms of the solar day, it stands for midday (noon) and midnight; and (6) in terms of the system of time measurement, it marks the boundary between one sixty-minute hour and the next (on the minute dial). (p. 50)

Thus learners should learn to identify the kind of time like whole, half, quarter, five and one units as this may be another important step in learning to read the time from an analogue clock (Williams, 2004).

Returning to the notion of dimensional thought in learners I discuss Case, Sandieson & Dennis (1986) notion on children's cognitive development into three sub-stages of dimensional thought as cited in Boulton-Lewis et al. (1997). For the purpose of this chapter I confine myself to the dimensional stage of year 4 learners (grade 4).

Literature suggests that after learners go through the final sub-stage of inter-relational thought from 3½ - 5 years are they able to recognise certain clock numbers time such as 3 o'clock and move then to the dimensional stage. The first sub-stage is where the learners move to the unidimensional thought at age of 5 – 7 years and are able to seriate elements of time and can thus compare most hours of time on the clock. The second sub-stage is bi-dimensional thought from 7 – 9 years of age (grade 1 – 3 and grade 4 in South Africa) where the learners are capable to coordinate elements such as minutes and hours simultaneously if no compensation is required when the minute hand approaches the half hour.

My convenience sample includes learners of 9 years of age. In the last sub-stage, namely integrated bi-dimensional thought from 9 – 11 years of age (grade 3 – 5 in South Africa), learners should be able read clock times which recognise compensation hence where the minute hand moves towards the hour.

In addition Friedman and Laycock's (1989) research demonstrated that learners employ a mixture of retrieval and procedural strategies when they tell time and older learners rely more

on retrieval strategies than younger children. They state that clock time telling includes attending to the numeral landmarks to which the hour hand points to get the hour value.

Friedman and Laycock (1989) suggests that learners more often struggle to read and tell time when the minute hand passed the half-hour mark. They also point that learners more often read 'past the hour side' like 11:20 successfully than 'to the hour side' like 11:40 or 20 to 12 because learners are influenced by the 'right sector advantage' of the clock face.

Siegler & McGilly (1989); Friedman & Laycock, 1989 and Boulton-Lewis et al. (1997) respectively argue that when learners get more familiar with the landmarks of 3, 6, 9, and 12 as representative of the quarter hours they show confidence in reading whole and half-hour analogue clock time because the child with experience use their mental image of the movement of the two hands on the clock. This underlines that analogue time knowledge and skills involves learners to know and apply different reference points for both clock hands simultaneously.

In conclusion I present an adapted Friedman & Laycock (1989) framework that identifies the strategies learners use to do particularly analogue clock time activities. The adaption in red colour particularly adds the language and digital component relevant from my experience at my school situation. My adapted description of strategies for clock reading draws on literature like Boulton-Lewis, Wilss & Mutch (p.144, 1997) and Burny (p.109, 2012). This framework is then used for the purposes of my study.

Table 1: Description of strategies for clock reading

	Strategies	Explanation
Immature strategies	<p>AnRef – ANALOG REFERENCE (Friedman & Laycock, 1989)</p> <p>DiRef – DIGITAL REFERENCE</p> <p>NoExp – No explanation (Boulton-Lewis et al., 1997; Friedman & Laycock, 1989)</p>	<p>The child referred to an analogue clock when explaining the reading of digital times</p> <p>The child referred to a digital clock time when explaining the reading of analogue times</p> <p>The child could not answer, or gave an incorrect answer and could not explain how this answer was reached</p>
Conceptual strategies	<p>IdHands – IDENTIFIED HANDS (Analogue) (Boulton-Lewis et al., 1997; Case, Sandieson & Dennis, 1986)</p> <p>LaQu – LANDMARKS (Friedman & Laycock, 1989; Siegler & McGilly, 1989), Quarters (Boulton-Lewis et al., 1997)</p> <p>PassHr - Passed Hour Rule (Boulton-Lewis et al., 1997 ; Friedman & Laycock, 1989)</p> <p>PassHr – Afrikaans& English half hour rule</p>	<p>The child recognised the short hand as the hours and the long hand as the minutes</p> <p>The child recognises 3 as 15 minutes or quarter past, 6 as 30 minutes or half, 9 as 45 minutes or quarter to and 12 as 60 minutes or o'clock</p> <p>The child refers to the upcoming hour when more than 30 minutes have passed</p> <p>The child refers to half hour time as a hour in advance in relative time in Afrikaans (e.g. 1h30 as half twee) The child refers to half hour time in English in absolute time (e.g. 1h30 as half past 1)</p>
Procedural strategies	<p>Inc5/1s – INCREMENTING IN 5's AND/OR 1's (Boulton-Lewis et al., 1997; Case, Sandieson & Dennis, 1986; Friedman & Laycock, 1989)</p> <p>Cal60 – CALCULATION ON 60 (Boulton-Lewis et al., 1997 ; Friedman & Laycock, 1989)</p> <p>Multi5 – Multiplication by 5 (Kamii & Russel, 2012)</p>	<p>The child counts around the clock face in increments of five, five and one, or one</p> <p>The child showed recognition of the fact that there are 60 minutes in an hour</p> <p>The child refers to the multiplication table of 5</p>
Retrieval strategies	<p>Knew – KNEW IT (Boulton-Lewis et al., 1997 ; Case, Sandieson & Dennis, 1986; Friedman & Laycock, 1989)</p> <p>NumVal – HIERACHIAL NUMBER VALUE (Kamii & Long, 2001)</p>	<p>The child stated the answer with no further explanation</p> <p>The child recognises the superimposed number values on the clock (e.g. long hand on 4 equals 20 min)</p>

2.3.5 LEARNERS' LEARNING AND DEVELOPMENT OF TIME

According to Piaget's (1969) ideas development is an essential spontaneous process and each element of learning occurs as a function of total development. It suggests that learning time requires the teacher to understand when and how learners acquire analogue clock time knowledge and skills through their cognitive developmental stages.

Kamii and Russell's (2010) research provides insight into children's learning of time. The research found that learners demonstrate operational time later in grade 3 when the learners are 8-9 (grade 3 – 4 in South Africa) years old as opposed to Piaget's 7 or 8 years of age. Therefore learner's conceptual knowledge of time is not always predetermined by developmental stage in years. It is this important to acknowledge that limited contextual variable used for learners to demonstrate logical reasoning skills may inhibit operational time development.

Recently Kamii & Russell (2012) argued that the main reason learners find difficulty with elapsed time was their inability to coordinate hierarchical units (hours and minutes). They proposed that learners construct time logically through reflective (constructive) abstraction of the coordination of hours and minutes. In my experience grade 4 learners find it difficult to perform mental operations to determine elapsed time like durations of events when given the start and the stop time.

Kamii & Russell (2012) also suggests that teaching practice should encourage conceptual thinking, by using the child's daily experience to think about duration of time. Importantly they recommend allowing learners to do their own thinking about the elapsed time, hence enabling learner's construction of logic-mathematical relationships. I support Burny (2012) which argues that learners need to have instructional support to acquire time-related competences. The time-related competences are basically mathematical activities that build upon children's mathematical knowledge because it includes mathematics, language and visual spatial competence.

Literature seems to suggest that spontaneous learning opportunities be created for young learners through which they can make meaning of clock time. Here teaching and learning time should be an integral part of the child's daily active life in and outside the school (Dutton, 1967). It seems that CAPS supports these ideas because it promotes that analogue clock time be taught on an ad hoc basis. In my experience I found that teaching clock time required a

formalised structure of a sequence of lessons per week because young learners struggle to conceptualise the abstractness of time and take long to make the transition to construct time logically.

2.3.6 READING A MECHANICAL TIME

As mentioned the educational perspective stresses the role of learning and instruction in the acquisition of time-related competences. Burny et al. (2009) dispute Piaget’s recognition of learning as an additional process to foster cognitive development of time conception. They argued that cognitive development can be the outcome of learning that is invoked by instructional processes.

Burny et al.’s (2009, p. 488) conceptual framework (see figure 2) shows the sub-competences learners should acquire to build proficient time conception.

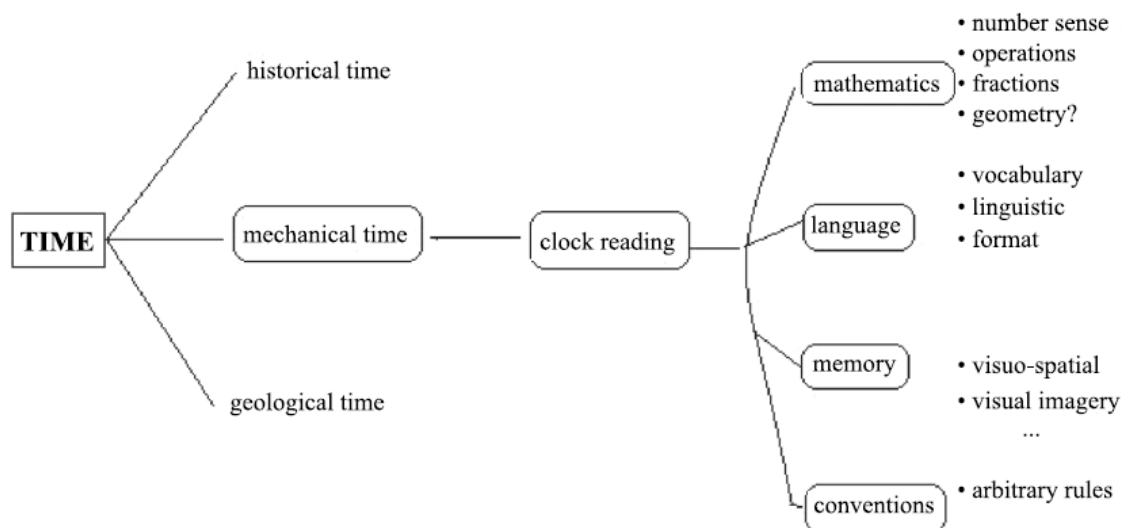


Figure 3: Conceptual framework of Burny et al. (2009, p. 488)

This section briefly unpacks what the framework assumed clock reading builds upon namely: mathematical, visuo-spatial and linguistic sub-competences and requires the development of cognitive conceptual representations (Burny et al., 2009, p. 485-486).

- **Mathematics**
According to Siegler & McGilly (1989) learners making the transition to skilled time-telling use a variety of strategies (e.g. counting or back-up strategy) within a single clock setting that is similar to mental arithmetic. Thus a variety of mathematical knowledge and skills is required in order to be able to tell the time. Firstly, it is needed

for learners to recognise numbers and the ability to count. Secondly, it is important for learners to have a basic understanding of fractions to appreciate the division of the clock face into halves and quarters. Finally, learners need addition and subtracting skills to be able to measure time-intervals.

- Language

Meeuwissen, Roelofse & Levelt (2003; 2004) and Bock et al. (2003) puts that perceptual experiences are grounded in and shaped through language. Time-telling requires the production of complex numerical expression using speech planning and development for a time-specific vocabulary. According to Whitrow (1988), Cockburn (1999), Korvorst, Roelofse and Levelt (2007) time-telling language has arbitrary word rules for telling and writing time.

Clock reading frequently uses two linguistic formats in time-telling like the relative and the absolute system (Bock et al., 2003; Williams, 2004). The relative expression 'half past three' mentions the relationship between an hour reference point and the minute, and puts the minute before the hour is commonly used when telling analogue clock time. On the other hand the absolute expression 'three thirty' does not require a reference point and put the hour before the minute and is more often used telling digital clock time.

- Visuo-spatial aspect

This aspect within research literature focuses on clock drawing as a screening task for the cognitively impaired (Burny et al., 2009). I suggest that the visual imagery necessitates spatial coordination that involves a mental visual map where to locate a clock landmark namely 3, 6, 9 and 12 in young children. The ability to recognise the top, bottom, right and left section on the clock face seems to reflect mental spatial (Freudenthal, 1986) awareness that is supported by memory. This also assumes visual perception and cognitive transformation of the hour land marks 3; 6; 9 and 12 as representations of minutes, for example, 15; 30; 45 and 60 minutes. Meeuwissen et al. (2004) underscores that conceptual transformation (for example, procedure applications or memory retrieval) in analogue clocks is based on the spatial position of the long hand of the clock.

- Cognitive conceptual representations

Firstly, learners need to develop a sense for succession and duration of the clock. Secondly, learners need to learn how these durations relate to each other in order to make meaning. Finally, individual learners need to develop a mental grasp of time direction, thus link or relate their own life experience of what an hour, a minute or a second feels like Freudenthal (1986). Williams (2004) eloquently summed up that time is first of all experienced and things experienced are the distinction between moments and the order structure. Thus time is unique and structured by living it (Freudenthal, 1986, p.549). Our human experience in space develops rich cognitive conceptual representations of time (Wilkening, Levin & Druyan, 1987).

Drawing on the ideas of Stahl (2003), I am cognisant that in order to engage in activities, learners must come to recognize meanings of artifacts, and interpret these meanings from their own perspectives employing the mathematics, language, visual-spatial aspect and cognitive conceptual representations. I also recognise that a range of literature could provide deeper understanding of the different time-related competences learners need to acquire to enable proficient clock reading and telling ability.

2.4 LOCAL AND INTERNATIONAL STUDIES

There is little evidence of research in this field in South Africa. Scanning South African journals and conference proceedings relating to mathematics education I found no articles on time over the past decade. While there are some significant international research studies that I will draw on (see below), there are only a few of these in the past decade.

The most appropriate literature that potentially relates to my research in an Afrikaans orientated context is the Dutch because of similar linguistic links. Research studies involving clock time in Dutch, for example the work of Bock et al. (2003); Meeuwissen et al. (2004); and Burny et al. (2009); and Burny (2012) closely relates to my research. Currently little research paper about telling time in South Africa both Afrikaans, English and traditional African language exists. There is thus a gap in the literature, particularly in the South African context.

2.5 REFLECTING

My research study will also seek to provide an idea of how a group of South African learners think and reason about the concept of time and the passage of time. Furthermore it will develop an understanding of how learners make meaning of the process and results of measuring time. The focus will be on grade 4 learners telling, reading and writing analogue clock time using

different strategies, as discussed in Boulton-Lewis, Wilss and Mutch (1997). They encourage the introduction of the clock landmarks such as 3, 6, 9 and 12 as representative of the hours earlier than grade four to lessen the processing load and subsequent errors. Further they indicate that counting forward and backwards in fives and / or ones as an important strategy to confirm time. Additionally they suggest instruction on placement of the hour hand and knowledge of the passed-hour rule be taught earlier to form a basis for recursive instruction.

2.6 CONCLUSION

In this section I presented the historical back drop of the evolution of the current mechanical clock and the factors that impacted on the invention of the mechanical analogue clock. In essence that a clock were primarily used to indicate a persons working hours during the beginning of the industrial revolution which also marked the recognition of each countries global position in the economic world even as it exist today.

Further I presented the complex and multifacet nature of analogue clock time that has shown to be difficult for learners to understand across the world. Literature suggests that is because of its abstract nature and the absence of concrete representations (Lakoff & Johnson, 1980; Siegler & McGilly, 1989; Burny et al., 2009, Burny, 2012). I noted in my own experience that learning to read, tell and write analogue clock time is a challenging topic for the learners.

CHAPTER 2 - CONTINUED

THEORETICAL FRAMEWORK

2.6 INTRODUCTION

This section is divided into sub-sections that would provide conceptual direction and purpose of my theoretical approach to my research topic. The theoretical arguments are supported by literature that gives deeper insight into how mediation processes occurs using tools like the analogue clock in meaning making of the clock time. The following sub-sections provide structure to my framework and enable me to flesh out the sociocultural tool mediation *per se*.

The sub-sections are:

2.6.1 Vygotskian Socio-cultural perspective

2.6.2 Tool mediation

2.6.3 Double nature of tool mediation

2.6.4 Internalisation and externalisation

2.6.5 The regulatory nature of the tool

2.6.6 Reflecting

2.6.1 VYGOTSKIAN SOCIO-CULTURAL PERSPECTIVE

My research topic fundamentally concerns how learners use the analogue clock as a human tool to make meaning of clock time. This study is informed by a Vygotskian socio-cultural framework to learning and development based on the concept that human activities take place in cultural contexts, are mediated by language and other symbols systems. John-Steiner & Mahn (1996, p.192) argues that: “*Vygotsky conceptualized development as the transformation of socially shared activities into the internalised process*”. In this way he rejected the false dichotomy between the internal and the external.

This well-known Vygotskian quote encapsulates interdependence between the external and internal learning process namely:

Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological), and then inside (intrapsychological)...All the higher functions originate as actual relations between human individuals (Vygotsky, 1978, p. 57 cited in Lerman, 2001).

The unit of analysis in my research is tool mediation which looks at how the analogue clock may enable or constrain children's meaning making of clock time. The construction and the use of the physical clock as a particular complex tool are characteristic of human activities. Even more characteristic of human activity is the value of the contribution of the analogue clock beyond the practical level, e.g. their contribution at the cognitive level (Bartolini-Bussi & Mariotti, 2008).

In expanding on my unit of analysis I draw on another Vygotskian idea which Minick (1989, cited in Cobb, 1994) frames as individual-in-action (see also Ernest, 1991). The action refers to where individuals create meaning through their interactions with each other and with the environment they live in. The interaction with the environment includes interaction with socially and culturally constructed tools such as clocks that the learners use to make meaning of time. From a Vygotskian point of view, the process of learning a scientific concept of time is a process of mediation between the child and what clock knowledge is to be learnt using the analogue clock. This interaction between the individual and the real world is controlled and transformed by the use of symbolic material and cultural tools which in this case is the analogue clock (John-Steiner & Mahn, 1996; Lerman, 2001).

2.6.2 TOOL MEDIATION

I attempt to present the concept of tool mediation through a Vygotskian socio-cultural approach to learning and development. According to Hedegaard (2001):

Tool mediation is a fundamental concept to psychology and education whereby tools (conceptual and manual) are seen as central in mediating between the person and the world (subject and object) and for development of the person's competencies. (p. 3)

For now I discuss the interpretation of the notion of mediation in the sociocultural perspective that I draw on for my study. According to Bartolini-Bussi & Mariotti (2008) mediation is a very common term in the educational literature which is used to refer to the potential of fostering the relationship between personal and mathematical knowledge towards the accomplishment of a task. The dialectical relationship of mediation necessitates overcoming the dichotomy between human beings and technologies, the unity between human and tool becomes the basic objective.

The dialectical nature of tool mediation is that in the practical sphere human beings use social physical tools purposefully to accomplish their tasks that would otherwise have remained out of reach. In return the psychological nature of the same tool supports and develops mental activities for later internalisation (Bartolini-Bussi & Mariotti, 2008). The former are directed outward, whilst the latter are oriented inward. The dialectic relationship between the tools namely the physical analogue clock and what the time is seems natural. The tool mediates support in shaping and constructing analogue clock time knowledge from a social to a psychological level to make meaning of clock time (Bartolini-Bussi & Mariotti, 2008).

In my research I consider the more obvious relationship between learners and the physical world that is mediated by concrete material tools namely the analogue clock rather than psychological mediation via conceptual and semiotic tools (Lantolf & Thorne, 2007).

2.6.3 THE DOUBLE NATURE OF TOOL MEDIATION

Bartolini-Bussi & Mariotti (2008); Bussi, Corni, Mariani & Falcade (2012) and Hedegaard (2001; 2004) suggest a potential double relationship of tool mediation. On the one hand the user of the tool attaches personal meaning using the clock, in particular in relation to the aim of knowing what the clock time is. On the other hand the analogue clock encompasses mathematical meanings which may relate to the analogue clock and its use.

Hedegaard (2004) explores the double nature of tools or instruments from a Vygotskian (1997) view on how the tool or instrument turns around and becomes a mental act, and thereby influences the individual's learning and development. In reference to Vygotsky's focus on human's psychological functioning with mental tools Hedegaard (2004, p.22) presents Vygotsky's ideas as follows:

The inclusion of a tool in the behavioural process... recreates and reconstructs the whole structure of behaviour just like a technical tool recreates the entire system of labour operations. Mental processes taken as a whole form a complex structural and functional unity. They are directed toward solution of a problem posed by the object, and the tool dictates their coordination and course. They form a new whole the instrumental acts ... The psychological tool changes nothing in the object. It is a means of influencing one's own mind or behaviour or another's. It is not a means of

influencing the object. Therefore in the instrumental act we see activity towards oneself, and not toward the object. (1997, p. 87)

In summary Hedegaard (2004) argues that Vygotsky's focus is on the change in the individual (subject) when interacting with the technical tool (also called artefact) on what is learnt (object). The main point made is the double change movement both of the object and the subject in the conceptualisation of the function of the instrumental act or mental act. The processes by which humans interact with and regulate objects and mental processes cannot be separated in understanding human learning.

Hedegaard (2004) captures the double nature of tool mediation eloquently by qualitatively distinguishing between material or technical tools and mental tools in directing that tools have a mental as well as an action aspect that is related to the material world in one way or another. Similarly Bartolini-Bussi et al. (2008) and Bussi et al. (2012) shares Hedegaard's (2004) idea on the unity of the mental and material aspects of an object as important for understanding humans as cultural beings taking part in social practices to which they contribute and are influenced by. The following figure portrays the double nature of the tool upon the subject and object.

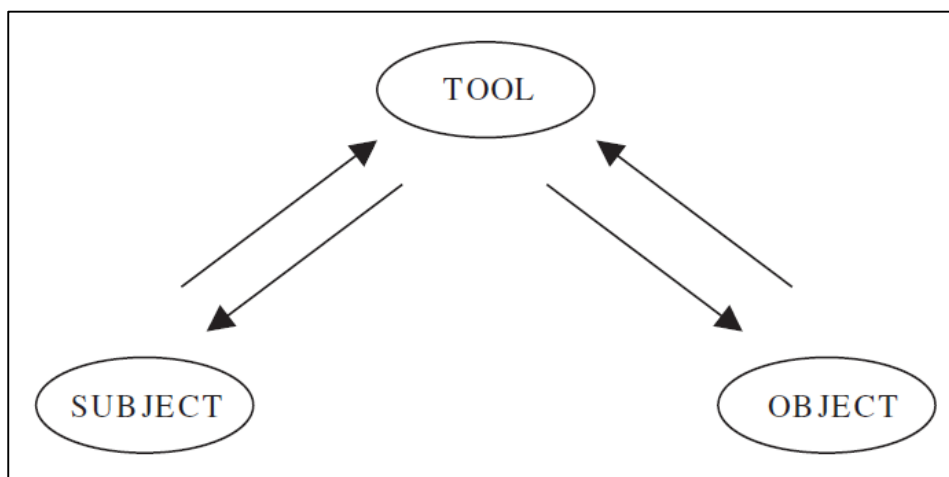


Figure 4: The model of how the instrumental act turns around and become a mental act (Hedegaard, 2004, p.22)

My analysis draws on Hedegaard's (2004) reformulation of Vygotsky's model summarised above that object and tool both have to be seen as artefacts (i.e., cultural phenomena) because they both have to be seen in relation to a human's needs and intentions. The subject cannot

experience the world as objects in themselves. Cultural artefacts always influence the experience that forms a person's needs and intentions. Hoyles & Noss (2003) also talks to the intent in the design of educational tools and express that tools do not, by themselves, make explicit how they work. The explicitness is activated when a person interacts with the embedded functions within the tool.

2.6.4 INTERNALISATION AND EXTERNALISATION

I begin to explore the notion of internalisation and externalisation considering the learner's meaning making using the analogue clock as a human cultural tool.

For Vygotsky, internalisation is not the process of bringing knowledge from the external world into the pre-existing internal mental plane of the individual but argues that the internal mental plane is formed in the process of internalisation (Leont'ev, 1981 cited in Lerman, 2001). With internalisation the tool transforms external interaction, the way one can act with the analogue clock that enables conjectures to be generated thus to a new form of internal interaction, that are unique to the analogue clock environment, as an appropriation of analogue clock outcome (Hedegaard, 2004; Mariotti and Bartolini-Bussi, 2008).

The internalisation process can be seen in people in the use of language as artefact (tools) in doing mathematics. For Vygotsky (1987) the use of language was also a form of mediation that recognised signs and psychological tools including conventional systems and signs as mediational means, here I will include the physical analogue clock (Kieran, 2001).

Kieran (2001, p.190) talks to internal and external mediational means in reflecting on Vygotsky's view:

Processes on both the inter-mental and the intra-mental planes are necessarily mediated by cultural artifacts. Vygotsky comment that word meaning is "*both [speech and thinking] at one and the same time; it is a unit of verbal thinking*" (Vygotsky, 1987, p. 47) is quite telling in this connection. It is because the same basic mediational means are used on the social and individual planes that transition from the former to the latter, as well as vice versa, is possible. In other words, the mediation that occurs on the social and individual planes is reconceptualised as two instances of communication. The notion of communication is one that is occasioned and shaped by the situation.

In summary the physical analogue clock as a human tool on the one hand influence the child's mental range (thinking) where it facilitates the extending meaning and understanding through internalisation for later use. On the other hand it also mediates externalising meaning and understanding when using the clock to communicate interpretations.

2.6.5 THE REGULATORY NATURE OF THE TOOL

In this section I am concerned about the regulatory ability of the tool, thus the physical clock in the child's learning and development of it.

Literature suggests that human constructed tools not only enable but constrain the individual actions in respect of using the tool to accomplish a task (Hedegaard, 2004; Bartolini-Bussi & Mariotti, 2008). The idea suggests that when a person uses a tool the tacit meanings and function of the tool frames the rule of engagement, more particularly how the person can and cannot interact with the tool. In turn Hedegaard (2004) says that the processes by which humans interact with and regulate objects and mental processes cannot be separated in understanding human learning (See Fig. 4 - instrumental act model).

Daniels (1993, p. 53) as cited in Hedegaard (2004) refers to Vygotsky's utterance on the regulatory function as follows: "*Such psychological tools not only functioned externally/socially they mediate or regulate internally the action of mental processes*". I would argue that, although a person learns to use the tool and how to make the tool, their interaction and interpretation are structured by the characteristics of the tool. Lerman (2001) underscores that the interaction between the individual and the real world is regulated and transformed by the use of symbolic material, cultural tools.

According to Hoyles & Noss (2003, p. 341) "*tools matter: they stand between the user and the phenomenon to be modelled, and shape activity structures*". In this respect I agree that cultural situated tools like the analogue clocks used at school and homes influence and regulate a person's interactional access to understanding and interpreting the meaning represented within the tool.

2.6.6 REFLECTING

Doorman, Drijvers, Gravemeijer, Boon & Reed (2012) suggest potential constraints to learning and development in the bilateral relationship between the tool and the person using it purposefully. Thus while the tool users knowledge guides the way the tool is used and in a

sense shapes the tool, the affordances and constraints of the tool influence the child's problem-solving strategies and the associated thought development of concepts experienced. In doing clock related activities I should be aware that the instrumental act (as discussed) can be deterred by inconsistencies between tool techniques and conventional paper and-pencil techniques (Doorman et al., 2012).

I also draw on Wells & Chang (1997) ideas that understanding children's learning necessitates one to look through the eyes of the learner to explore what the learners had learned. The learners' acquisition of time-related competences will be explored through tool mediation in the meaning making process.

2.7 CONCLUSION

The purpose of this chapter was to provide a conceptual and theoretical backdrop to the study. In an effort to gain insight into how learners make meaning of time mediated by the analogue clock, the following aspects were explored:

The first section entailed a historical perspective to provide the cultural development of the concept time and the mechanical clock and the multifaceted nature of conventional time presented in literature.

The last section gives the theoretical framework in which my research is grounded namely, a socio-cultural approach. In addition attempts to explore tool mediation from a sociocultural perspective and tease out tool mediation as enabling or constraining in how learners' meaning making of clock tools in a situated cultural context like school or home.

The study focuses only on the learners learning in an intervention programme that uses selected activities to explore the learners' analogue clock learning. My research aims towards an educational perspective rather than a cognitive descriptive insight in how learners make meaning of time mediated by an analogue clock. The manner in which these aspects relate to the methodology of the study forms the basis of the following chapter.

CHAPTER 3 - RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter documents the research design and methodology used in the study. It begins with the description of the goals of the research, the choice of paradigm and the research methods employed in the study. It then describes the research instruments used in the study, the sample design and sampling techniques, the data collection and fieldwork practices, the data capturing process and editing, and the procedures used in the data analysis. Consideration is also given to issues related to validity and reliability as well as ethics, which are crucial features of the research. Finally, the chapter concludes by briefly stating the limitations of the present research.

3.2 RESEARCH GOALS

The aim of my research is to explore how learners interpret analogue clock time and how the physical clock mediates meaning making. Through this research I hope to gain insight and understanding of how learners make meaning of analogue clock time in the intermediate phase at primary school level. The motivation for this research is grounded in my personal experience of teaching analogue clock time in which learners find it difficult to grasp.

3.3 CHOICE OF RESEARCH PARADIGM

3.3.1 Interpretive Orientation

This research will be conducted within an interpretive paradigm. According to Cohen, Manion & Morrison (2000) an interpretive paradigm gives the researcher an opportunity to understand and interpret the world in terms of its actors. Similarly I will be concerned to make sense of what is going on in the experiences being investigated. The researcher tries to make sense of what is going on in the classroom through a reflexive process operating (Hammersley & Atkinson, 1995, as cited in Maxwell, 2008) through data gathering and analysing data close to the original meaning of the data.

Hodgskiss (2007, p.38) also expresses that the interpretive paradigm aims to “reach an understanding of some phenomenon that is not yet well understood”. This paradigm is suitable as a framework for my study because I am interested in understanding and gaining insight as well as interpreting how primary school learners in grade four make meaning of analogue clock time in mathematics using the physical clock.

Since the interpretive paradigm focuses on experiences of participants as outlined by Cohen, Manion & Morrison (2000), I intend to find out not only the learners' meaning making (thinking and ways of thinking) but also the actions they use to accomplish the tasks in practice.

According to Cobb and Yackel (1996) the interpretive framework of the sociocultural perspective is concerned with the collective processes and individual processes of the learners thinking generated by or derived from their participation in social activities. The interpretive paradigm matches my research because it acknowledges and explores the cultural and historical interpretations of the social world (O'Leary, 2004). The interpretive paradigm is also subject to issues of rigor, trustworthiness and validity.

3.3.2 Qualitative framework

Qualitative research, as incorporated by the interpretive paradigm, enables the collection of data through observations, interviews and document analysis. The qualitative framework enables my research to explore how the learners interpret analogue clock time when interacting with a social artefact.

Maxwell (2008) suggests that qualitative studies look at a variety of events in the research study like physical events and the behaviour taking place. Moreover how the participants (learners) make meaning of these events and actions and how their understandings influences their behaviour. The qualitative framework as my choice provides the foundation that assumes that in the real world individuals interpret and construct meaning when interacting in their social worlds and that meaning is embedded in individuals' experiences and is mediated by the researcher's interpretation (Merriam, 1998).

The qualitative framework fits my research because it typically involves a relatively small number of individuals or situations. In his explanation in using a qualitative approach in research, Maxwell (2008) noted that qualitative approach in a relative small research preserves the individuality of each of the events in the researcher's analyses, rather than collecting data from large samples and aggregating the data across individuals or situations.

Thus researchers are able to understand how events, actions, and meanings are shaped by the unique circumstances in which these occur.

The way to gather and capture these events and actions of qualitative research will be through data collection instruments such as interviews and/or observations as well as interactions with activities linked to exploring the analogue clock as a cultural artefact.

The ontological framing and the epistemological principles that underpin this research are seated within a broad social-cultural framework. My research foci are insight oriented, that is the research is about insight into experience, sense and process, which points me towards qualitative research.

3.4. RESEARCH DESIGN AND METHOD

3.4.1 A CASE STUDY

This research study used an explorative interpretive case study of a sample of four learners chosen from a class of 38 learners on how they interpret and make meaning of analogue clock time using the physical clock. I explore to understand and interpret the learners learning process and consequently how these learners in the teaching experiment learn analogue clock time. According to Steffe & Thompson (2000, p. 269) a teaching experiment “essentially looks behind what learners say and do in an attempt to understand their mathematical realities”. Thus my research study will not be concerned with outcomes but with the process that lead to these outcomes (Maxwell, 2004). This particular teaching experiment does not attempt to do remedial work during the intervention programme with regard to the learners’ performance.

I concur with Maxwell (1996, p. 6) that “the methods you use must enable you to answer your research questions and also to deal with plausible validity threats to these answers”. Thus for this half thesis I find a case study plausible to explore the learners’ meaning making of analogue clock time. Furthermore Creswell (1998) states that a case study enables the researcher to explore a single observable entity limited by time and place (in this case, the afterschool learning activities), and the collection of detailed data through a variety of methods.

According to Geertz (1973) cited in Cohen et al. (2000, p. 182) case studies can provide a ‘thick description’ of participants lived experiences of, thoughts about and feelings for, a situation. The focus is to explore the research questions by seeking a range of different kinds of evidence that has to be abstracted and collated in the research setting to get the best possible answer to the research questions (Gillham, 2000).

In addition I focus on what participants say, and what participants do as this will enable the researcher to understand the meaning of what is going on in a particular context. The strength is that the case study can illuminate issues and turn up possible explanations in particular to the sample of learners' analogue clock time competence.

3.4.2 SEMI-STRUCTURED INTERVIEW

According to Gillham (2000, p. 62), "interviewing, even in its most unstructured, 'natural' form is not something you rush into". I decided to use semi-structured interviews to gather data because it allowed flexibility and discretion when asking questions. It also allows a seamless flow of consensual conversational sharing of individual experience of analogue clock time in comfortable and familiar environment at school.

I concur with Cohen et al. (2000, p. 267) that "interviews enable participants – be they interviewers or interviewees – to discuss their interpretations of the world in which they live, and to express how they regard situations from their own point of view". Since the research is a qualitative study of how individuals make meaning and in particular interpret the mediational value of the physical analogue clock, interviews provide a verbalised thinking opportunity to the interviewee. On the other hand Cobb, Confrey, diSessa, Lehrer & Schauble (2003) suggests that interviews develop a one-on-one relationship of trust and appreciation of the learners' thinking and reasoning. The interview instrument would flesh out relevant data that is important towards answering my research questions.

According to Hitchcock and Hughes (1995), the semi-structured interview is the most favoured instrument of educational researchers. This is because "it allows depth to be achieved by providing the opportunity on the part of the interviewer to probe and expand the respondent's responses" (p. 154). Therefore I used interviews to ascertain the interviewees' response to directed questions about analogue clock time. In the learners interview dialogue I was then be able to explore and understand, for example, why certain questions in the analogue clock time were poorly answered.

More often case studies and qualitative research used interviews to triangulate the findings obtained from different sources of data (Cohen et al., 2000). According to Hitchcock and Hughes (1995) triangulation helps the researcher to establish the validity of the findings by

cross-referencing different perspectives obtained from different sources, or by identifying different ways the phenomena are being perceived.

Since my concern for this study is to use multiple methods to cross-reference the findings obtained from different sources and to validate the findings of the research, I decided to construct semi-structured interviews as the second instrument for this study because I wanted to understand and gain insight how teacher and learners' experience analogue time. Both the teacher and learners participating in the interviews seemed to value it as an opportunity to express how they experience analogue clock time in school.

3.4.3 DOCUMENT ANALYSIS

In planning and designing my baseline and intervention programme I used the CAPS document to ascertain the knowledge and skills the learners' are envisaged to develop. I looked at the range of analogue clock knowledge and skills learners from grade three and four were required to acquire. The curriculum document provided the mathematical knowledge and skills the learners had to acquire, like what content rather than how learners' are to be taught the topic of analogue clock time.

In CAPS (2011) the phase overview of measurement of time says what content are to be covered and the concept and skills namely:

- reading time and time instruments (include clocks and watches)
 - read, tell and write time in 12-hour and 24-hour formats on both analogue and digital instruments
- calculations and problem solving time include time intervals in minutes and hours

(p. 27)

In line with Maxwell's (1996, p.6) recommendation, the purpose of my study was "informed by current theory and knowledge, whereas the choice of relevant theory and knowledge" was informed by my research question and goals. In the baseline and intervention programme activities I had drawn on ideas from literature.

3.4.4 BASELINE (DIAGNOSTIC) ASSESSMENT

I used the terms baseline and diagnostic assessment interchangeably according to the learning context of my research and not separately. As mentioned, in planning and designing my baseline assessment task I used the CAPS document to guide me in structuring the type of

questions to pose. Importantly the range of knowledge and skills the current curriculum envisaged learners in grade four to be able to do. I do not imply that I solely used the CAPS as benchmark but also my own experience that would speak to my research question.

The aim of the assessment was twofold namely:

- Baseline assessment – Since the research study will include activities not yet taught to the grade four learners (RNCS, 2002). Therefore the baseline task will establish what learners already know towards planning my intervention programme activities (see Appendix 1)

This also served diagnostic purposes. My baseline assessment includes eleven activities that cover a range of basic to problem solving clock knowledge (See appendix 1). The baseline task served to inform me (researcher) of the performance of different learners across the spectrum for later selection.

After conducting the baseline assessment task I did an analysis of all the 38 participants' responses which were quantified in a distribution table. The responses were classified according to the main focus of each question and marked correct and incorrect to make it easily manageable. In the analysis of the learners' performance I considered the relevance to my research question rather than purely correct or incorrect response.

3.4.5 VIDEO-TAPED RECORDINGS

My primary instrument of data gathering was video-taped recordings of learners' interactions with activities and the analogue clock as a mediating artefact in mathematics. The learners' actions during interviews and particularly during the intervention programme task were captured on video-tape to enable transcription of appropriate and meaningful data that is useful towards answering my research question.

Jaworski (1990) and Mason (2002) warn that video-taped analysis should guard against generalised interpretation and judgement of the acts and intentions of the participants in the video-taped recordings. Mason (2002) suggests that a distinction should be made between giving accounts *for* phenomena compared to accounts *of* them. I will be mindful of the above when looking for critical incidents that talk to my research questions.

According to Cohen et al. (2000) video-taped recordings make it possible for the researcher to pick upon such details such as non-verbal communication. Therefore I used the video-taped recordings accordingly and transcribed critical incidents that were relevant in answering my research questions. The video-taped recording served as a back-up instrument that enabled authenticity of giving accounts for the phenomena. For the teaching experiment during an intervention programme I used a video recording because excerpts from video transcripts can be later analysed in detail (Cohen et al., 2000).

3.4.6 MY JOURNAL

I used the journal for variety of purposes in my research. My journal was unstructured and I recorded daily events that seemed important and necessary for later reflection.

First, I made anecdotal notes of actions learners performed in the teaching experiment during the intervention programme that related to my research questions. I used a free style narrative approach to record events I observed which suggests that the representation or interpretation thereof would be my personal view rather than an objective stance. I reflected the moment in action experience of myself as researcher as observer and teacher-researcher as participant in the learning situation. More often I took the position of “participant as observer” (Merriam, 1998, p. 101) in the teaching experiment during the intervention programme. My primary role was to experience, through the eyes of the learners, how learners make meaning of analogue clock time.

Lastly, I used the journal to note my experience and certain significant events during the research. The journal provided a way to organise and manage my research programme with regard to logistical and personal events. For example notes about logistics example the time and date of the sessions.

3.5 RESEARCH STUDY SAMPLE

This section describes the sample and the criteria used in the choice of the sample.

3.5.1 RESEARCH SITE AND SAMPLE DESIGN

Before deciding on the research site and sample size of my study, I took into consideration factors such as expense, time and accessibility that in most cases prevent researchers from

gaining information from the whole population (Cohen et al., 2000). Therefore I selected to conduct my research study at the primary school where I teach.

Prior to the purposeful selection of my sample, the following aspects were also considered.

- Relevant grade to my research study
- Accessibility to research site
- Who taught the content to these learners previously?
- The research method and approach

I chose the level of grade 4 at my primary school because it is the level at which I teach and am familiar with the content and context of primary schooling. It is also easy to reach learners and I am in good working relations with the participants in my research. I know the school and school community that is close to my home. I would thus not incur excessive travelling expenses during my fieldwork. I was confident that learners would not hesitate to participate fully in my research. I also chose to teach the sample of learners through continual collaboration with them and with their social milieu, with the children's desires and readiness to act together on the clock activity (Davydov & Kerr, 1995; Rogoff, 2008).

3.5.2 Sampling Size and Sampling Techniques

Cohen et al. (2000, p. 103) pointed out that “in purposive sampling, researchers handpick the cases to be included in the sample on the basis of their judgement of their typicality. In this way, they build up a sample that is satisfactory to their specific needs”.

Before deciding on the sample size I consulted with my supervisors on the number of learners and agreed to select three learners but to include an extra fourth learner in the event of unforeseen withdrawal.

The sample learners in this case study research were from the school where I teach. It was a convenience sample (Cohen et al., 2000) because it is the class of learners whom I teach mathematics and it was thus easy to arrange and organise the after school teaching experiment during an intervention programme with the consent of all relevant stake holders (Steffe & Thompson, 2000). The four learners were selected according to their performance on a baseline assessment instrument provided to the whole class ($n = 38$). I selected my four case-study learners from across the spectrum of performance, including one individual that

performed poorly, two with average performance and one that performed well in the baseline assessment.

I also interviewed the grade 3 teacher who taught these selected learners the previous year. This enabled her to share personal and mathematical experience and insight of how learners make meaning of analogue clock time. I have worked with the teacher during the NICLE workshops and gained insight as to the possibility for this teacher to share reflective insight in her mathematics teaching practice. The teachers' openness to share with other teachers and myself convinced me that she would bring rich insights to my research.

3.6 KEY ISSUES IN RESEARCH

3.6.1 VALIDITY AND RELIABILITY OF DATA

Cohen et al. (2000) regard validity as the basic and fundamental key to effective research in both the qualitative and quantitative research. Accordingly in qualitative research, validity is concerned with issues such as "honesty, depth, richness and scope of the data achieved, the participants approached, the extent of triangulation and the disinterestedness or objectivity of the researcher"; while in quantitative research it is related to issues such as "careful sampling, appropriate instrumentation and appropriate statistical treatments of the data" (ibid, 2000, p.105).

On the other hand Maxwell (1992) refers to validity as the relationship between an account and something outside of that account, whether this something is construed as objective reality, the constructions of actors, or a variety of other possible interpretations. This implies it is possible and important to get other equally valid accounts from different perspectives. Therefore despite interviews and analysis of documents, I consulted a range of literature pertaining to the mediational value of the physical analogue clock and learning of analogue clock time in mathematics practice.

The research reflects a multiple data collection approach such as video-taped critical incident analysis, baseline assessments, interviews and document analysis to ensure and enhance validity and reliability.

Maxwell (1992) says that participants' feedback, similar to interviews, provide valid responses. Since the learners in grade four was not be able to validate data I only give the teacher the transcript of the interview data for respondent validation.

Maxwell (1992) highlights rich data enabled by video recording and transcripts provide thick description the researcher can pick upon in research triangulation. Anderson (2000) suggests that triangulation could help eliminate bias and may detect errors or anomalies in my discoveries. For the purpose of triangulation I used a variety of data collection methods as discussed above.

Additionally McMillan and Schumacher (2001, p. 407) argue that validity in qualitative research is the "degree to which the interpretations and concepts have mutual meanings between the participants and researchers". Although reliability and validity are important in any discussion of rigor in scientific research, Graven (2002) puts that these two concepts might differ based on the nature of the research conducted and the philosophical and ontological assumptions of the researcher.

3.6.2 ETHICS

Cavan (1977) as cited in Cohen et al. (2000, p. 56) defines ethics as "a matter of principled sensitivity to the rights of others" Thus ethics has to do with what is right and what is wrong in every situation. The researcher has the exclusive responsibility to make sure that participants are fully protected by not disclosing information that leads to disclosure of their identity.

Cohen et al. (2000) suggests that informed consent is the foundation of ethical procedures. Therefore as a teacher doing research it is important to ensure ethical procedures are adhered. This is especially important since I engaged with young learners in my classroom as well as a teacher at my school. Written permission to conduct research at my school was obtained from the on-site manager, namely the school principal (see Appendix 2). I obtained written permission from the teacher and parents of the participating learners in my research (see Appendix 3 for an example of teacher permission; see Appendix 4 for an example of parent permission).

Confidentiality, anonymity and privacy of each individual participant or institution was explained and assured. Furthermore I explained that all the participants had the right and freedom to choose to withdraw at any stage without question or prejudice.

Importantly I informed all the relevant stakeholders about the purpose of my research. Hence provided all participants with an informed consent form (see Appendix 2; 3 & 4 for an example of each) in which the purpose and method of data collection in this study is clearly explained.

3.7 RESEARCH PROCESS AND TECHNIQUES

The empirical field of my research is the intervention programme in which I conduct my teaching experiment that explores how learners use the analogue clock tool to mediate clock meaning making.

The process I followed involved performing reflective analyses on the transcripts from these lessons, adjusting my assumptions accordingly to new ideas and thinking and improving the activities in line with the adjusted teaching experiment during the intervention programme (Steffe & Thompson, 2000). I then repeated the procedure by implementing the new set of activities in a subsequent cycle, and learning from the group-experiences for, once again, powering the next thought research.

This process contributed to establishing and refining my teaching experiment. To ensure the practicality of my findings, I took into account both the cognitive development of the individual learners, as well as the social context (i.e. people, setting and type of instruction) in which the instruction experiment took place.

In table 2 below I present a summarized table format of the research process and techniques used to gather the relevant data towards answering my research questions.

Table 2: The summary of my research process

Stages	Technique / Tool	Participant	Purpose	Data
1.	Document analysis – CAPS in mathematics for grade 4	Researcher	Know content of my research topic that the learners should learn at school. It informs how to design analogue clock activities.	Qualitative data to align baseline and teaching experiment during an intervention programme activities
2.	Baseline assessment task	Researcher and 38 learners in grade 4	To ascertain the learners knowledge and skills about analogue clock time. Inform me which 3 or 4 learners to select for my teaching experiment and the general thinking and reasoning skills of all the participants.	Qualitative and quantitative data to gain insight into learners abilities
3.	Semi-structured interview	Researcher teacher	To gain insight into the one teachers experience in practice. To triangulate data gathered from learner scripts, learner discussions and teacher comments	Qualitative data of personal experience and mathematical experience
4.	Semi-structured interview on baseline task	Researcher, 4 sampled learners	Sampled learners are given the opportunity share their thinking and reasoning about analogue clock time questions	Qualitative data of personal experience and mathematical experience
5.	Video-taped interviews and teaching experiment during an intervention programme after school	Researcher , sampled learners	Individual learners or member of a group in the teaching experiment do a sequence of analogue clock activities to demonstrate how they learn. Learners get a glimpse of each ones strategies and improve their own thinking and reasoning skills (Lerman, 2001).	Individual and group actions analysed according to questions asked.
6.	Journal	Researcher	To record and reflect on events	Ongoing reflective qualitative data

3.8 DATA ANALYSIS

An important strategy proposed by Miriam (1998) is to do simultaneous data collection and analysis for generating categories and building theories.

When I did my document analysis I focussed on the curriculum requirements that grade four learners had to meet when learning the topic analogue clock time. This assisted me to zoom into particular learning concepts and skills such as the ability to read, tell and write analogue clock time when using time measuring instruments. When I analysed the baseline task I considered the learners general appreciation of certain basic foundational knowledge in their responses which were categorised according to possible procedural and conceptual skills the learners demonstrated and marked as either correct, partially or incorrect responses. The teacher interview was used to triangulate the possible learner responses with what the teacher experienced the previous year and also how the teacher anticipated the learners may perform in the baseline task. I analysed the video-taped baseline and intervention programme task and transcribed critical incidents that emerged. I also categorised emerging ideas and events that provided a glimpse of the actual or possible learning demonstrated by the learners.

The triangulation of semi-structured conversational interviews, baseline assessment or diagnostic assessment and teaching experiment during the intervention programme after school aimed at providing a rich, in-depth collection of data that is trustworthy (Cohen et al., 2007). The stimulus response interview with the sampled learners allowed me to clarify the learners thinking and understanding of the questions posed in the baseline task. It also allowed me to gain a deeper understanding the learner's interpretation of the pen-and-paper task and practical activity. The data captured were then organised and categorised according to possible emerging themes.

I then collated all the information which included visual picture or snapshots of the learning actions displayed by the learners. The different data sources such as document analysis, interviews and pen-and-paper tasks and also video-taped material were then organised systematically into tables and vignettes. The analysed data attempted to provide a coherent whole that is close to the original situation.

In my research I viewed recorded data and only transcribed critical incidents for the analysis pertaining to my research questions. The feedback discussions were intended to elicit mediated focused conversation between my sampled group of four learners and the teacher (myself). This informed my future instructional development and my research.

3.9 LIMITATIONS

As researcher I am aware about my position as teacher researcher and that this positionality may have impacted on the participants when obtaining my data of how learners make meaning of analogue clock time.

Being the teacher of the grade four mathematic classes, I recognised my power position may have influenced how the sampled learners responded during the interviews and teaching experiment during the intervention programme. Therefore during the interview process, I probed where necessary, but tried not to impose my ideas about analogue clock time on any of the learners and teacher I interviewed.

I found it difficult to maintain a balance between teacher and observer during the intervention programme as to how much guidance and support I should provide to the learners as a researcher. Gravemeijer (1994) alerts to the participation-dissociation balance which indicates that the researcher must maintain a balance between being too much dissociated and too much

involved. This positionality also worked in my favour as learners were comfortable to work with me and it seemed easy to develop a relationship of trust with participants.

At all times I respected the individual teachers' and learners decision and carried on with other questions. In my research I attempted not to control the participants in responding to questions and encouraged them to feel free to express their own thinking of moment-to-moment events. I acknowledge that my write-up represents my interpretation of what I observed rather than a totally objective view. However such objectivity is not possible because I intentionally planned and designed the activities so as to recognise a measure of control of the process.

Other limitations, such as time constraints and my small sample of learners also need to be considered. The nature of a half thesis limits the time within which the research is carried out.

3.10 CONCLUSION

In this chapter, I discussed and argued reasons for the methodological framework I found most suitable for my research. The methodological framework was designed in line with my research goals. Presentation and justification of my choice of approach, research methods, sampling as well as techniques and methods of data collection was provided. I outlined and discussed validity and ethical issues in my research. I then discussed how I analysed my data and the limitations thereof. In the next chapter I will present and analyse the data collected.

CHAPTER 4: DATA PRESENTATION

4.1 INTRODUCTION

In this chapter I present the collected data through my three data gathering instruments as previously described in Chapter 3. I provide an analysis and interpretation of the collected data through the instruments used.

- Firstly, I analyse and interpret the data collected through the baseline assessment questionnaire;
- Secondly, I analyse and interpret the data collected through the interviews;
- Thirdly, I analyse and interpret the data collected through the teaching experiment (intervention programme).

I begin with a general descriptive account of the data analysis section that informs my study. The presentation of the data in this study was framed by the interpretive paradigm. I use predominantly qualitative but also quantitative formats to analyse and interpret the data collected. The qualitative analysis generated themes or indicators that emerged from the data collected while the quantitative data analysis used tables to analyse and interpret the findings. The data collected through both the baseline assessment pen-and-paper task, the teacher interview and sampled learner stimulus response interviews were used to triangulate with the findings of the after school intervention programme.

My research is an explorative study to understand and gain insight into how learners make meaning of analogue clock time. The key question is how the analogue clock as a human tool mediates the meaning making process; in particular its impact on the learners thinking and way of thinking.

4.2 DESCRIPTION OF CONTEXT AND PARTICIPANTS

I begin with a brief description of the context and include some general background of the learners in the research.

4.2.1 THE SCHOOL

My research was carried out at a semi-rural primary school where I teach in the Eastern Cape Province of South Africa, situated in the town of Alexandria which is about 70 kilometres from

Grahamstown. The school was established in 1985 and has 14 classrooms with a teacher for each class. This is a state funded ordinary public school that is categorised as a section 21 no fee school, which means that school fees are not compulsory. The school community includes mostly parents of low to middle income groups, commonly referred as historically disadvantage groups. Evidently the school nutrition programme is an important contributing factor in the learners schooling, e.g. nutritional meals to alleviate hunger influence in the learning process.

The teaching staff component consists of 11 female teachers and three male teachers. Currently the majority of teachers are coloureds while there is one white and one isiXhosa teacher at the school. The learner enrolment is about 406 learners of different race groups like coloured, isiXhosa and whites. The classes range from grade R – 7. The language of instruction at the school is Afrikaans with English as first additional language. Most of the learners' attending school live within a radius of 5 kilometres from the school and travel by foot or use transport to get to school.

The school is well maintained and provides a secure and safe environment for both learners and teachers. Each of the classrooms has electricity, proper desks and learner support material and teaching resources. The school has running water and flushing ablution facilities for both boys and girls. The school ground has enough physical space outside the classroom and also practice sports like handball, netball and rugby.

4.2.2 LEARNER PARTICIPANTS

In my research I used the grade four class learners whom I teach mathematics at my school. The number of learners that took part in the research was a sample of 4 from 38 learners in the class with a balance between coloured and isiXhosa learners who were also in the baseline sample. The baseline performance as well as the learners' communication skills was a consideration in selecting my sample group.

The grade 4 class learners' average age was about 9 years. The class comprises of mix ability groups with a large number of weak to average ability groups in mathematics. In my sample group I had four learners consisting of three girls and one boy. Of the three girls two were isiXhosa home language speakers while the other girl and boy were Afrikaans home language

speakers. Unfortunately the one isiXhosa girl had to attend a bereavement ceremony in Port Elizabeth during the intervention programme.

After the baseline assessment task I identified the four sampled learners according to their performance. The Afrikaans home language speaker boy was of average ability while the Afrikaans speaking girl was low ability. One of the two isiXhosa home language speaking girls was classified average and the other as high ability performers.

4.2.3 TEACHER PARTICIPANT (Teacher of the learners in the previous grade)

The selected teacher interviewed had taught most of the learners in grade 3 the previous year at the school where I teach. The teacher has about 10 years of experience in teaching grade three mathematics with a combined total of 36 years in the foundation phase. She is also the head teacher for this phase and had earlier indicated that there was a challenge teaching analogue clock time.

The teacher is well conversed with the learning content of teaching analogue time and implemented CAPS from 2011. The teacher seemed appreciative to want to know how to improve teaching analogue clock time to grade three learners. Further her willing attitude to share her personal and mathematical challenges teaching analogue time and her experiences teaching it provided me with a useful background foundation.

As phase head teacher in grade 3 this teacher would provide insight about reported or shared challenges of the learners learning analogue clock time. This teachers' wealth of experience in classroom based teaching and learning would provide rich insights and information about how she experienced how these young learners learnt and also how she taught and they responded to analogue clock time knowledge and skills learners demonstrated. In particular she provided a picture of how the learners make meaning of analogue clock time when using the physical clock.

4.3 THE NATURE OF ACTIVITIES (BASELINE AND INTERVENTION)

The study consisted of two major parts: a baseline study and an intervention programme, both supported by interviews. In this section, I will outline the learner activities I used in my research and provide the purpose for the type of question tasks used. I sub-divide this section into two parts as shown below:

4.3.1 Baseline assessment questionings (pen-and-paper)

The pen-and-paper questions posed to the learners (n=38) aimed to determine their knowledge and skill level in answering analogue clock time. Table 3 briefly explains the purpose of each question task.

Table 3: Summary of baseline activities 1 -11 (See appendix 1)

Questions	Description of activity	Purpose
1	Counting forward and backwards in 5's	To determine the learners ability to count forward and backwards in five because it plays an important role in reading and telling as well as calculating minutes accurately.
2	Identify the analogue clock in the picture	To determine the learners grasp of the difference between analogue and digital representations.
3	Select the number of hands on the analogue clock	To determine how the learners interpret hands in an analogue clock displayed picture.
4	Identify the hour hand on the analogue clock	To determine if the learners can distinguish between hour and minute hands because reading and telling as well as writing analogue clock time requires recognition of such differences.
5	Order events according to acceptable time	To determine if the learners are able to order or sequence events according to their daily time frames in "real" life that reflects the learners' appreciation of events in time. Thus the learners' use of personal and mathematical knowledge.
6	Say what the time is on the clock	To determine if the learners recognise and grasp the meaning to the landmarks 3 and 6, thus 15 minutes and the half or 30 minutes of the analogue clock representations. Also to check whether they understand "kwart oor" and "half oor of voor die uur". Also see if the learners use relative or absolute time descriptions.
7	Draw the time on the clock	To determine how the learners position the two hands on the clock when they read and write the representations of the hour and minute hands correctly. I want to determine if the learner are able to allocate the distinct arms to the correct position according to their descriptions.
8-11	Solve time-related problems	I want to determine if the learner can solve time problems by calculating the passage of time correctly, here the start and stop of the event (duration). I want to determine if the learner can solve time problems by calculating passage of time correctly, here the start and duration of time to determine the stop of the event (duration). I want to determine if the learner can solve time problems by calculating passage of time correctly, here the stop and duration of time to determine the start of the event (duration).

4.3.2 Intervention programme activities

The intervention programme was spread over about two weeks. The choice of activities used in the programme was informed by the learners' performance in the baseline assessment task as well as their reflective response when I interviewed them.

The following activities were included in the intervention programme conducted after school at my school. During the intervention process I used analogue card games to stimulate mental thinking and reasoning where the learners had to verbalise thinking when communicating (Lerman, 2001; Ernest, 2011). In this way the formal pen-and-paper activities were supported by physical analogue games. The games served two purposes namely, to make learning fun and to develop collaboration among the participants through sharing ideas and supporting each other's thinking. Table 4 summarises the intervention programme activities (1 – 6) as follow:

Table 4: Summary of intervention programme activities (See appendix 5)

Activity	Description of activity	Method
1.	a. Use a pendulum to measure events in seconds and minutes b. Pick up card game: analogue time say (read) and show time on the clock	Learners group work Teacher guidance Learners Teacher supervise
2.	a. Make a paper plate analogue clock b. Pick up card game: analogue time say (read) and show time on the clock	Individual learner Learners Teacher supervise
3.1	a. Read, say and write analogue time in two different ways shown on the 9 iconic clocks b. Pick up card game: analogue time say (read) and show time on the clock	Individual learners Learners Teacher supervise
3.2	a. Read, say and write analogue time in one way you like shown on the 9 iconic clocks b. Pick up card game: analogue time say (read) and show time on the clock	Individual learners Learners Teacher supervise
4.	a. Draw the time on the 9 blank clock faces. Use a model if needed. b. Read time drawn and show it on the model clock c. Consolidation of questions: True or False	Individual learners Learners Teacher supervise Learners
5.1	Passage of whole hour time on two iconic clocks. Set of 8 clocks	Group work
5.2	Passage of whole and half hour time on iconic clocks. Set of 18 clocks. Use model clock to help	Group work
5.3	Passage of time. Draw the time on three iconic clocks and determine the time passed between each clock. Set of six clocks. Use model clock to help.	Group work
6.	Problem solving questions without any iconic clocks.	Individual learner

In the above section, I presented a brief overview of the activities the learners had to do. The following section presents the initial analysis of the data.

4.4 QUALITATIVE DESCRIPTIVE DATA AND ANALYSIS OF THE TEACHER INTERVIEW

The initial qualitative data analysis looked for events that expose possible patterns or regularities in the data content that illuminate the phenomenon (Cohen et al., 2000; Sandelowski, 2000) namely how grade 4 learners interpret and make meaning of analogue clock time.

4.4.1 Teachers' interview

This section presents collected data of the grade 3 teacher who taught mathematics to this current grade four group of 38 learners the previous year. The semi-structured interview data presents the individual teacher's experience about how learners in grade 3 in particular learn analogue clock time. I used the interview to triangulate the response of the learners prior to implementing the baseline assessment task and intervention programme. The interview questions focused on the teachers personal teaching and learning experience of how the learners learn analogue clock time. The collected data served to inform me about possible difficulties if any the learners may experience prior to my intervention programme. The collected interview data was analysed and interpreted according to relevance to how learners learn analogue clock time in school.

4.4.2 Analysis of the teacher interview

This experienced teacher reflected that teaching and learning analogue clock time is challenging. The following four notable opinions emerged from the teacher interview on how the grade 3 learners learn analogue clock time:

- They can confidently read and tell whole hour clock time
- They find it difficult when reading quarter and half hour time
- They read and tell the half hour time in English easier than in Afrikaans for example half past one is read as "half twee" in Afrikaans
- They make mistakes about which side is "past" and "to" in the clock. For example, the teacher says that the learners place the minute hand at the "past" side when it should be at the "to" side for example 20 minute 'to' is presented as the 20 min 'past' side.

On the other hand the teacher states that the learners can easily recognise the minute hand position and value. These opinions provided a platform for discussion in the next section.

Although the interview was conducted in Afrikaans I will present a translated vignette of a selected section thereof. The following comments were expressed by the teacher on how learners learn analogue clock time. This is a free style translation from Afrikaans to English (See appendix6). In this brief vignette each of the four issues arose.

Interviewer: *In your experience describe how do learners learn analogue clock time?*

Teacher: *How they learn it? How I feel ... how I feel. According to me learning analogue time is difficult. You know that I asked different people about analogue time. To teach the hours is quite fine for example nine o'clock ... but the other especially in Afrikaans certain aspects are confusing like "oor" and "voor" whilst in English it is easier ... like "past" and "to". The half concept [in Afrikaans] is challenging.*

Interviewer: *Can you give examples?*

Teacher (used an analogue clock to demonstrate): *In English you would say it is half past one; that is logical. They learn the time language at home ... they are taught this is half past one [in English].*

Teacher (points to the clock): *Now they have to learn this is "half twee" in Afrikaans. What I do ... I say: 'Stand still and look this is "dit is 'n half uur na twee uur toe"(it is a half hour going towards two o'clock)'. That is what I tell them.*

Teacher: *If you suddenly ask the child to read this time (pointing to half past one on the clock) ... they would say "Half past one" (using English) ... then I ask them to answer me in Afrikaans. What is the time? Some would answer you "half twee" because it is "half na twee uur toe".*

Teacher (demonstrates on the clock – see Photo 4.1): *It is "oor" and "voor" and "half" children get confused. You see I draw the half line and the quarters with dotted lines. Children see the words I wrote on my clock "oor" and "voor" but they still get confused. For example one o'clock and ...the confusion are not on the minute and hour hands but rather the use of "oor" and "voor" and "half".*

Photo 4.1: The grade 3 teacher uses the clock to demonstrate clock time



Interviewer: *What about the hands? I see the clock has two colours.*

Teacher (confident): *They don't have a problem ... they know that the long hand is the minute and short hand the hour. I don't get lots of problems with it.*

Interviewer: *Which hand do learners read first?*

Teacher (amused): *uh ... yes the longhand first ... 5 past eight (5 oor agt) then the short hand.*

The data collected through the interview provides information about how the learner might experience learning analogue time. The teacher stated that learners are confident to identify the hour hand from the minute hand. She also says that learners more often read the minute hand before the hour hand. Further she describes the learners' difficulty in learning analogue time as related to the different languages used at home and school namely English and Afrikaans when saying half hour time. The teacher mentions that the learners learn the half concept confidently in English like half past one instead of Afrikaans half twee.

In addition the teacher describes the difficulty that the learners find in using the concepts "past" and "to" in the correct position. The teacher states that her teaching clock has two lines of symmetry: one vertical to help learners to see the right and left side for "past" and "to" as well as "half"; the other the horizontal to show the quarter past and the quarter to markers.

The data suggests that the learners find telling half hour time in English easier than the Afrikaans version of half hour time. For example, in English we say "half past one" but in Afrikaans half past one are read "half twee" which requires a person to remember the advance hour convention for the Afrikaans format. The data suggests that learners have difficulty remembering the advance hour convention for the Afrikaans format.

The interview data also suggests that learners find it difficult at first to grasp (some aspects) of the relational interpretation of the hour and minute hand in reading and telling relational clock time. The relational interpretation here refers to the ability to see the two clock hands working together; it is not viewing the hands independently. For example, in the time 5 past eight, the minute hand and the hour hand are seen in relation to each other.

One particular aspect of this confusion that the teacher reports (see Appendix 6 line 20 of the interview) is where when the child is asked what the time is. (It is 5 past 7 on the clock being shown to the child) says one past the hour instead of 5 past the hour, using the hour numbering

which is on the clock face instead of counting to 5 which for the minutes. In correcting the child the teacher asked them to count in minute units from the 12 to the minute hand and they counted 5 units and this seemed to help them with reading the minute numbering, which is implicit and in fact not shown on the clock.

In conclusion I noted the teacher's prediction about the learners' performance when answering the baseline assessment question (see Appendix 7 for her prediction).

4.5 QUALITATIVE DESCRIPTIVE DATA AND ANALYSIS OF THE BASELINE ASSESSMENT TASK

4.5.1. Baseline assessment task

This section provides an overview of data across the 38 learners on the written baseline assessment task. These are the 38 learners in my class who had just completed grade 3 and are about to enter grade 4. The objective was to test their knowledge and understanding of analogue clock time. This task was described in section 4.3.1 and full details are provided in appendix 1. I also provide a summary of the findings on the activities of the 38 learner participants' responses. I then discuss the implications of these results for my study.

The activities covered a range of clock knowledge and skills. I chose to focus on the content of questions 6; 7 and 8 -11 it provide richer insight into the learners understanding of analogue clock time. While in questions 1-5 most learners were confident and less noteworthy to my research. I therefore focus on analysing data in regard to these questions in the following section:

6. The percentage of learners' response in saying what the time is on the clock is;
7. The percentage of learners response in drawing the hands on the clock to display the time;
- 8-11. The percentage of learners response to solving time-related problems

Table 5 below provides a summary of the learners' response in question 6.

Table 5: Summary of learners' response ($n=38$) to reading time (question no. 6)

Q.	Say what the time is on the clock (picture given)	Correct	%	Partially	%	Incorrect	%	Others	%
A	four o'clock (relative) or 4 hours (absolute)	28	73.7	0	0	7	18.4	3	7.9
B	quarter past seven (relative) or 7 15 (absolute)	13	34.2	2	5.3	21	55.3	2	5.3
C	half past 1 or one 30 (Afrikaans half twee or 30 voor 2)	13	34.2	4	10.5	19	50	2	5.3
D	five to ten or 9 55 or 55 min past 9 or 5 voor 10	4	10.5	6	15.8	26	68.4	2	5.3
E	quarter to seven or 15 too seven or 6 45	7	18.4	4	10.5	24	63.2	3	7.9

Question 6:

The results are presented using percentages in the above table. I looked at different ways learners could express the time on the clock. The results were marked correctly irrespective if relatively or absolute format were used. The correctness were also determined by the correct language (words) or symbols used to write the time. In the category partial correct it refers to when the learner has at least provide some recognisable idea of the time that may be incomplete in terms of numeric value or mixed clock hands relative to the reference point like the sides past or to. The last category namely others refer to unclear or irrelevant response to the particular question.

The data demonstrates that a majority of learners (question 6.a, 73.7 %) confidently can read and say whole hour time. While only 34.2 % of the learners correctly read and say quarter past and half past the hour time (i.e. questions 6. b & c). The result 10.5% in 'to' the hour time (i.e. question 6. d) demonstrates a poor performance. This result demonstrates that learners find it difficult reading and saying minutes in units of 5's like five to ten or 5 to the hour. Further the result 18.4 % in answering quarter to the hour is also poor. The data demonstrates that learners find it difficult to recognise quarter to landmark position on the clock face (see question 6. e). Thus demonstrates that the learners would more often find reading and saying quarter to or 'to' time difficult.

Following the summary of learners' responses in terms of correctness I decoded the types of responses according to whether the learners answer was given as a time in: (i) relative format (ii) absolute format or (iii) digital format. The summary of the learners' responses is given in the table 6 below.

Table 6: Learners' analogue clock format in baseline question no. 6

Question 6: Decoding the picture representation of the time	<i>Number of learners (n): 38</i>					
Categories of how learners write (record) the time	Relative format		Absolute format		Digital format	
Displayed time on the clock	No. of learners	%	No. of learners	%	No. of learners	%
a) Min hand at 12 & hour hand at four <i>Whole hour</i>	29	76.3	7	18.4	2	5.3
b) Min hand at 3 & hour hand between 7 & 8 <i>Quarter past the hour</i>	26	68.4	9	23.7	3	7.9
c) Min hand at 6 & hour hand between 1 & 2 <i>Half hours</i>	27	71.1	8	21.1	3	7.9
d) Min hand at 11 & hour hand between 9 & 10 <i>Units of five</i>	25	65.8	10	26.3	3	7.9
e) Min hand at 9 & hour hand between 6 & 7 <i>Quarter to the hour</i>	26	68.4	8	21.1	4	10.5
Average %		70%		22.1%		7.9 %

In table 6, I classified relative format when learners used words or symbols like 20 minutes past 2 or half past two or ½ past 2 (half drie in Afrikaans) or quarter past or to the hour or units of 1's or 5's in describing the minutes for example five to ten. I classified absolute time when the learner expressed the current time like one thirty or thirty one. Lastly, I classified digital time when the learners expressed the time 14:00 or 2:00 instead of 2 o'clock.

The result 70 % on average used the relative format across the 5 questions when writing the time. And 22.1 % or about a fifth of the learners used the absolute time format to write the time. Only 7.9 % of the learners used the digital time format to write the clock time which possibly indicates less familiarity with digital time. Table 6 above shows that three types of clock expressions materialise when learners looked at the time displayed in the analogue clock however the relative format was most pronounced. The three types of output generated from analogue input also describe the variety of functional time expressed by grade four learners.

Question 7:

The results are presented in percentages in table 7 below. The data presents the learners' response in drawing hands on a picture clock according to prescribed times presented to them. The questions included eight clock pictures of different times like: whole hour, half, quarter and units of five. It also included locating the past and to positions on the clock.

The learners' ability to draw the two hands required them to encode the provided text time. Encode refers here to the ability to convert language (spoken or written text) into signs or symbols. The data on the task would show the learners ability to recognize the particular reference point and direction or side of the two hands on the clock face. It would provide insight into the learners' understanding of the relation of the hour and minute hand with regards to the interval position and the angle of the two hands. The collected data informs me how the learners' represent the two hands according to the numeric value and position and can show where the learners may be having difficulties in placing of the hands.

In Table 7 I, presents a summary of data collected of the learners' responses to question 7 of the baseline assessment task.

Table 7: Summary of the learners results of encoding the clock hands on the picture clock

Encoding the clock hands by learners. Number of learners (n=38)					
Question 7: Drawing hands on the iconic clock					
		Hour hand		Minute hand	
	Text Time to be encoded	Correct	Incorrect	Correct	Incorrect
A	Twaalf uur (twelve o'clock)	31	7	37	1
	Percentage (%)	81.6	18.4	97.4	2.6
B	Half twee (half past one)	8	30	20	18
	Percentage (%)	21.1	78.9	52.6	47.4
C	Twintig minute oor agt (twenty minutes past eight)	6	32	19	19
	Percentage (%)	15.8	84.2	50.0	50.0
D	Kwart oor vier (quarter past 4)	6	32	15	23
	Percentage (%)	15.8	84.2	39.5	60.5
E	40 min oor ses (40 min past 6)	3	35	15	23
	Percentage (%)	7.9	92.1	39.5	60.5
F	Kwart voor een (Quarter to one)	9	29	15	23
	Percentage (%)	23.7	76.3	39.5	60.5
	<i>Average % per correct and incorrect response</i>	27.7 %	72.4%	53.1 %	46.9 %

The result 81.6 % and 97.4 % shows that the learners were very confident in drawing whole hour time on the clock face (See A above) and demonstrates that most of the learners correctly positioned of the hour hand and the minute hand. But one must qualify this by noting that it was only 12 o'clock that they had to identify and here both hands are placed on the same number.

When however moving to times when the minute hand is no longer at the 12 position with the hour hand, then many more began to make errors, but more were able to correctly place the minute hand than the hour hand. Thus for example, (See B above) when asked to draw half past one 52.6 % were correct and confident in the placement of the minute but only (21.1 %) placed the hour hand correct.

Another feature was that when representing 20 past the hour (See C in the Table) 15.8% got the hour correct and some 50% the minute hand correct, but when representing 40 minutes past the hour (See E in the Table) only 7.9% got the hour correct and only

39.5% got the minute hand correct. Initially I also accepted the learner’s response if the hour was positioned on the hour number position (See C in the Table). Only later when the learners became comfortable and confident did I request that the hour hand be correctly positioned. This is a puzzle. The literature (Friedman & Laycock, 1989, p. 369; Boulton-Lewis et al., 1997, p.145) speculates or points to a “right-sector advantage” in which they find it easier to count on the right hand side of the clock. The finding above suggests also that there seems to be a problem with the transition past the 6 or 30 minute point as one goes ‘up’ the other side. But the precise nature or reason for this problem is not apparent from the above data.

Question 8-11:

This section presents question 8 – 11 which focus on the learners’ ability to solve time-related problems. In the tasks given to them was to ascertain how the learners’ solve time related problems without being presented with an iconic or physical representation of an analogue clock. The questions were related to “real” life events that humans are faced with in their daily lives. These include for example: how long an event lasts (duration); to calculate the start time of an event if the duration and stop are given; to calculate the stop time when the start and duration is. Appendix 1 present the four time- related problems the learners were asked to complete.

Table 8 below, shows the data collected about the learners’ response to these time-related questions pertaining to the passage of time.

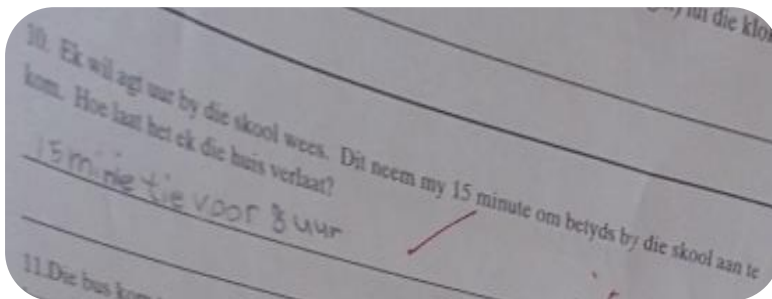
Table 8: Solving time-related problems without a clock image

Learners’ responses to question 8-11	Learners’ response (n=38) to five questions pertaining to passage of time							
	Correct	%	Partially	%	Incorrect	%	Others	%
Q8: calculate duration of an event: start 2 o'clock and stop quarter past 2	4	10.5%	0	0%	33	86.8%	1	2.6%
Q 9: calculate duration of an event: start 8 o'clock and stop half past 8	3	7.9%	0	0%	34	89.5%	1	2.6%
Q 10: calculate the start of an event: stop 8 o'clock and duration is 15 minutes	2	5.3%	2	5.3%	33	86.8%	1	2.6%
Q 11: calculate start of an event: stop 2 o'clock and duration is 45 minutes	0	0%	0	0%	37	97.4%	1	2.6%

The table shows the data according to correct, partially correct, incorrect and other. In 2 cases I classified responses as partially correct when the learner provided a reasonably justified calculation in response. I used the category other to describe those responses with no written response.

Table 8 shows that the grade 4 learners' performance in solving time-related problems without an image of the clock was generally poor; between 87% and 97% were wrongly answered.

Photo 4.2 below provides a snapshot of how learner J calculated question 10. Most of the participating learners in the baseline task incorrectly answered these two questions.

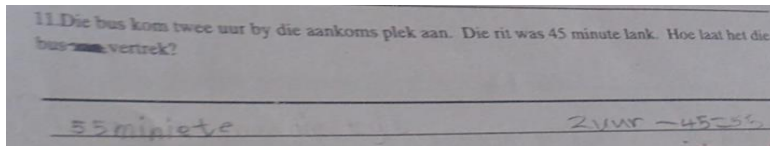


Question 10 asks: I want to be at school at eight o'clock. If it takes me 15 minutes to be on time at school, at what time do I leave the house?

Looking at Learner J's answer, he seems to be able to reason that that the departure time is 15 minutes before 8 o'clock. He calculated the departure time without using a picture clock or a physical clock which shows the ability to reason abstractly about the elapsed time. The learner expressed that it took 15 minute before 8 o'clock thus the departure time should be 15 minutes to 8 o'clock. This particular learner demonstrates the ability to use his logical reasoning skills to determine the departure time and simply the task posed in question 10.

Question 11 asks: The bus arrives at two o'clock at its destination. The journey was 45 minutes long. What time did the bus depart?

Photo 4.3 shows learner J's strategy to calculate the departure time of the bus.



Learner J started by subtracting the duration time of 45 minutes from the arrival time of 2 o'clock without using a drawing of a picture clock. The algorithm seems to indicate that he knows that the departure time should be 45 minutes earlier than 2 o'clock. It also suggests that he is aware that subtracting the 45 minutes from 2 o'clock would present the departure time. It is not clear how he got 55 ($2 \text{ o'clock} - 45 = 55$). Seemingly he reasoned that $100 - 45 = 55$ which suggests the he did not convert the hour (o'clock) to minutes to perform unit subtractions.

Table 8 indicates that all the learners could not calculate the departure time (start time) when given the stop time and duration. It shows that learners in the beginning of grade 4 find it more difficult to calculate start time than duration and stop time. Thus suggests that learners find it difficult to count backwards from the one side to the other side of the clock when the minute value is more than 30 minutes. In particular for learner J he could calculate the 15 minutes before the start time but could not correctly determine 45 minutes before the start time.

The data in questions 8-11 suggests that some learners were able to calculate the duration of events but a majority found it difficult to calculate the stop time and start time. In questions 8 and 9 some learners could perform calculations with quarter and half hour time. Although questions 10 and 11 also contained quarter hours learners seem to find it difficult to do calculations in the third quarter and also counting backwards to determine the start time. The data suggests that most learners at age 9 in the study find reversibility of counting difficulty.

The learners seem to perform better in calculating the *duration* of events (given the start and end times) for example 10.5 % and 7.9 % got correct responses, as oppose to the *stop time* of events (given the duration and stop) where only 5.3% got it correct and none (0 %).

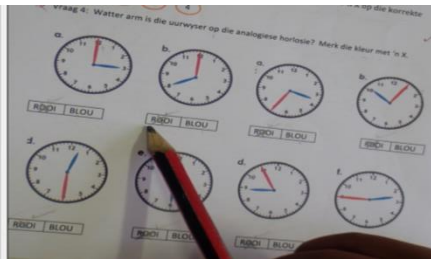
The learners poor response in this section perhaps are explained by the absence of the physical tool, a picture of a clock, in solving time-related problems.

4.5.2 Learner interviews

In this section I provide data from the interviews of the 4 purposively sampled case study learners, about their responses to the baseline assessment task. I focus only on the responses that provide deeper insight into my research questions, namely baseline questions 4, 6 and 7.

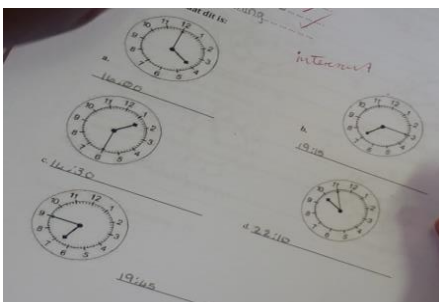
In question 4, using the learner's baseline worksheet, I asked the individual learners to look at the eight different clocks and identify the hour hand. Each of the clocks had a blue coloured short hand and a red coloured long hand. The learners were asked to explain how they identified the hour hand. I asked each learner to look at each clock but if the learner gave a response that the blue hand in all the clocks were the hour hand then I allowed it. The photo below shows the eight clocks of which the learners had to identify the hour hand.

Photo 4.4: The eight clocks in which the learners had to identify the hour hand.



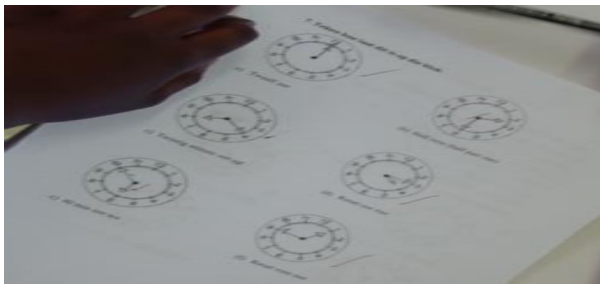
In question 6 (see photo 4.5 below) I asked the individual learners to explain how they read the represented clock times. Here the picture clock contained a short and a long hand in black colour. The learners had to explain how they recognised what the different hands indicated and how they made meaning of their interpretation of the two hands in relation to each other. The interview provided insight into the knowledge and skills the learners used to interpret the displayed time on the picture clock.

Photo 4.5 below presents the five clocks the learners decoded.



In question 7 the learners had to draw the hour and minute hands to represent the text time below each of the clocks. The learners were asked to explain how they draw the hands on the clock. Here the learners had to explain how they read the text time and how they made sense of it when placing the two hands at the different positions on the clock to correctly represent the time asked. The learners' individual response was noted and I only asked learners to clarify explanations when I was uncertain of their explanation of what they see or I asked.

Photo 4.6: The six clocks in which the learners had to draw the two hands



After this interview stage I identified the key responses the individual learners when presenting explanations for their actions in completing the initial baseline assessment task. Then I group the key responses that seem to explain the learners' answers towards the questions asked namely 4, 6 and 7.

In table 9 I summarised the learners' key explanations. This is not to compare individual learner's explanations.

Table 9 below, shows the sampled learners' different responses to questions 4, 6 and 7.

Table 9: Collection of 4 learners' interview responses in baseline assessment task

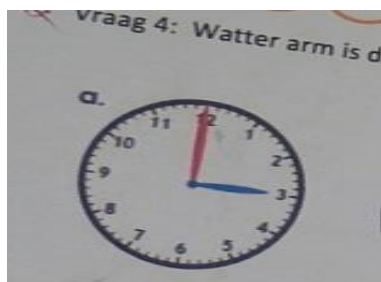
Selected interview questions from baseline assessment task	A brief collection of different learner interview responses to questions 4, 6 and 7
<i>Q: 4 Let's look at the eight clocks in question 4. How did you identify the hour hand?</i>	The long hand is the always hour marker. When it stand at the 12 number I know the short hand is the hour hand Short is hour hand wherever it stand The long hand because it always show to 12 or other numbers
<i>Q: 6 How did you write the time shown on the clock?</i>	
<i>Q 6 (a): 4 o'clock</i>	Long hand at 12 and short hand at 4 I counted in 5's and at 12 I count 60. I wrote 60 minutes past 4 Long hand at 60 min and short hand point to 4 I wrote 16:00 as 4 o'clock. I wrote the phone time
<i>b) 7:15</i>	Read as 15 past 7, know 3 is 15 minutes count in 5's to get minutes $\frac{1}{4}$ past 7, I get confuse with past and to. I know where $\frac{1}{4}$ I count in 5's to get 15 minutes and put the short hand at 7 Wrote 19:15, I know 7 is 19:00
<i>c) 13:30</i>	Know long hand half hour at 6 Get confuse which hand to count as hour Six is half when it goes through the middle and short hand goes to two Count in 5's start from 12 number till 6 number to get 30 6 position shows 30 minutes, know 30 is half Wrote 14:30 and say "half twee" (half past one)
<i>d) 09:55</i>	Count in 5's from 12 to get 55 and wrote 10:55 Counted in 5's from 12 and get 55 min past 10 Count in 5's till 55. Long hand at 55 at 11 number and short hand at 10 number Wrote the 22 hours first then 10 minutes
<i>e) 6:45</i>	I know 45 minute mark, count in 5's till 45, I say 45 min past 7 Counted from 12 number in 5's till 45 at 9 It's $\frac{1}{4}$ past 7, I know 3 and 9 is quarter I counted in 5's to get 45 minutes. Long hand is at 9 it's 45 minutes and short hand at 7, only way Wrote 19:45, count forward till 45 than backwards in 5's till 9 is 15 minutes
<i>Q 7: How did you draw the two hands on the clock to show the time?</i>	
<i>a) Twelve o'clock</i>	Long and short hand at 12 position, I just knew it Both hands at the 12 Long hand is hour because long hand always the hour hand
<i>b) Half past one</i>	Count min hand from 12 till 30. Know half is at 6 Short hand point to 2 and long hand to 6 Short hand point to 1 and long hand to 6 30 min past 2, I count in 5's and recognise 6 is half as 30 min I know half mark is 6, difficult in Afrikaans
<i>c) Twenty minutes past eight</i>	Long hand is 20 minutes and short hand at 8, I counted in 5's from 12 mark Long hand is minute hand easy, counted in 5's till 20 and short hand at eight Incorrect anti-clock count from 8 hour number till 4 hour number to get 20 minutes, I say 20 min past 8
<i>d) Quarter past four</i>	Long hand at 3 and short hand at 4. I counted in 5's till 15. I know quarter past is 15 I get confuse with quarter past and to i.e. 3 and 9 Long hand is 15, I know 15 is quarter. I know past and to sides
<i>e) 40 min past six</i>	Draw short hand to 6 hour number first and long hands to 8. The 8 represent 40 min. I counted in 5's from 12 till 40. First draw long hand to 8 is 40 minutes and short hand at six I ever heard about 40 minute I count long hand at 8 is 40 min Draw hour hand at 6 and count from 6 in 10's to get 40 min
<i>f) Quarter to one</i>	Draw short hand at 1 and long hand at 3 Count in 5's for quarter but forget past or to Know that quarter is like 3 and 9 Long hand first at 9 and short hand at 1, I know 9 is quarter to

In the above table I report the learners' responses and then identified emerging themes that I will use to design and interpret the intervention programme data.

Question 4 of the sampled learners' baseline task interview

In question 4, the data shows that half of the learners can recognise the short hand represents the hour hand. Learners see the 12 marker as an important point on the clock that indicates the hour (hand). This was evident with learner C. The following vignette particularly highlight learners C's identification of the hour hand.

Photo 4.7 shows question 4a which learner C explained.



Excerpt 4.1 presents learner C's response to question 4a about 12 marker on the clock during the interview. I remind the reader that these interviews with the learners were conducted in Afrikaans.

T: *Which is the hour hand? [Watter is die uur wyser?]*

Learner C: *Blue one (short hand) [Blou een]*

T: *Let us look at A. Why is blue the hour hand? [Kom ons kyk na A. Waarom is blou die uur wyser?]*

(Learner C says that her friend (-s) sitting next to her said she must pick blue, now she wants present her own understanding)

Learner C: *The red hand is the hour hand. [Die rooi wyser is die uur wyser]*

T: *Why do you say the red hand is the hour hand? [Waarom sê jy die rooi wyser is die uur wyser?]*

Learner C (pointing to the 12 marker on the picture clock 4a): *The long hand always shows the hour because it always points to 12 or other numbers. [Die lang wyser is altyd die uur want dit wys altyd na 12 of ander nommers]*

The excerpt shows that learner C regard the 12 marker as an important point on the clock that indicates the hour. Learner C says that when the long hand is at the 12 marker than it is the hour hand. She regard the long hand pointing to the 12 marker as the hour hand rather than

seeing that each hand long and short together represent 3 o'clock in question 4 a below. Learner C states that when the hour is represented when the long hand always points to the 12 marker. I surmise that she sees the 12 marker (hand at this position) as the hour (hand).

In question 6 the data shows how the learners recorded the time displayed on the analogue clocks.

In brackets I provided the possible correct answers that the learners could present but also accepted other relevant responses.

Question 6a: The sampled learners' baseline task interview

In question 6a (4 o'clock) the data shows that some learners read the long hand positioned at the 12 marker as the indication of the hour time while the position of the hour hand indicated the number of hours. The learners explained that they counted in 5's till the 12 marker and got 60 minutes and positioned the hour hand to point to the 4 number. These learners seem to recognise and know that the 12 marker represents to different units namely 60 minutes and whole hours. On particular learner says that she used the phone time (digital format) to record the time for example 16:00 to represent 4 o'clock.

Question 6b: The sampled learners' baseline task interview

Question 6b (15 minutes past 7) responses show that most of the learners had counted in 5's till the first quarter mark to get 15 minutes. Some responded that they had knew the 3 number also represent 15 minutes while one learner explained that she gets confused which side is past and to on the clock. The excerpt below shows how learner J answered question 6b.

Photo 4.8: Learner J says that he counted the minutes first and then placed the hour hand.



Excerpt 4.2 shows how learner J read the ‘past’ and ‘to’ side on the clock face

T: *Tell me how did you do 6b? [Sê hoe het jy 6b gedoen?]*

Learner J: *I started to count in 5’s from here (pointing to the 12 marker) 5, 10 and 15. [Ek het getel in 5’s hiervandaan (wys na 12 merk) 5, 10 en 15.]*

Learner J: *I see this is quarter [Ek sien dit is kwart]*

Learner J: *Then it is $\frac{1}{4}$ past 7 (his initial written response was $\frac{1}{4}$ before 7 see photo) [Dit is $\frac{1}{4}$ oor 7]*

T: *What did you write? [Wat het jy daar geskryf?]*

Learner J: *Before sir. [Voor meneer]*

T: *Why? [Waarom?]*

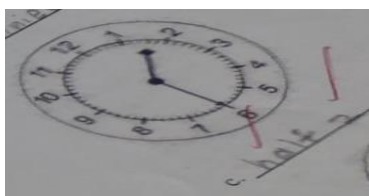
Learner J: *I get confused with past and to. [Ek raak deurmekaar met oor en voor]*

The data shows that learner J used the counting strategy to determine the minute hand position. Here the learner counted in 5’s starting from the 12 marker position and stop at the three number when he got to 15. Learner J says that he recognised that the 3 also represents 15 minutes and is also referred to as a quarter. During his explanation he adjusted his written response from $\frac{1}{4}$ ‘to’ 7 to $\frac{1}{4}$ ‘past’ 7. I did not ask him to explain this change of the sides on the clock but expressed that he gets confuse with “oor” past and “voor” to.

Again learner L used the digital format to express the time. She indicated that she knew that 7 represent 19:00 and also recognises that the quarter at 3 count 15 minutes.

Question 6c: The sampled learners’ baseline task interview

Photo 4.9: The photo below shows how learner J recorded the half time in Afrikaans.



Excerpt 4.3 illuminates learner J understanding of the half hour mark on the clock.

T: *What did you say here (6c)? [Wat het jy hier gesê?]*

Learner J: *Half two [Half twee]*

T: *Why do you say half two? [Waarom sê jy half twee?]*

Learner J: *Because the six is at half [Want die ses is by half]*

T: *What is half, how does it look? [Wat is half, hoe lyk dit?]*

Learner J (pointing from the 12 marker vertically downwards to the 6 marker): *Half is when it goes through the middle. [Half is wanneer dit deur die middel gaan]*

T: *Why did you say it half two [Waarom het jy gesê dit is half twee?]*

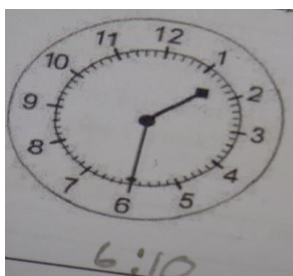
Learner J (pointing to the space between the 1 and 2 numbers and later to the 6 marker): *Because the short hand is going to the two and the long hand will point to six]*

T: *Okay*

This interview as did the earlier data shows that most of the learners recognised the 6 marker as the half position on the clock. The learners expressed that they knew that when the long hand stands at the 6 marker it indicates the half hour or 30 minutes. Again most of the learners used the counting strategy in 5's by starting from the 12 marker to the 6 marker to get the 30 minutes.

The interview as with the other data also indicates that most of the learners confidently recognised the 6 marker as 30 minutes. The written response and the oral response indicated that learner J expressed the displayed as half past one (half twee in Afrikaans) with ease. It perhaps shows that some learners are able to recognise the hour advance rule for Afrikaans when given the time displayed on the clock.

Photo 4.10: Learner Z's misconception of reading the half hour time in question 6c.



Excerpt 4.4 shows how she read the displayed time.

T: *What did you do here (6c)? [Wat het jy hier gedoen?]*

Learner Z: *I counted in 5's 5 and 10 [Ek het in 5 getel 5 en toe 10]*

T: *Show how you counted [Wys hoe jy getel het]*

Learner Z: *I counted like this, 1 counts 5 and 2 counts 10. I got 10 minutes [Ek het so getel meneer, 1 tel 5 en 2 tel 10. Toe kry ek 10 minutes]*

T: *Ok this is how you counted [Ok so het jy getel]*

Learner Z: *Yes sir, it is 10 minutes past 6 [Ja meneer, dit is 10 minute oor 6]*

T: *Which hand is the minute hand? [Watter wyser is die minute?]*

Z (pointed to the short hand between 1 and 2 on the clock): *The long hand sir [Die langste een meneer]*

T: *Which one is the short hand? [Watter een is die kortste een]*

Z (pointing to the long hand at to the 6): *This is the short hand [Dit is die kort wyser]*

In this particular excerpt learner C seems to use the incorrect properties to describe each of the two hands. She seems to know that the long hand is the minute hand but when pointing to it on the clock refer to the short hand. When asked which hand is pointing to the 6 marker she indicated that it is the short hand while it was the minute hand. It is not clear if the learner misconceived the two hands on appearance. She read the time as 10 minutes past 6 which suggests that she regard the long hand pointing to the 6 as important or the 6 marker in itself as more important than the short hand position.

Question 6d of the sampled learners' baseline task interview

Photo 4.11: Learner C shows how she read the time displayed when both the minute and hour hand is on the left side of the clock.



Excerpt 4.5 presents learner C's way of reading the time shown at the 'to' side of the clock.

T: *What did you write here? [Wat het jy hier geskryf?]*

C: *55 minutes past 10 [55 minute oor 10]*

T: *How did you get it? [Hoe het jy dit gekry?]*

C (pointing to the 12 marker): *I counted in [Ek tel in] 5's 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55.*

T: *Ok you got 55 minutes [Ok so het jy die 55 minute gekry]*

C (pointing to the short hand): *Then I wrote 10 [Toe skryf ek die 10]*

T: *Is there another way of saying this time? [Is daar 'n ander manier om die tyd te sê]*

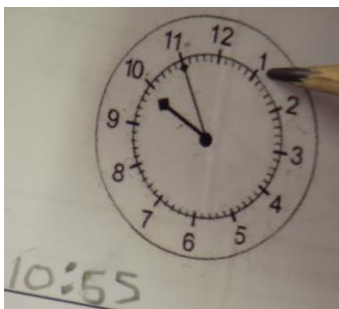
C: *No sir [Nee meneer]*

The data indicates that learner C used the counting strategy to determine the minute hands value. She says that she counted in 5's in a clockwise direction from the 12 marker position and got 55 minutes at the 11 marker. She feels confident using the 'past' the hour time as opposed to the 'to' the hour time. Further expressed that this is for her the only way to read the time irrespective if the hands are at the right or left side of the clock.

Learner C read the time as 55 minutes past 10 while it should read as 55 minutes past 9. Here the learner read the position of the hour hand incorrectly. It suggests that the learner read the hour in advance similar to reading the hour in advance for the Afrikaans half hour time. It shows that some learners may experience difficulties in placing the hour hand at the correct position hand opposed to the minute hand.

The following excerpt further illuminates the learners' difficulties reading the hour hand when it is past the whole hour time.

Photo 4.12: Learner Z's incorrect reading of the hour hand.



Excerpt 4.6 shows learner Z's difficulty positioning the hour hand

T: *What did you do here 6d? [Wat het jy hier gedoen?]*

Z: *The small (short) hand points to the 10 and the big (long) hand to the 11 [Die klein (kort wyser) wys na die 10 en die groot (lang wyser) na die 11]*

Z: It is 55 minutes past 10 [Dit is 55 minute oor 10]

T: How did you get 55 minute? [Hoe het jy 55 minute gekry?]

Z (pointing on the picture clock): *I counted the minutes in 5's from here (12 marker) 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 it is 55 minutes at the 11 number [Ek tel in 5's van hier 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 dit is 55 minute by die 11 syfer]*

T: *So it is 55 minutes [So dit is 55 minute]*

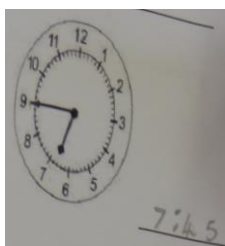
Z: *Yes sir, 55 minutes past 10 [Ja, meneer 55 minute oor 10]*

The data shows that learner Z find it easy to determine the minute hands value like 55 minutes but misread the hour hands position on the picture clock. While the hour hand is positioned between the 9 and 10 markers this learner expressed that it is pointing to the 10. In general the learners allocated the hour hand to a precise position although it is past the whole time. In whole hour time the hour hand points directly to a precise marker for example 9 o'clock while for 55 minutes 'past' 9 or 5 'to' 9 the hour hand is relative to either the past hour or the upcoming hour time.

Although learner Z wrote 10:55 she says the time as 55 minutes past 10, it suggest that the learners reading, saying and writing of time displayed on the picture have different representations. It also shows that when learners read their own written response aloud they give another version of the same representation. In this case the learner used the word "past" to describe the written time (10:55) which is not visible. If the learner wrote the time in the way she is saying it for example 55 minutes past 10 then she could have realised her mistake with the hour hand position.

Question 6e of the sampled learners' baseline task interview

Photo 4.13: Learners Z recognised the 9 marker as 45 minutes but misread the hour hand.



The excerpt 4.7 below provides learners Z misconception when reading the hour hand position.

T: *What did you do here (6e)? [Wat het jy hier gedoen?]*

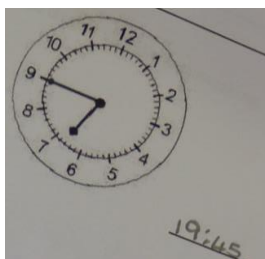
Z: *I counted the minutes 5, 10, 15, 20, 25, 30, 35, 40, 45. It is 45 at the 9. [Ek tel die minute 5, 10, 15, 20, 25, 30, 35, 40, 45. Dit is 45 by die 9]*

T: *What is the time you (wrote)? [Toe sê jy hoe laat is dit daar?]*

Z: *45 minutes past 7 [45 minute oor 7]*

The data shows that the learner used the counting procedure to determine the minutes and also recognised that 45 minutes would be at the 9 marker. Learner Z used the past hour time approach rather than the ‘to’ the hour approach but read the hour as ‘past’ hand for example “45 minutes past 7” incorrectly. The learner seems to use the relative format when saying the time but use the digital format when writing the displayed time on the picture clock. Similar to the previous case above learner Z misread the position of the hour hand.

Photo 4.14: Learner L uses digital format to write the read time on the clock



Excerpt 4.8 below shows that learner L’s written and oral response present different interpretation of the displayed time on the picture clock.

T: *How did you this 6e? [Hoe het jy hier gemaak?]*

Learner L (pointing to 7 and 9 on the picture clock): *[Ek het 7...7... kwart. 15 minute voor 7]*

T: *You said 15 minutes before 7. How did you know it? [Jy sê 15 minute voor 7. Hoe het jy dit geweet?]*

Learner L (pointing to the 12 marker and counting clockwise): *I counted 5, 10, 15, 15, 20, 25, 30, 35, 40, 45, 50, 55 [Ek het getel 5, 10, 15, 15, 20, 25, 30, 35, 40, 45, 50, 55]*

Learner L (stop at 45 and started to count in 5's forwards and also anti-clockwise from 12-marker): *I count now 5, 10, 15. I see it is 15 minute to. [Ek tel nou 5, 10, 15. Ek sien dit is 15 minute voor]*

Learner L (pointing to written response 19:45): *It is 45 before 7 [Dit is 45 minute voor 7]*

The data shows that learner L used determined the minute value by counting and was able to reason that if she counted the 45 minutes and another 15 minutes till the top of the hour it meant it is 15 minute before 7. The written response 19:45 indicates that it is 15 minutes before 8 instead of 7. The mistake does not present it when she says the time she read on the clock. The misread of the hour hand seem to contribute to the learners' mistake.

The next section presents learners approach to how they decide to draw the two hands on the clock to show the text time.

Question 7 consisted of five different text clocks which the learners give responses about. Here I present selected vignette to show how certain learners interpreted the text time and drawn it on the clock face.

Question 7a asks the learners to draw twelve o'clock on the clock

Initially learner C explained how she positioned the two hands on the clock to show twelve o'clock but when I asked her to explain how she set the physical clock hands for 4 o'clock and 5 o'clock it became apparent that she interpret it differently. She sees the long hand at the twelve marker as representing hours rather than the position of the hour hand (at the 4 or 5 o'clock numbers) in relation to the minute hand at the marker twelve.

Photo 4.15: Learner C says that the long hand at the 12 position refers to hourness



Excerpt 4.9 illuminates this particular learner's interpretation and meaning making of whole hours. This excerpt begins where I asked her to set 4 o'clock on the physical clock.

T: Set it at 4 o'clock [Sit dit op 4 uur]

Learner C: 4 o'clock [4 uur]

Learner C (actions): Use her left hand to keep the long hand at 12 marker position and move the short hand in cyclic motion to the 4 number

T: Where is the long hand? [Waar is die lang wyser?]

Learner C: At the 12 [Op die 12]

T: and the short hand [En die korte?]

Learner C: At the 4 [By 4]

T: Set it at 5 o'clock [Stel dit nou op 5 uur]

Learner C (actions): Kept the longhand at 12 and moved the short hand to the 5 number.

T: Which hand did not move? [Watter wyser het nie beweeg nie?]

Learner C: The long hand [Die langwyser]

T: Which hand moved? [Watter wyser het beweeg?]

Learner C: The short hand [Die kortwyser]

T: What is the time now? [Hoe laat is dit nou?]

Learner C: 5'clock [5 uur]

T: Which hand is the hour hand [Watter wyser is die uur wyser?]

Learner C: The twelve indicator (pointing to the long hand at the 12) [Die twaalf wyser]

This particular excerpt shows that some learners regard the 12 position on the clock face as an important reference position for hourness. Learner C argued that when the long hand is at the 12 position it then represents hourness. Here the long hand is seen as the hour indicator rather than the short hand which is normally regarded as the hour hand (indicator).

Question 7b asks the learners to draw the time half past one

Learner L states that she get confused with the two text time namely ‘half twee’ and ‘half past one’ and sees them as different representation. The following excerpt briefly captures this particular learners interepretation of the the two text time.

Photo 4.16: Learner L sees the two text time as different representations.



Excerpt 4.10 focuses on learner L’s interpretation of the two text time.

T: *Is your short hand at the correct position? [Is jou kort wyser op die regte plek?]*

Learner L: *No sir [Nee meneer]*

T: *Which one confused you? [Watter een het jou deurmekaar gemaak?]*

Learner L: *This one ‘half past one’, sir [Hierdie een ‘half past one’ meneer]*

T: *Why? [Hoekom?]*

Learner L *(shows to the two text time below the clock): ‘Half past one’ is not the same as ‘half twee’. [‘Half past one’ is nie dieselfde as ‘half twee’ nie]*

T: *That is why you draw it like this. [Dit is hoekom jy dit so geteken het]*

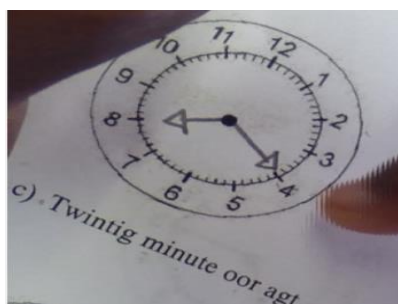
Learner L: *Yes, sir [Ja, meneer]*

Learner L indicates that she know where the half position is on the clock face and positioned the minute hand correctly. She states that half past one confused her when drawing the hour hand because it is not the same as ‘half twee’. Looking at 7b it suggests that she interpreted ‘half twee’ as half past two and positioned the hour hand between 2 and 3. This excerpt shows that in English (half past one) there are indications whether it is past or to the hour while in Afrikaans the learner has to anticipate that ‘half twee’ refers to the upcoming hour.

Question 7c asks the learners to draw the time twenty minutes past eight

Excerpt 4.11 below shows how learner L determined the position of the minute and hour hand to represent the text time of twenty minutes past eight.

Photo 4.17: Learner L explained that she first placed the hour hand at the 8 number and counted backwards from the 8 number to the 4 number to get the twenty minutes position.



T: *What is the time at 7c? [Watter tyd sê hulle by 7c?]*

Learner L: *Twenty minutes past eight [Twintig minute oor agt]*

T: *What did you do? [Toe hoe maak jy?]*

Learner L: *I put the short hand at eight [Ek sit die korte by agt]*

T: *Than [En toe?]*

Learner L (counted backwards with her pencil on the clock from the 8 number): *I (counted) 5 (at the 7 number), 10 (at the 6 number), 15 (at the 5 number), 20 (at the 4 number)... 20 minutes past eight [Ek het 5, 10, 15, 20 ... 20 minute oor agt]*

T: *Where did you see it? [Waar het jy dit gesien?]*

Learner L (pointing to text time): *Here (pointing to question 7c) it say twenty past eight. [Hier sê dit twintig minute oor agt]*

The data indicates that some learner use the hour position as the reference point to calculate the minutes. Here learner L does not recognise the 12- marker or label as an important start position for both the hour and the minute hand positions. She states that she counted from the 8 hour position to get the 20 minutes. She also sees the hour position as fix at the eight while it is actually past or after 8 o'clock. I observed that most of the learners positioned the hour hand incorrectly when it is past or to the hour.

For questions 7d – 7f I refer to the summary in table 9. I present notable responses which illuminates key ideas.

Question 7d asks the learners to draw the time quarter past four

The learners indicated that they recognise the quarter position at the 3 marker. The learners seem to be aware of the quarter landmarks on the clock face and know that 3 number marker also represents 15 minutes when they counted from the start position at the 12. Similar to previous data learners more often struggled to position the hour hand at the correct position when it is past the hour.

Question 7e asks the learners to draw the time 40 min past six

Learners used the counting procedure to get the 40 minutes. Learners were confident to calculate the 40 minutes (long hand position) although they indicated that it was not familiar to them.

Question 7f asks the learners to draw the time quarter to one

Some learners indicated that although they know the quarter landmarks they get confused with the sides ‘past’ and ‘to’ on the clock. Learners seem to find it difficult to make the transition from the right ‘past’ side to the left ‘to’ side when distinguishing quarter ‘past’ and quarter ‘to’ time.

4.5.3 Case study data

In this section I will analyse the video-taped data of the intervention programme for the sampled learners. Several themes relating to the telling and meaning making of analogue clock time, emerged from this data. These themes will be used to structure my presentation of the case study data. I draw illuminating vignettes (episodes) from the interviews with photos and transcripts, where useful in order to illustrate the learners’ responses.

THEME 1: THE NEED TO USE THE 12-LABEL AS A REFERENCE POINT, WHEN WORKING WITH TIME USING THE ANALOGUE CLOCK

The 12 helps in physically constructing a clock face

The task required the learners to insert the numbers 1-12 in the correct order in a cyclical on the clock face. They also had to insert the dots between the numbers to indicate the minutes. In the end attach the two hands in the center of the clock using a pin.

The following extract (Extract 4.12) from the paper plate construction activity illuminates one example of the use of the 12 label by a student in her construction of a clock face. She uses it here as a safe and reliable starting point for constructing the clock face that prevents her from making errors in placing the subsequent numbers.

Extract 4.12: The 12 helps placing the configurations on the paper clock

Teacher: *Where did you first start? [Waar het jy begin?]*

Learner C: *From the 12 [Van die 12]*

Teacher: *You started from 12 ... why? [So jy begin by 12 ... waarom?]*

Learner C: *If you don't start at twelve I will get confused where the numbers go [As jy nie by 12 begin dan sal ek deurmekaar raak waar die syfers gaan]*

The making of the paper clock allowed learners to become aware of the different configurations of the clock. The actual construction when putting the parts together to form the whole clock seemed to encourage the learners to take careful note of the different numbers and hands on the clock. The spatial orientations of the numbers in relation to their particular position were reinforced to the learners, even though this concrete experience did not guarantee successful learning of the clock configuration. Through the apparent location of the numbers I observed that some learners were aware of the importance of tracking the major landmarks on the clock.

Mixing up placing of hour and minute hands doing a whole hour

The task was for learners to select a card on which a clock time was represented on a clock face, and then they had to copy that onto a physical analogue clock, and then read out aloud the time.

Excerpt 4.13 presents a case of a learner C who when representing a whole hour on her card, correctly identified the 12 label for one hand and the hour for the other hand, but she mixed

up the minute and the hour hands. She prematurely but correctly read out the time from the card, but then copied the placement of the hands incorrectly.

Excerpt 4.13a:

Photo 4.18: Learner C's representation of the whole hour



Learner C (picks up game card and reads out): *Two o'clock*

Teacher: *Show two o'clock on the clock [Wys twee uur op die klok]*

(learner C sets the clock hands in response with the short hand on the 12 and the long hand on the 2 – see picture above)

Teacher: *Show it to your friends ... put the clock on the table so that we can see it.*

[Wys dit vir jou maat ... sit die klok op die tafel soda tons kan sien]

Recognizing the 12 label's as 60 minutes and hourness¹ but over generalizing it

The task was for learners to select a card on which a clock time was represented on a clock face, and then they had to copy that onto a physical analogue clock, and then read out aloud the time.

In the same exchange the one learner responds by pointing out that the clock that C had made up was not 2 o'clock as the card had indicated it should be and points out how it should in fact look in the following exchange

Except 4.13b

Teacher: *R, we all must say something ... what do you say? [R, ons almal moet iets sê ... wat sê jy?]*

¹ Hourness here means when the long minute hand points to the 12 level that also means that the small hand is on an hour number and is X hour.

Learner R: *uh ... Sixty minutes past two [uh ... sestig minute oor twee]*

Teacher: *Sixty minute ... why do you say so? [Sestig minute ... waarom sê jy so?]*

Learner Z (shaking her head): *No (low voice) [Nee]*

Learner R: *The long one must stand on the twelve and the short one must stand on two [Die lang een staan op die twaalf en die kort een moet op twee staan]*

Teacher: *Must the long one stand on... [Moet die lang staan op ...]*

Learner R, identifies the mistake and tells how to fix it, but then reads out the time as 60 min past 2. This shows a correct use of the double units, a correct interpretation of the hands (short – hour, long – minute). But then seems to overgeneralize the ‘minutes past’ construction to an o’clock configuration where it is unnecessary (suggesting his overriding focus may be on the ‘minutes past’ construction, possibly leading to this overgeneralisation to a configuration where it is not necessary).

THEME 2: THE NEED TO USE BOTH CLOCK HANDS AND THE RELATIONSHIP BETWEEN THEM, TO INTERPRET ANALOGUE CLOCK TIME.

The task was for learners to make an analogue paper clock plate that included the number and hand configuration, and then read out aloud the time displayed on it.

In the analysis of the intervention, it appeared that learning to read clock time that involved a non-zero minute value was not a matter of merely relating the hour and minute hands to reference points on the clock face (identifying reference points). The process seemed more complex than this. For the correct interpretation of the hour hand generally required relating it to the clock face and the minute hand (or the interpretation of the minute hand). The correct interpretation of the minute hand correctly only required the learners to relate it to the clock face. The following excerpt shows one aspect of the complexity of reading clock time in this case. Specifically it demonstrates the learners’ difficulty in finding reference points for the minute hand without relating it to the hour hand.

Photo 4.19: The learners' difficulty in recognising reference points



Excerpt 4.14: The learners were asked to read the time shown on the paper clock. The activity shows how some learners interpret the reference position of the two hands.

Teacher (set the clock): *What is the time? [Hoe laat is dit?]*

Learner L: *Quarter past one [Kwart oor een]*

Learner Z: *Five minute past three [Vyf minute oor drie]*

Teacher: *What did you say L? [Wat het jy gesê L]*

Learner L: *Five ... fifteen ... ten minutes past three [Vyf ... vyftien ... tien minute oor drie]*

Teacher: *Why ten minutes? [Waarom is tien minute?]*

Learner Z: *Five minutes past three [Vyf minute oor drie]*

Teacher: *Why do you say so? [Waarom sê jy so?]*

Learner Z: *Because it five here, sir (pointing to 1 numeral) [Want dis vyf hier, meneer]*

Teacher: *Does the one count five minutes [Tel die een vyf minute]*

Z: *Yes, sir [Ja, meneer]*

Learner L (disagree): *Five; ten, sir (counting on the clock) [Vyf; tien; meneer]*

Teacher: *Where does it show to now? [Waarna wys dit nou?]*

Learner L: *Five; ten, sir [Vyf; tien, meneer]*

Teacher: *Why do say ten? [Waarom sê jy tien?]*

Learner L (pointing with her pencil to the number on the clock): *I count from 1 to 2 give 5 minutes than to 3 in total 10 minutes [Ek tel van 1 na 2 toe kry ek 5 minute toe na 3 is saam 10 minute]*

In excerpt 4.14 above, the data shows that learner L started from the minute hand and counted on 10 minutes to the hour hand (here the minute hand is the reference and the hour hand the 'aim'). She seems to work relatively between the two hands to get the minute value, rather than just relating the minute hand to the face.

Excerpt 4.15: Shows learner L's interpretation of the reference points.

Teacher: *Where does point to now (show with finger to the minute hand at 1 numeral)*
[Waarna wys ddit nou?]

Learner L: *Five, sir [Vyf, meneer]*

Teacher: *So its' five and not fifteen right, it shows here [So dis vyf en nie vyftien reg, dit wys hier]*

Teacher: *And how many is this (pointing to the hour hand on the 3 numeral) [En hoeveel is dit?]*

Learner L: *Fifteen [Vyftien]*

Teacher: *What is its' name? [Wat is sy naam?]*

Learner L: *Hour hand [Uur arm]*

Learner Z: *Five minute past three [Vyf minute oor drie]*

Here learner L seems to know the difference between the hands but counts the minute value as ten minutes. The observable absence of zero minute position perhaps constrains her to count meaningfully. She seems to count in 5's the gap between the numbers 1 till 3 as a total of ten minutes. Although she later express that the minute hand at numeral 1 counts as 5 minutes but still seems to get confuse with the idea of the application of hierarchal value attributes. This is evident when she says hour hand at 3 is fifteen.

The complexity of storage and retrieval of the analogue clocks configurations and bi-dimensional thinking requires tremendous focus and concentration. It requires a range of knowledge and skills as well as the ability to co-ordinate and separate the hour and minute hand and to be able to do compensation as well. The clock seems to act as a tool that enables learners' to make meaning by tracking the auditory time in a concrete way. It allows the learners to make conjectures and proof their thinking aloud while visibly demonstrate their own individual understanding of the visual perception articulated in a particular language (photo 4.17 and excerpt 4.14).

It provides an opportunity for assistance to correct the learners' mistakes. The learner model clocks seem to constraint the idea of double movement of the hour and minute hand. While the teacher model clock seem to address the bi-dimensional though because the hour and minute hand simultaneously function together as a unit.

In excerpt 4.16 below, shows learners grappling with using the concepts of ‘past’ and ‘to’ when reading a clock.

Photo 4.20: The learners’ difficulty with past and to on the clock



Learner L (action): *Set the clock above and read the time [Sit die tyd op die klok en lees die tyd]*

Learner L (read): *Twenty minutes to (before) three [Twintig minute voor drie]*

Teacher: *Is she correct? [Is sy reg?]*

Learner Z: *No, sir [Nee, meneer]*

Teacher: *Tell her why you say it [Sê vir haar waarom jy so sê]*

Learner Z (pointing to the clock): *It is two and not three [Dis twee en nie drie]*

Teacher: *Help her [Help haar]*

Z: *It is twenty minutes to (before) two [Dit is twintig minute voor twee]*

Teacher: *Ok ok*

Teacher: *Learner R how does you say? [Hoe sê jy?]*

Learner R: *Twenty minutes past [Twintig minute oor ...]*

Teacher: *Twenty minutes past what? [Twintig minute oor wat?]*

Learner R: *Past six [Oor ses]*

Teacher: *Ok*

The data shows that all the learners easily recognised the minute units as 20 but disagreed about the position of the hour hand on the clock. Learner L stated that the hour hand read as ‘before’ three while learner Z argue that it read as ‘to’ two. The learners seem to struggle to comprehend the relational directionality involved in ‘past’ or ‘to’ which relates to how they see and read the hour hand to the minute hand. Looking at photo 3 the hour hand is just before the 2 which if you start with the hour hand it would lead us to suspect that we would be working with a few

minutes to 2. The minute hand is not well aligned with this position of the hour hand (because it points to the 4), so if you start with the minute hand you would have to choose between 20 past 2 and / or 20 past one time. So this extract may show that the learners are basing their choice of 'past' or 'to' on the hour hand and not the minute hand

Photo 4.21a: The learners' representation and interpretation of half hour time



Excerpt 4.17, shows the learners' interpretation of the half hour concept.

Learner L (read time on iconic card and read set clock): *Half before four [Half vier]*

Teacher: *Learner L, you can say it in English if you want to [L, jy kan dit in Engels sê as jy wil]*

Learner L: *Half past four*

Teacher: *Put it on your clock as you say it [Sit dit op jou klok soos jy dit sê]*

Teacher: *Quickly put it on your clocks ... Learner C, do not look at hers [Gou sit dit op jul klokke ... C moenie na haar ne kyk]*

This excerpt shows that the hour hand is shown as less than 5 and the minute hand at the 6 (half hour) landmark. The data indicates that learner L used English and Afrikaans to say the clock time. She used English to express the time correctly namely, half past four. Here she seems to be able to recognise the English convention reference of reading the half hour for the upcoming hour. While in Afrikaans the learner may seem uncertain about the reference position and how to use the half hour reference. For example, learner L said 'half vier' which means half past three in English. The use of a particular language to express the visualised time seems to impact on the learners' conception of the relational link between the minute hand and the hour hand. The learner also failed to interpret the minute hand as half an hour before the upcoming hour or even as half an hour past the hour.

Excerpt 4.18, shows the different interpretation of the half hour concept.

Teacher: *See if she is correct [Kyk of sy reg is]*

Teacher: *Half past ... half past? [Half oor ... half oor]*

All (unison): *Half after four [half na vier]*

Teacher: *In Afrikaans way say? [In Afrikaans se manier]*

Learners C and Z: *Half five (low voice) [Half vyf]*

Learner R: *Half before four (low voice) [Half voor vier]*

Teacher: *Is it like that? ... Right ... [Is dit reg so? ... Reg ...]*

Teacher: *Show them L [Wys hulle L]*

Teacher: *Is she correct ... Is she correct? Don't swing it L, their eyes will get confuse [Is sy reg ... Is sy reg? Moenie dit swaai nie L, hulle oë sal deurmekaar raak]*

Learner Z: *Yes, sir [Ja, meneer]*

Teacher: *Can you see where the hour hand is ... is on the four or between the four and three [Kan jy sien waar die uur wyser is ... is dit op vier of tussen die vier en drie]*

Learner Z: *Between the four and five [Tussen die vier en vyf]*

Teacher: *Four and five ... so there it must be than it is half past four. It is past the four, right [Vier en vyf ... so daar is dit half oor vier. Dit is oor vier, reg]*

The data shows that learners are flexible to think of different ways to express the half hour time on the clock. The learners stated that they can read the half hour time as half before four (half voor) and / or half after four (half na) and / or half past four (half vyf). Similar to excerpt 5, the half hour reference is easily identified while the positioning of the hour hand in relation to the minute hand is not yet stable.

Excerpt 4.19, shows the learners' conceptual understanding of the half hour concept.

Teacher: *So it is "half vyf in Afrikaans" [So dis half vyf in Afrikaans]*

Learners (unison): *Yes [Ja]*

Teacher: *Right ... good. You have said something interesting you said half after four [Reg ... goed. Jy het iets interessant gesê half na vier]*

The data also indicates that some learners develop a conceptual understanding of the half hour concept for Afrikaans language. In excerpt 7, the reference convention for the Afrikaans reading of the hour in advance to the upcoming hour when the minute hand is positioned at the

6 landmark (half hour mark) seems to develop slower. While the learners' preference to use the 30 minute past the hour time format is noted.

Next, I present a brief summary of collected data of the learners' responses when asked which hand they read first when using analogue clocks during the intervention programme. This data will provide an idea of the learners' conception of the order in which the hands are read in relation to a particular time displayed.

Table 10 below, shows the individual learners' preference of clock hands when reading different clock time:

Table 10: Learners' indication of the hand they read first on the clock

Clock time displayed	Learner Z	Learner C	Learner J
2 o'clock	Hour hand – because if I start with minute hand than get confuse where to put hour hand	Minute hand – place it at 12 place, not to get confuse e.g. 12 hour and 2 minutes	Hour hand - will get confuse and say 10 min past (oor) 12
Quarter past 2	Minute hand- will get confused if she read the hour hand first and minute hand at 2	Minute hand - She feel it is easier, by just moving minute hand (long hand)	Minute hand – because I will get confuse. He feel he will say 10 minute past (oor) 3
Half past two (half drie)	Minute hand - She feel if she read the hour hand first than she will get confuse	Minute hand - say minute hand move only don't have hour hand	Minute hand - Begin with the half because 6 is half
Quarter to 3	Minute hand - because reading hour hand first will get confuse. She says hour hand will be at 9 than minute hand at 3.	Minute hand - Don't have to move the hour hand but only the minute hand.	Minute hand - it is easier don't get confuse. Say minute hand quarter placed at numeral 9
10 past 10	Minute hand - She see minute hand first before telling the time [182mp14:00]	Minute hand - minute hand is more important , no motivation	Minute hand - feel the hour hand is important but read and say the minute hand first.

The collected data shows that all learners regard the hour hand as an important indicator when reading whole hours namely o'clock time on the analogue clock. Learner C recognises the 12 number or label as the 'hourness' position, placing the minute hand at the 12 label and also reads the minute hand position before the hour hand in this case. On the hand, learners Z and J state that they read the hour hand first because they would get confused about the number of hours. The learners have different approaches to reading whole hours or o'clock time.

Generally the collected data shows that learners learn to first read or track the minute hand position when reading or telling the past hour time like past, half and to the hour time. All the

learners say it is easier and limits confusion of the position of the hour and minutes. For example learner Z and J argue that in quarter to 3 it is easier to place the minute hand at the quarter numeral 9 and the hour hand towards the three. The learners explained that it limits the confusion of hour hand at 9 than minute hand at 3. Finally, the learners do mention that although they read the minute hand first in the above-mentioned they still regard the hour hand as important without motivating why.

THEME 3: THE NEED TO MAKE AN EXPLICIT DOUBLE USE OF THE SAME MARKERS FOR TWO DIFFERENT PURPOSES, WHEN WORKING WITH ANALOGUE TIME.

Excerpt 4.20 below, shows how learners' use the physical clock to justify their own reasoning as they set up their own clocks to show the clock time, 20 past 2 [20 oor 2]. In particular, the excerpt illuminates the usefulness of the availability of the physical clock for learner C.

Photo 4.21b: The learners' use of the physical clock



Teacher (picture clock showing 20 past 2): *What is the time now ... show it and say it [hoe laat is dit nou .. wys hom en se hom]*

Learner C (back clock): *40 minute wait ... 20 minute past two [40 min wag... 20 minute oor twee]*

Learner Z (front clock): *15 minute [15 minute]*

Teacher: *Show it on the clock [Wys hom op die klok]*

Learner C: *20 minutes past two ... 20 past two [20minute oor twee ... 20 min oor twee]*

Learner Z: *20 minute past two [20 minute oor twee]*

Teacher: *Is it? [Is dit?]*

Learner Z: *Yes [Ja]*

Teacher: *20 minute [20 minute]*

Teacher: *Let's look at the clocks [Kom ons kyk op die klokke]*

The data shows that learner C stated that the 4 is 20 and the 3 is 15. The data suggests that she appears confident to identify the double nature of the numbers on the clock. She recognised the different value each marker represents on the clock. Learner C makes the difference explicit when stating that the 4 is 20 minutes and the 3 is 15 minutes.

Reflecting on excerpt 4.13, the data also shows that learners struggle to recognise the double use of the markers for two different purposes, because learner Z is repeatedly uses 1-units to count the minutes. She, when reading it (photo 4.18), reads the short hand correctly (showing that in reading she correctly uses the hour hand to identify the hour count – in this case interpreting the hour hand correctly), but cannot make the unit ‘switch’ from hours (counting in ones) to minutes (counting in fives).

While in excerpt 4.15, learner L is not certain about the position of the reference point on the clock. The data shows that learner Z seem to interpret the hour hand as 15 minutes may only be a minor overgeneralisation of the minute units because I have been focussing strongly on the minute units of 5 in the previous interchange (and so this disturbed a reasonably stable distinction between hour and minute units). Or it may be a more substantial overgeneralisation because her distinction between hour and minute units is not very stable. After some explanation from learner Z that the minute count starts from the 12-label did learner L modified her ‘15’ easily to a ‘3’ for the hour and ‘5’ for the minutes.

In the next activity I noted that the $\frac{1}{2}$ hour rule is different for English and Afrikaans. Thus, in English we say half past two for 02:30 but say half drie (half three) in Afrikaans meaning i.e. half before 3. This is evident in the teacher data that languages create some difficulties for learners who are familiar with both languages. In the excerpt below I illuminate the nature of the difficulty.

The following section presents the learners’ interpretation of the half hour concepts in relation between hour and minute hand position.

Excerpt 4.21 below, shows the learners' read and display the following clock time 1:30.

Learner Z (read and display): *half before two [half twee]*

Learner C (does not place the hour hand between 2 and 3 numbers): *30 min past [30 minute oor]*

Learner C (read): ... *60 minute past two [60 minute oor twee]*

Teacher: *Set it on the clock [sit dit op die klok]*

Teacher: ... *do you say 60? [sê jy 60?]*

Learner C: *30 minute past two [30 minute oor twee]*

Teacher: *What is the time you say? [Hoe laat sê jy?]*

Learner Z: *Half before two [Half twee]*

The section below (see photo 4.21c) illuminate the learners' uncertainty of reading and telling half hour time in Afrikaans.

Photo 4.21c: The learners' uncertainty with the Afrikaans half hour



Excerpt 4.22 below, shows the influence of language in telling half hour time.

Learner Z: *Yours is not correct [Jou is nie reg nie]*

Learner Z: *The short one must be between 1 and 2 [Die korte moet tussen 1 en 2 wees]*

Teacher: *So it's half past the ... one ... so it's still going to two [So dit half verby die ... een ... so hy gaan nog na twee toe]*

Teacher: *In Afrikaans we read it a half hour in advance hey but in English we say half past one [In Afrikaans lees ons die half vorentoe ne in Engels sou ons se half past one]*

I (Teacher) observed that learners seemed not to anticipate the half hour rule for Afrikaans. For example that the hours is read one hour in advance while it is not the rule applying in English.

This is shown in the following excerpt. The excerpt also shows that learners use different ways of telling the half hour, like using relative and absolute format.

In this section the collected data shows that learners use different ways of telling the half hour time like relative and absolute format.

Photo 4.21d: The learners' say half hour time in different ways



Excerpt 4.23 below, shows that learners flexibly use different ways to tell half hour time.

Learner J: *Half before five [Half vyf]*

Teacher: *L what did you do there ... say quickly for us [wat het jy hier gemaak ... sê gou vir ons]*

Learner L: *Here, sir. [Hier, meneer]*

Teacher: *Yes [Ja]*

Learner L: *I wrote half five [Ek het half vyf geskryf]*

Teacher: *Ok. Why did you write "half vyf" half five? [Ok. Waarom het jy half vyf geskryf?]*

Learner L (pointing to iconic clock): *Because when it comes to the middle than is "half vyf" [Want as dit by die middel (wys na minuut wyser) is dan is dit half vyf]*

Teacher: *O, when it comes in the middle than its "half vyf".. o [O, wanneer dit by die middel is dan is dit half vyf]*

Learner L: *It is past 4 [Dit is oor 4]*

Teacher: *So it is going to the ... [so dit gaan nog na ...]*

Learner L: *Five [Vyf]*

Teacher: *How did you say the time was, J? [Hoe het jy gesê J?]*

Learner J: *I said it is 30 minutes ... 30 minutes ...30 minute past four [Ek sê dis 30 minute ... 30 minute ... 30 minute oor vier]*

Teacher: *30 minutes past four ... are you all satisfied? Happy [30 minute oor vier ... is jy tevrede]*

Learners (unison): *Yes [Ja]*

Teacher: *Satisfied? What did you write, L? [Tevrede? Wat het jy geskryf, L?]*

Learner L: *30 minutes before five [30 minute voor vyf]*

Teacher: *Yes we can also say it like that yes [Ja ons kan ook so sê ... ja]*

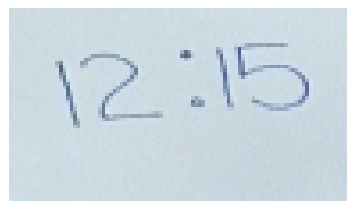
Learner J: *It is the same, sir [Dis dieselfde, meneer]*

The data presented shows the link between the languages used when the learners used past or to in order to tell the time. The data seem to present that the learners more often prefer to work conceptually with what has “passed” (i.e. already happened) than what is to come (i.e. 15 minutes before). This is possibly because conceptually learners can understand and see the 5; 10; 15; 20 minutes after (clockwise direction), but not the (anti-clockwise) counting before 55 as 5 minutes to 50 as 10 minutes to, etc.

Photo 4.22: Clock format and digital format



Clock format



Digital format

The next excerpt 4.24, presents one learners’ use of the digital format in analogue clock time.

The data collected shows that learner L used the digital format to record the time from the analogue clock, for example 12:15 as presented in photo 5 above. The data suggests that learner L is comfortable and confident using the digital format to represent clock time. While some other learners are not comfortable with the digital presentation. Learner C stated that she does not know where the hours and minutes are and see the colon as representative of the hours and minutes.

Teacher: *You wrote something here [Jy het iets hier geskryf]*

Learner L: *Fifteen minutes past twelve [Vyftien minute oor twaalf]*

Teacher: *I want you to see what L wrote. L wrote something like this 12: 15 [Ek wil hê julle moet sien wat L geskryf. L skryf iets soos die 12:15]*

Teacher: *Wait let's give her (Learner Z) a chance to speak [Wag laat ons haar (Z) 'n kans gee]*

Learner Z: *I don't like it [Ek hou nie van dit nie]*

Teacher: *Why don't you like it? L doesn't feel happy about her saying she doesn't like it [Waarom hou jy nie van dit nie? L. voel nie gelukkig oor dit nie sy hou van dit]*

Teacher: *L why do you like it? [L waarom hou jy van dit?]*

Learner L: *It is easy, sir. 12:15. I can't write the minute way [dit is maklik, meneer. 12:15. Ek kan nie die minute manier skryf nie]*

Teacher: *Oh you can't write the minute way [Oh jy kan nie die minute manier skryf nie]*

Learner L: *I know this one - 12:15 and not the clock one [Ek verstaan die een - 12:15 en nie die klok ene]*

Teacher: *Yes, C you wanted to say something [Ja, C jy wil iets gesê het?]*

Learner C: *I don't know if the middle (pointing to colon :) is the minutes or hour [Ek weet nie of die middel die minute of uur is]*

With regard to research question 2, namely how do learners' learn to make meaning of analogue clock time, the following themes will be used as sub-sections to categorise the data content:

THEME 4: THE AVAILABILITY OF THE CLOCK MEDIATES THE PROCESS BY EXTERNALIZING THE PERCEIVED TIME.

In the following section I present data collected when the learners were challenged to expand their thinking and reasoning about elapsed time. The following excerpt illuminates the learners' ways of interpreting elapsed time.

Photo 4.23: The learners' conceptual understanding of elapsed time



Excerpt 4.25, shows how the learners use the physical clock to externalise elapsed time.

Teacher (shows time on clock): long hand at 3 and short hand to the 7

Teacher: *What was the time 15 minutes earlier? [Hoe laat was dit 15 minute vroeër?]*

Learner Z (pointing to the clock in the teacher's hand): *minute hand must be at the 11 number [Die minute wyser moet by die 11 syfer is]*

Teacher: *Use the clock and set your clock alike [Gebruik die klok en sit jou klok so]*

Teacher: *Count 15 backwards [Tel 15 terug]*

Teacher: *What was the time? [Hoe laat was dit?]*

Learner L: *7 o'clock [7 uur]*

It seemed that learner Z was the first to form an idea that the minute hand will move backwards because of the way she gestured the direction.

Learner Z shows the presence of mind to count anti-clockwise which would seem a reasonable approach, but learners rarely experience a visual concrete image of the clock hands rotating in an anti-clock way. The physical clock seems to enable these learners to externalise their personal understanding and adapt it when using the clock to check their initial understanding. For example, learner Z used the clock to assist and support her thinking when demonstrating her thought process using the clock. The data suggests that the physical clock enable the learners' initial mental image to become concretise. It allows the learners abstract thinking to become external and observable to others (teacher and group members).

In the following excerpt 4.26, learner C began to explicitly voice her response by taking a position to argue her thinking and reasoning.

Excerpt 4.26 below, shows how learner Z developed the confidence to help and correct other members in the group. Here she uses the physical clock to justify her reasoning in the picture clock time, 20 past 2 [20 oor 2]. The following sequence of the episode above illuminate the usefulness of the availability of the physical clock for learner C.

Photo 4.24: The learners' different interpretation of clock time



Learner C (back clock): *It's at four when the long hand ... then its 20 [hy's by vier wanneer lang wyser ... dan is dit 20]*

Teacher: *What are you saying? [Hoe sê jy Z]*

Learner C: *That at three it is 15 [Daai by drie is dit 15]*

Teacher: *What is C saying? [Hoe sê C?]*

Learner C: *She thought the long hand is at three [Sy het gedink die lang wyser by die drie]*

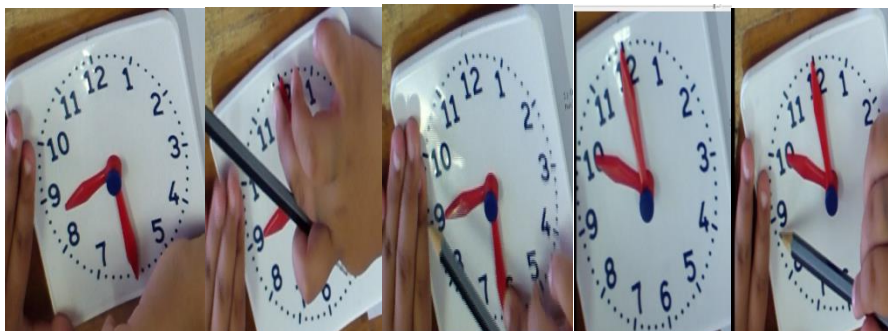
The collected data seem to indicate that the use of the physical clock support counting the minutes correctly and enable learners to compare concrete setting with the picture representation.

THEME 5: THE CLOCK AS A HUMAN TOOL ALSO EXTENDS THE MENTAL RANGE OF THE CHILD, FOR LATER INTERNALISATION.

Excerpt 4.27, shows how the clock was used to mediate meaning making by externalising the internal. This is the response from learner J to question 2 from the problem solving activities during the intervention programme.

Question 2: We leave the house at about 8 30 the morning and arrive at 10 o'clock in Port Elizabeth. How long did we travel to Port Elizabeth?

Photo 4.25: The clock extends the learners' mental range



Excerpt 4.27 below, shows how the learner use the physical clock to extend their mental range

Learner J (reads question 2 aloud): [Ons verlaat die huis om ...8 30 die oggend en kom 10 uur in Port Elizabeth. Hoe lank het ons na Port Elizabeth gery?]

Learner J: *Sir, how much is this? (Pointing to 8 30) [Meneer, hoeveel is die?]*

Teacher: 8 30

Learner J: 8 30

Learner J: *So this is 30 minute before eight? [So dit is 30 minute voor agt?]*

Learner J: *Past eight? [Oor agt?]*

Learner J: *Jo, I need a clock for this one [Jo, ek need 'n klok vir die een]*

Teacher: *Hey? [He?]*

Learner J: *I need a clock for this one [Ek need 'n klok by die ene]*

Teacher: *Do you need a clock? [Het jy 'n klok nodig?]*

Teacher: *This clock? ... ok [Hierdie klok ... ok]*

Teacher: *Place your clocks on the table so we can see how you worked ... you did it alone [Sit dit op die tafel datons kan sien hoe jy werk ... jy is moes alleen]*

Learner J (actions when setting clock): Long hand on 30 minutes (marker 6) and short hand towards marker 8. Then move hour hand clockwise a little past the 10 numeral **Learner J:** *Eight thirty [agt dertig]*

Learner J (actions): Moves the hour hand between 8 and 9 and then to the 9. Then move the minute hand from the 30 minute position clockwise to the 12 numeral (whole hour) the hour hand staying on the 9 numeral. Moves the minute hand clockwise another half hour and continues till the whole hour and sets the hour hand now to the 10 numeral (ten o'clock)

Learner J (actions): Looks at the calibrated dots between 8 and 9 numerals and write

J (record): *2 hours [2 ure]*

Teacher: *What did you do there? Tell us [Hoe het jy daar gemaak? Sê vir ons]*

Learner J: *Sir, I counted here from eight. Then I went around ... I came to nine o'clock. Then I went around again [Meneer, ek het getel hier van agt af. Toe gaan ek om ... toe kom ek by nege uur uit, meneer. Toe gaan ek weer om en om ...]*

Teacher: *With what did you go around? [Met wat het jy om gegaan?]*

Learner J: *With the long hand, sir ... than I get to twelve ... than the short come to ten and I see it's two hours, sir [Met die lang wyser, meneer ... toe kom ek hier by twaalf uit... toe kom die korte by tien uit toe sien ek dis twee ure, meneer]*

Teacher: *You got 2 hours ... ok happy? [Jy het 2 ure gekry ... ok happy?*

Learner J: *Yes [Ja]*

The data shows that learner J was uncertain what the absolute format 8 30 meant. The learner seem to recognise 30 minutes but seem not to be familiar with the format and the relation of the numeral with regard the past or to hour time.

When learner J had to determine the duration of the elapsed time from 8 30 till 10 o'clock he immediately decided to use the clock. The deliberate opting to use the clock seems to begin when the learner was unsure about the representation of the time 8 30. The data suggests that he then decided to use the physical clock to transfer 8 30 time onto the clock. The learner thus used the clock see and conceptualise the 8 30 representation.

The data shows that the use of the clock enabled him to count that from the 8 30 start to the 10 o'clock stop time. In counting cyclic on the clock the learner seemed to forget about the initial half hour start. Although the physical clock supported and assisted him to develop a gradual understanding of the concept duration it was difficult for the learner to check his count. Thus the learners need to be aware of the reference convention when determining duration of events.

This learner was also more inclined to calculate whole hours although he started counting in minutes from the 30 minute (number 6) position on the clock face. The learner seems to interpret that when the minute hand moved from the half landmark to the 12 label position a whole hour was attained. The learner then moved the minute hand around again to show the passing of a whole hour, linking this with a movement of the hour hand from the 9 to the 10. This gave a total of 2 hours. Learner J did not seem to take into the account the 30 minutes of the hour that had already passed to get to the start time (8:30) and so calculated an elapsed time of 2 hours.

The data also shows that he was not sure how to mentally calculate this and so decided instead to do it physically and concretely. He watched how the hands moved as he moved then from 8:30 to 10, and interpreted this movement as showing the passing of a corresponding period of time.

The data shows how using the clock assists the learner to calculate elapsed time. The clock seems to bridge the complexity of the abstract concept of elapsed time and the formal symbols used to describe and calculate it into a concrete spatial representation. To physically carry out the calculation using the clock representation, learner J needed apply his bi-dimensional thought about analogue time, as he performed his actions. He did this appropriately, when he moved the minute hand completely around the clock, while simultaneously moving the hour forward from 9 to 10 in a clockwise motion to show a whole hour of elapsed time. While his linking of the first movement of the minute hand from the 6 to the 12, to an elapsed period of half an hour as inappropriate. In both cases, this excerpt shows that the learner used a range of clock knowledge and skills to determine the duration of the event.

The data seems to suggest that learner J's attention is more on the whole hour concept. Thus whole hour dominance of seeing the 9 o'clock on the physical clock becomes the focus object while the half hour becomes obscured by the focus on the whole hours, namely 9 and 10 o'clock.

THEME 6: PHYSICALLY CONSTRUCTING THE CLOCK, MEDIATES LEARNING THE CLOCK REPRESENTATION.

Photo 4.26: The physical clock mediates mental visualisation



The following excerpt 4.28, illustrates how the physical construction of the analogue clock mediates meaning making of clock configurations.

Learner C used the physical clock to help her draw the paper clock. She used the physical clock to count the interval between the numeral on the clock to indicate accurately the division

and numerals on the clock. The learner seems to realise the procedural actions in duplicating the displayed information onto the paper plate.

Teacher: *Where did you first start? [Waar het jy begin?]*

Learner C: *From the 12 [By die 12]*

Teacher: *You started from 12 ... why? [Jy het by 12 begin ... waarom?]*

Learner C: *If I don't start at twelve I get confuse which numbers goes where [As ek nie by 12 begin nie sal ek deurmekaar raak waar die syfers gaan kom]*

The data seems to suggest that the making of the paper clock allowed learners to become aware of the different configuration on the clock. Thus suggests that the spatial orientations of the numbers in relation to their particular position were reinforced to the learners. Although the apparent location of the numbers on the clock face learners were not attentive of the importance of tracking the major landmarks on the clock. The actual construction when putting the parts together to form the whole clock seems to make learners attentive of the different configurations on the clock. Unfortunately this seems not guarantee that the concrete experience ensured that the learners would complete their meaningful learning of the clock.

The above excerpt suggests that although the learner could construct the clock she seem not to recognise the different hands effectively.

THEME 7: THE PHYSICAL CLOCK REPRESENTATION IMPACTED LEARNERS' THINKING ABOUT ANALOGUE TIME.

The following section presents different ways learners read and tell physical clock time. The following excerpt 4.29, shows how the physical clock mediates meaning making

Photo 4.27: The clock mediates learners' ability to tell time in different ways



Teacher: *What is the time now? [Hoe laat is dit nou?]*

Learners J and L: *Quarter to [Kwart voor]*

Learner Z: *Forty five minutes past four [Vyf en veertig minute oor vier]*

Teacher: *Ok. You can say 45 minutes past three [Ok. Jy kan ook sê 45 minute oor drie]*

Teacher: *But when I say quarter to four because its' before the four hours ... can you see [Maar wanneer ek sê kwart voor vier want dis voor vier uur ... kan jy sien]*

The data seems to show that learner Z grasps the idea that the past and to side shown on the model clock is not limited to a particular side on the clock. Learner Z appears confident to read the time as forty five minutes past although the model clock labels indicate the side on the left as the “to” side of the clock. Thus learner Z is extending the range of the past side across while accepting that the “to” side can be simultaneously maintained.

The data seems to indicate that learner Z is aware of the reversibility of the sides referenced as ‘past’ and ‘to’ and of its extended borderlines. Thus the learners transition of packaged idea of past or to in terms instructional experience in the previous grade 3 is adapted.

The data shows that learners prefer counting forward rather than backwards. Saying 45 minutes past seems to come more naturally than saying quarter to the hour

In conclusion, the description of the collected data present the following themes which illuminate the learners’ meaning making of analogue clock time when interpreting and using the clock representation:

Theme 1: The need to use the 12-label as a reference point when working with time using the analogue clock

Theme 2: The need to use both clock hands and the relationship between them, to interpret analogue clock time

Theme 3: The need to make an explicit double use of the same markers for two different purposes, when working with analogue time

Theme 4: The availability of the clock mediates the process by externalizing the perceived time

Theme 5: The clock as a human tool extends the mental range of the child, for later internalisation

Theme 6: Physically constructing the clock mediates the development of a mental image of the clock's configuration

Theme 7: The physical clock representation impacts learners' thinking about analogue time

In the following chapter 5, I discuss and interpret the presented data in chapter 4 to illuminate my findings. Thus chapter 5 will provide possible findings that is categorised under the particular themes that had emerged.

CHAPTER 5: DISCUSSION AND INTERPRETATIONS OF FINDINGS

In this section I summarise and discuss the themes that have emerged and have been presented in the previous chapter of data presentation and analyses. I will structure this discussion according to my two main research questions which are:

1. How does the child interpret the analogue clock time representation?
2. How does the analogue clock mediate the meaning making process of analogue clock time?

RESEARCH QUESTION 1: HOW DOES THE CHILD INTERPRET THE ANALOGUE CLOCK TIME REPRESENTATION?

Within the research question 1, I look at the child's interpretation of the tool in terms of the concept of analogue clock time. The research conducted suggests key themes which are important for learning to interpret analogue clock time.

THEME 1: THE NEED TO USE THE 12-LABEL AS A REFERENCE POINT, WHEN WORKING WITH TIME USING THE ANALOGUE CLOCK.

My initial thought was that, to read and say the whole hour time, learners would simply distinguish the hour and minute hand based on the length of the hands. My data showed that learners appear not to simply separate between hours and minutes by looking merely at what the short hand and the long point to. Learners stated that whole hours are indicated by a hand pointing to the 12 number at the top position on the clock face while the other hand gives the hour number. The learners thus see the 12 label on the clock face as an important indicator of hourness when reading and saying whole hours.

The significance of the 12 and the movement from the 12 (or '0 position') is important however, at times learners seemed to focus on this at the expense of understanding the relationship between the hour and minute hand. That is, learners fail to pay attention to the relationship between the hour and the minute hand at a particular reference position and to distinguish between these by the length of the hands. Thus, the 12 position on the clock face may dominate the child's attention more than the length of the hands. Learners may thus read 'whole hours' irrespective of which hand points to the 12 label. For example in the photograph 5.1, learner C reads the clock as representing 2 o'clock.

Photo 5.1: The learners' interpretation of the 12 - label



On the other hand where a learner failed to see the significance of the 12 and that the 12 is also the '0' position also created a problem. For example, in building his clock, learner J showed that he started with 1 at the top position and eventually realised that counting should start at hidden "0" position located at the 12 label. Learner C also stated that she used the 12-label to guide her to position the numbers correctly on the clock (excerpt 1).

These findings relates to Williams (2004) ideas that the label 12 has many associations as demonstrated by the learners interpretation of the 12-label in this section.

THEME 2: THE NEED TO USE BOTH CLOCK HANDS AND THE RELATIONSHIP BETWEEN THEM, TO INTERPRET ANALOGUE CLOCK TIME.

2.1 The learners' uncertainty in naming the hour

I found that the learners find it difficult to interpret the hour and minute hand in relation to each other in terms of position and imposed meaning. As mentioned for theme 1, the interpretation of hour and minute hand for learners is not simply a dichotomy based on the length. More often learners appear to learn that the hour and minute hand represent definite numbers on the analogue clock with a particular numeral reference point. This is particular to whole hours or o'clock time that refers to a specific instant in time or a precise reference point in time. The case study suggests that learners in grade 4 are uncertain where the hour hand should be positioned when it is past the whole hour. More often learners' seem not to place the hour hand between the digits when expressing past the hour time. The ability to position the hour hand seems to be challenging to learners in grade 4 because it requires recognising the double movement and position of both hands simultaneously.

2.2 The learners' interpretation of the count direction

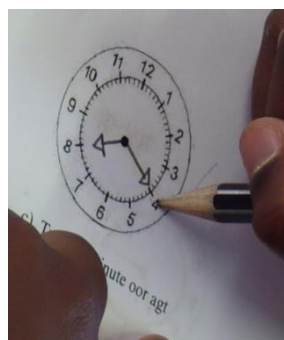
The learners' seem to interpret the 12 label as a critical feature on the clock to perform mathematical operations such as counting from 0 (12-label), resetting to and counting

backwards from 60 (12-label). However in analogue time the interpretation of the hour and minute hand involves coordinating the reading of the hour hand with the count direction chosen for the minute hand. It reflects that two ‘systems’ (for hours and minutes) are continuously operating and the hands indicate either hours or minutes with a particular set of units - either 1’s for hours (1-12) and 5’s for minutes (0-60). The learners have to choose the particular hand and also the particular unit for the hand and position it on the clock face.

Recently Kamii & Russell (2012) argued that the main reason learners find difficulty with elapsed time was their inability to coordinate hierarchical units (hours and minutes). Kamii & Russell (2012) also suggests that teaching practice should encourage conceptual thinking, by using the child’s daily experience to think about duration of time. Importantly they recommend allowing learners to do their own thinking about the elapsed time, hence enabling learner’s construction of logic-mathematical relationships.

Learners at times read the distance from the position of the hour hand to the minute hand to calculate the interval time rather than calculating the minute hand from the 12 (0) position in 5’s. For example, when learner L (see photo 5.2) drew twenty past eight, she had counted backwards from the hour hand position to the minute hand position to get the twenty minute interval drawing both hands on the clock. This gave the correct time but by a wrong method.

Photo 5.2: The learners’ interpretation of the reference position



2.3 The learners’ failure to use the hour and minute hand differently

The ability to draw or set the hands on the clock requires the learners to make meaning and interpret the complex configurations of hour and minute hands on the clock. Some learners find it difficult to conceptualise the functional difference of the hands. For example, some learners differentiate the hour hand in relation to the minute hand in configurations like 20

minutes past four in relative clock time. They first start to position the minute hand position easily by counting clockwise from the 12 label until the 20 unit and similarly position the hour hand to the four instead of the upcoming hour. The learners thus use the minute and hour hands the same instead of recognising that the two hands embody different meaning when positioned on the clock.

The data suggest that the learners fail to conceive the relational interpretation of the two hands when reading for example 20 minutes past eight, which shows the measured interval time distance from one hour to the next although having the same starting position. The learners seemed to routinely act in positioning the two hands by separately tracking the minute and hour hand values on the physical analogue clock.

The above mentioned difficulties learners relates to Williams (2004, p.86) ideas that learners find it difficult to understand that the motion of each hand on the clock face “starts” at the top (the 12) and proceeds in a particular direction (clockwise), completing a cycle when it reaches the top again—even though the motion of the hands is actually continuous, neither starting nor stopping at any point, and is so slow that the hands appear stationary.

THEME 3: THE NEED TO MAKE AN EXPLICIT DOUBLE USE OF THE SAME MARKERS FOR TWO DIFFERENT PURPOSES, WHEN WORKING WITH ANALOGUE CLOCK TIME.

The learners seem to use different ways to read, tell and write the analogue time displayed on the clock. The learners demonstrated different preferences when expressing the analogue clock time. The learners were also flexible in using different ways to express the clock representations. The following sub-section will talk to these findings:

3.1 Relative and Absolute time

The data discussed above showed that the majority of learners in the study prefer to use the relative format as opposed to the absolute format (see table 6). The relative format involved saying the present time as a relationship to some reference time such as twenty past six or quarter to four. The clock readers first track the minute hand in relation to the hour hand value. For example learners were confident saying 30 minutes past seven (Afrikaans: 30 minute oor sewe). The absolute format were seen as fixed at the present which involved reading, saying

and writing the hour and minute units separately from each other without any relational attributes, like seven thirty (7 30).

The data suggests that learners looked at the half-hour concept in the relative time format. Learners expressed the English system like half past one with confidence while the Afrikaans system provided a challenge because it involved reading and saying the minute hand as half to the upcoming hour like “half twee” instead of the previous hour in English. The visual conceptual representation displayed on the clock required the Afrikaans-speaking clock reader to remember the advance hour-rule when reading and saying the hour or quarter to the hour time.

Learners found it difficult to draw or place the hour hand correctly to instantiate the advance hour-rule on the iconic and physical clock. For example, learners reading half past one (Afrikaans: half twee) and found the Afrikaans way challenging when the “twee” referred to the upcoming hour time while the one in English shows the past hour. The majority of learners reflect that reading, saying and writing English half hour time is easily recognisable.

3.2 Conceptualisation of the borders of past and to position

The data shows that learners found locating the ‘past’ position easier than the ‘to’ position in relation to where the minute hand is. The learners would often use the past hour rule, like 45 minutes past 7 (Afrikaans: 45 minute oor 7). For the learners, this simply involved locating the minute hand and calculating the minute and hour units by counting on from the 12 - label and reading the previous past hour reference.

The findings suggest that the learners were more confident with the right-sector advantage ‘past’ (Afrikaans: oor) hour time and find it easier to cross the border of the ‘to’ (Afrikaans: voor) side and use ‘past’ in the clock. The learners showed a greater appreciation for the ‘past’ hour time in the relative format than for the ‘to’ hour time. Learners found it easier to count forward than backwards from the 12 reference point in a clockwise cyclic direction. Also the learners seem to develop ‘past’ the hour clock time skills earlier than ‘to’ the hour clock time skills.

This finding relates to the literature (Friedman & Laycock, 1989, p. 369; Boulton-Lewis et al., 1997, p.145) that speculates or points to a “right-sector advantage” in which learners find it easier to count on the right hand side of the clock.

3.3 Digital in analogue clock

In the data discussed, learner L used a digital time format when expressing the analogue clock time. This learner wrote that the time displayed on the clock was 8:45 or 6:15. This learner had tracked the reference position of the hour and minute hand. The learners' interpretation of the configuration as an 8 hour value and 45 minute value was helped by her understanding of the landmarks on the clock face.

The finding suggests that when learners first used the digital absolute and thereafter the analogue relative to write the displayed clock time, it limits mistakes such as the language of 'past' and 'to'. Furthermore the data showed that some learners were more aware of digital absolute representation at home which impacts on their ability to move confidently from digital to analogue time representation like 6:15 or quarter past six. Noticeably, learners wrote 8:45 when expressing the analogue clock time. Here learners observed that the hour hand is between the 7 and 8 hour labels and chose to read the upcoming hour thus wrote 8 hours while in fact if they read 8:45 in relative time we say quarter to 9.

Unlike the analogue clock the digital clock reading only requires the retrieval of number names, whereas the analogue clock demands complex mental procedural sequences (Friedman & Laycock, 1989; Burny, 2012). Studies done suggests that learners were more successful in reading digital clock time such as 06: 30 because the learner essentially read the numerals separated by a colon as 6 hours and 30 minutes (Boulton-Lewis, Wilss & Mutch, 1997).

3.4 Clock based strategies

The data shows that the learners used the analogue clock to perform different clock based strategies. The learners used the analogue clock to visually show and describe the time in hours and minutes on the clock. In this sense the visual clock-tool did not inform their conceptualisation of hour and minute time rather it indicated only the concept of time. For example, when the learners think how to display three o'clock they used the clock tool to show it. The clock-tool here does not tell how the learners think and form a mental image about the concept three o'clock.

On the other hand when the learners had to calculate elapsed time, they used the clock to do the mathematics of counting the elapsed time. In using the clock to perform these calculations it became incorporated into their mathematical thinking. This underlines the observation that

the clock enabled the learner to think in different ways do complete mathematical tasks using the clock.

This section can be related to Siegler & McGilly (1989) strategies for time telling processes employed by the sampled learners. In addition Burny (2012) argue that learners can acquire time-related competences to enable meaning making of time and clock time if instructional support are available to them.

In conclusion, I became aware that learners flexibly interpret multiple symbolic representations when making meaning relating to the clock.

RESEARCH QUESTION 2: HOW DOES AN ANALOGUE CLOCK MEDIATE THE MEANING MAKING OF ANALOGUE CLOCK TIME?

The following findings suggest how the physical analogue clock mediates the meaning-making process of analogue clock time. The findings promote the importance of the physical analogue clock as opposed to the iconic representations of the clock in acquiring analogue clock skills.

THEME 4: THE AVAILABILITY OF THE CLOCK MEDIATES EXTERNALISING THE PROCESS OF PERCEIVING TIME IN THE ICONIC REPRESENTATION.

The data shows that learners' required the physical clock to communicate their individual sense of the clock time represented in the iconic and symbolic pen-and paper activities. The more capable learner Z used the physical clock to concretely communicate her thinking so that the others could understand her (See excerpt 4.13 & 4.14 for learner Z's gesture). This seemed to suggest that the iconic and symbolic representations limit learner's communication. The more capable learner was able to use the physical clock to explain her position so that the other members could follow and grasp her thoughts.

The learner resorted to the concrete tool to externalise her clock knowledge and skills. This reflects the importance of the clock to mediate the externalisation of the thought process in making meaning of the clock representations. The availability of the clock seems to allow the learner to concretise her thinking and understanding. The physical analogue clock enabled the abstract or iconic representations to become concrete. Thus allowing learners to practically

present their thinking and reasoning in a meaningful way other than using words, signs and symbols to communicate understanding of iconic or symbolic representations.

The learners used the physical clock to externalise the internal interpretations and understanding of the whole system of symbols such as numbers (digits), clock language and the position of the hands that they had learnt. The physical clock seemed to accommodate externalisation better than iconic and symbolic representations. The dynamic feature of the hands on the physical clock allows for demonstrations and observations to be implemented followed by learners manipulating the clock themselves. In contrast the iconic and symbolic tools are static and fixed and appear to limit meaningful concrete observation.

Kieran's (2001) idea that communication is occasioned and shaped by the situation suggests that external tools influence sense making of events. The physical analogue clock as a human tool on the one hand influence the child's mental range (thinking) where it facilitates the extending meaning and understanding through internalisation for later use. On the other hand it also mediates externalising meaning and understanding when using the clock to communicate interpretations.

In conclusion the availability of the physical clock provided the opportunity for the learner to externalise their inner voice or thinking to others. The physical clock mediated externalisation of embedded knowledge and skills that the more capable learner had acquired through interacting with the clock to other members in the group. Theme 5: The analogue clock as a human tool extends the mental range for later internalisation.

Learner J asked for the physical clock to do a problem solving activity involving the duration of elapsed time. The learner's action reflected the need for the external tool to mediate the internal cognitive ability. It suggested that the particular learner has reached the limit of what he could do internally and therefore requested the physical analogue clock to extend his range. Here the physical tool extended the cognitive range of the learner. Once the learner's range was extended he became able to move to internalise the acquired knowledge and skills. The analogue clock thus acts to extend the range for later internalisation.

In this way, the clock becomes an important tool for learning because without the clock the learner cannot go further when he / she reached the end of his / her range. I concur with Bartolini-Bussi & Mariotti (2008) that the physical clock as a tool mediates support in shaping and constructing analogue clock time knowledge from a social to a psychological level to make meaning of clock time.

THEME 6: PHYSICALLY CONSTRUCTING THE CLOCK MEDIATES THE DEVELOPMENT OF A MENTAL IMAGE OF THE CLOCK'S CONFIGURATION.

The data shows that the learners became aware of the intricate nature of the physical clock when they had to construct their own analogue clock using paper plates. I observed that the learners learned valuable technical knowledge and skills about the physical clock.

The actual designing and making of the paper plate clock provided learners with an experience of the practical structure and layout of the different clock configurations. The configurations include spatial attributes such as the cyclic shape, cyclic arrangement of the numbers, and visual-spatial arrangement of key landmarks on the clock face and also the relation of the two hands and their distinguishing lengths.

Importantly the design and construction of the physical clock mediated learning to make meaning of clock time. When the learners labelled the configuration on the clock it created cognizance about how different parts of the whole clock function in relation to each other. Also it contributed to the mindfulness of certain invisible features such as the numbers 0 and 60 when reading, telling and writing the units for hours and minutes of the clock. The learners understanding of the configurations like, the short hand for the hour hand and the long hand for the minute hand and the two systems of unit values that each hand represents, was supported and extended in the making of the physical clock.

The social interaction when making the analogue paper plate clock created an opportunity to practically experience the social conventions (symbols and numbers) embedded in the clock representation. Conventions like the double meaning of the number labels 1-12 and the relation of the two hands to each other as well as the position to the number labels. The learners could experience and reflect on the double movement of the two hands to tell the time, hence they

could make sense of each hand's meaning and the units that each represents when doing time tasks.

Siegler & McGilly (1989); Friedman & Laycock, 1989 and Boulton-Lewis et al. (1997) respectively argue that when learners get more familiar with the landmarks of 3, 6, 9, and 12 as representative of the quarter hours they show confidence in reading whole and half-hour analogue clock time because the child with experience use their mental image of the movement of the two hands on the clock. This underlines that analogue time knowledge and skills involves learners to know and apply different reference points for both clock hands simultaneously.

In conclusion the making of the analogue representation shaped the ways of thinking about the mathematical attributes. It served a practical and reflective purpose that supported the learners' appropriation of the intricate clock configurations represented to a cognitive level.

THEME 7: THE PHYSICAL CLOCK REPRESENTATION IMPACTS LEARNERS' THINKING ABOUT ANALOGUE TIME.

The data shows that learner engagement with the physical clock impacted on the learners' thinking and ways of thinking when attempting to accomplish certain tasks or activities. The learner's practical use of the physical clock seemed to elicit and support conceptual understanding, which was previously not yet stable as indicated by the baseline assessments and observation of initial intervention sessions.

The learner's interaction with the physical clock encouraged the making of personal conjectures and supported learners to explain and justify their conjectures using the physical clock. The physical clock supported and extended the learners personal meaning and mathematical meaning of the clock representations. The learners showed confidence when they determined the passage of time (time interval) using two or more clocks to calculate the duration by setting the one clock at the start time and the other at the stop time position. The learners seemed to find it easier to calculate the whole hour, half hour, quarter hour and 5 minute increment time.

The learners' initial understanding and interpretation of the analogue clock transformed from only reading and telling the time to seeing the clock as an instrument that measures time intervals. In the collected data, I observed that the various clock activities carried out provided the impetus for new generated understanding of the physical clock as a measurement tool.

Observation of intervention sessions showed that the learners thinking in solving time related problems seemed to be supported and extended through the use of the clock. For example the learners had to calculate the duration of the event starting at eight o'clock and ending at quarter to nine. The clock configurations in which mathematics, language and visual-spatial knowledge are embedded supported the learners in counting cyclically using an actual dynamic movement of both hands. Lastly the language used to make conjectures and justification while using the physical clock encapsulated both personal and mathematical knowledge.

The physical clock allowed other members in the group to track and pin point how a particular learner made meaning of the task. The physical clock also assisted and guided the users to reflect on their own thinking when giving a possible solution explanation to a solution if required. Technical demonstrations by users enabled the other members of the group to follow the thinking trajectory and this adapted or influenced their own or the user's thinking in action. Thus the physical clock seemed to increase flexibility of thinking and allowed learners to remember clock facts like that quarter minutes past time is 15 minutes after. The physical clock seemed to facilitate transition from concrete to higher level symbolic thinking.

I support Hoyles & Noss (2003) that the design of educational tools do not, by themselves, make explicit how they work. The explicitness is activated when a person interacts with the embedded functions within the tool.

In conclusion the physical clock supported learners to concretise their thinking and use the clock to illustrate their thinking trajectory when justifying their solutions to problems. In turn the clock assists and guides the user to illustrate the mental picture using its configurations.

Below I present a summary of the emergent themes. Thereafter I present chapter 6 that will conclude my thesis.

SUMMARY OF EMERGENT THEMES

Table 11 a: Summary of themes related to the child’s interpretation of an analogue clock time

Method / tool	Research Data	Interpretation of data	Themes that emerged
Intervention programme; Interview – learners stimulus response ; - Learning activities	Learners meaning making of clock configurations. Recognising the importance of 12-label in hourness. Learners reading and telling hourness. Recognising the major landmarks 3, 6, 9 and 12.	-Learners use of the 12 label to indicate hourness -The positioning of each hand - Ability to label the paper plate face according to clock configurations	The need to use the 12-label as a reference point, when working with time using the analogue clock
Intervention programme; -Interview – learners; -Learning activities	Conceptualising hour and minute hands. Naming the hour and minute hand Position the hour hand and minute hand on the clock Reference point for the hour and minute hand Seeing the two systems for the same label like 1 represent 1 hour and also 5 min.	-Learners understanding the relation between the hour and minute hand -Difference between hour hand and minute hand value - The two ‘systems’ hours or minutes with a particular set of units -The position hour hand to in past whole hour time -Learners conception of analogue clock in digital form -Reference point for counting hours and minutes on the clock	The need to use both clock hands and the relationship between them, to interpret analogue clock time <ul style="list-style-type: none"> • Uncertainty to use hands differently • Digital in analogue • Clock based strategy
Intervention programme; -Interview-learners; -Interview – teacher	The learners’ preference of learners to use the relative format. The use of ‘past’ and ‘to’ concepts. The use of relative format for half hour clock time. The language difference in English and Afrikaans saying half hour time.	- The learners confidence to use relative format when saying 30 min past the hour rather than half before the hour in Afrikaans - The overgeneralisation of the relative format of 30 minutes past - Conceptualising the “past” and “to” position the on clock face - The Afrikaans language to tell half clock time	The need to make an explicit double use of the same markers for two different purposes, when working with analogue clock time. <i>Relative and Absolute time</i>
Intervention programme; -Interview – learners; -Learning activities	The learners use digital format to tell analogue time. The way learners interpret analogue time digitally.	The awareness that some learners use digital format to interpret analogue time The interchange between analogue clock time and digital interpretation	The need to make an explicit double use of the same markers for two different purposes, when working with analogue clock time. <i>Digital in analogue clock</i>
Intervention programme; -Interview – learners; - Learning activities	The learners’ mathematical use of the clock to count. The Flexibly use clocks to calculate elapsed time.	The ability to show the elapsed time using clocks. Using the physical clock to perform calculations	The need to make an explicit double use of the same markers for two different purposes, when working with analogue clock time. <i>Clock based strategies</i>

Table 11 b: Summary of themes related to the clock mediation of analogue time meaning

Method / tool	Research Data	Interpretation of data	Themes that emerged
Intervention programme Physical clock	The learners use the physical clock tool to perform task The learners mental action supported and extended using the clock The use of the clock develop clock experience	The clock- tool to mediate internal meaning making of time The clock allow support and extend mental range to do clock activities The use of the clock assisted the child to acquired clock knowledge and skills	Clock as a human tool extends the mental range for later internalisation
Intervention programme Physical clock	The learners use the physical analogue clock to communicate. The learners use the clock to explain their thinking The learners use clock to justify their thoughts concretely	The physical clock allow concrete communicate of the learners thinking The symbolic representation may limits learners communication The use of the analogue clock enables learners to physically observe each thinking and reasoning when using the clock.	The availability of the clock mediates externalising the process of perceiving time in the iconic representation
Intervention programme Physical clock	Physically constructing the clock enables the acquisition of technical knowledge and skills Personal mathematical experience improve awareness of different clock configurations	The learners awareness of the different social conventions (symbols and numbers) embedded in the clock The learners' cognizance of the explicit and implicit meanings of the different configurations.	Physically constructing the clock mediates the development of a mental image of the clock's configuration
Intervention programme Physical clock	The physical interaction with the analogue clock enables sense making of time. The clock used to calculate durations and intervals of events. The learners justify own conjecture using the clock.	The clock elicits and support conceptual understanding of time. Enable solving time related problems. The use of the physical clock develop flexibility of thinking The use of the clock enable explanation of conjectures made	The physical clock representation impacts learners' thinking about analogue time

CHAPTER 6: CONCLUSION

1. INTRODUCTION

In this conclusion chapter I summarise the findings and the contribution of the study. This study explored two questions, namely:

1. How does a child interpret analogue clock time representation?
2. How does an analogue clock mediate the meaning making of analogue clock time?

The case study data included interviews with one teacher, 38 learners' written baseline assessment responses and 4 learner interviews as well as video-taped data of an intervention programme with the 4 learners. This data yielded rich insights into the nature of the process of learning to tell the time and how the tool of a physical clock can mediate this learning.

Three key themes relating to learning to interpret the analogue clock (reading the clock) emerged from research question one. These are:

THEME 1: THE NEED TO USE THE 12-LABEL AS REFERENCE POINT WHEN WORKING WITH TIME USING THE ANALOGUE CLOCK

One of the core features of working with (and learning to work with) the analogue clock is that all aspects of analogue clock time gets referred back to the 12-label / position. The learners need to know and understand the importance of the 12-label as reference point because all whole hour time, minute counts starts at and stop at the 12-label. The learners' thus need to recognise the 12-label as the most important major landmark on the analogue clock face.

THEME 2: THE NEED TO USE BOTH CLOCK HANDS AND THE RELATIONSHIP BETWEEN THEM, TO INTERPRET ANALOGUE CLOCK TIME.

Working with analogue clocks requires knowing and understanding important conventions to master the tool. The learners need to learn key conventions to make the implicit nature of the analogue clock accessible for example, the child is generally told that the hour hand points to the hour, but this ignores the difficulty of what hour is it pointing to the 3 or the 4 (when pointing to the interval between the 3 and 4). The relational nature of each of the two hands

involves working together to get the reference position on the clock. For example, the hour hand and the minute hand represent different values because of each hands reference position.

THEME 3: THE NEED TO MAKE AN EXPLICIT DOUBLE USE OF THE SAME MARKERS FOR TWO DIFFERENT PURPOSES, WHEN WORKING WITH ANALOGUE CLOCK TIME.

Teachers should explicitly teach the double nature of the 1-12 labels on the clock face so that learners easily recognise it. The learners need to understand that although the numbers start at and stop at the 12-label in fact time continuously move and never stops. The learners need to recognise the double use of the markers 1 – 12 on the clock face. For example, when the long hand point to the 4 number it is 20 minutes and importantly that the 12 – label represents implicitly 0 and 60 minutes.

For the research question 2, on tool mediation four themes emerged namely:

THEME 4: THE AVAILABILITY OF THE CLOCK MEDIATES EXTERNALISING THE PROCESS OF PERCEIVING TIME IN THE ICONIC REPRESENTATION.

The use of the physical analogue clock allows the learners to concretely communicate their thinking. The more capable learners can use the physical clock to justify his / her explanation so that the other members could follow and grasp his / her thoughts. The learners can resort to the concrete tool to externalise his / her clock knowledge and skills. This reflects the importance of the physical clock to mediate the externalisation of the thought process in making meaning of the clock representations.

THEME 5: THE ANALOGUE CLOCK AS A HUMAN TOOL EXTENDS THE MENTAL RANGE FOR LATER INTERNALISATION.

The use of the physical clock supports and extends the learners ability to make sense clock time. The learners use the clock to calculate elapsed time by setting the clock hands to represent the time and adjust it to get a visual picture that assist with mental calculations.

In this way, the physical clock extend the learners cognitive (mental) range he / she become able to move to internalise the acquired knowledge and skills. The analogue clock thus acts to extend the range for later internalisation.

The clock thus becomes an important tool for learning because without the clock the learner cannot go further when he / she reach the end of his / her range.

THEME 6: PHYSICALLY CONSTRUCTING THE CLOCK MEDIATES THE DEVELOPMENT OF A MENTAL IMAGE OF THE CLOCK'S CONFIGURATION

The actual designing and making of the paper plate clock provided learners an experience of the practical structure and layout of the different clock configurations. The configurations include spatial attributes such as the cyclic shape, cyclic arrangement of the numbers, and visual-spatial arrangement of key landmarks on the clock face and also the relation of the two hands and their distinguishing lengths.

When learners constructed the analogue paper plate clock it created an opportunity to practically experience the tacit social conventions (symbols and numbers) embedded in the clock representation.

THEME 7: THE PHYSICAL CLOCK REPRESENTATION IMPACTS LEARNERS' THINKING ABOUT ANALOGUE TIME.

The learner's practical use of the physical clock seems to elicit and support conceptual understanding. The use of the physical clock encouraged learners to make sense of personal and mathematical conjectures. It also supports learners to explain and justify their conjectures using the physical clock. The physical clock supported and extended the learners personal meaning and mathematical meaning of the clock representations.

The physical clock supports learners to concretise their thinking and use the clock to illustrate their thinking trajectory when justifying their solutions to problems. In turn the clock assists and guides the user to illustrate the mental picture using its configurations.

2. POSSIBLE IMPLICATIONS FOR TEACHING

A key motivator for me as a teacher was to understand how learners make meaning of reading and telling as well as writing analogue clock time.

My research informed me that teachers need to pay particular attention the learner's conception of: the 12- label; the relational interpretation of the hour and minute hand, and the language embedded in the tool and social reference to it. I suggest that teachers teach the technical meaning of the 12-label explicitly in order for the learners to use the clock- tool effectively. Teachers should first start by teaching the learners the conventions and properties of the different configurations on the clock such as the double meaning of the number labels and the relation of each clock hand when indicating time on the clock.

Teachers can also encourage learners to explore different formats to read and tell clock time such as relative format or absolute format before directing learners to a particular format.

I have also become increasingly aware of the potential of the physical clock to mediate meaning making of analogue clock time. More so the usefulness of the physical clock in solving time-related problems for the CAPS.

In this intervention program I ensured that each learner had his / her own physical plastic analogue clock that could be easily manipulated. I would recommend to all my colleagues teaching time to invest in such a set of clocks and / or get learners to make their own clocks. The physical construction develops the learners' visual-spatial awareness the different configurations on the analogue clock face.

In terms of my learning I will endeavour to share my findings and insights through presentations to colleagues and at conferences such as AMESA, SAARMSTE and SARAECE.

3. LIMITATIONS OF THE RESEARCH

This is a very small explorative study that is limited to generalisability so the themes identified here would need further research to 'validate' it in general. In addition the study may risk subjectivity as teacher and researcher because my personal teaching experience informs me that learners struggle to learn analogue clock time. This is also noted in international research literature that learners find it difficult to read, tell and write analogue clock time because of the complexities involved in making sense of analogue clock time (Boulton-Lewis et al. (1997); Friedman & Laycock (1989); Williams (2004) and Burny (2012). In the data and research process the data could not carry further analysis. Since I am familiar and teach at the site it

could possibly have influenced the participants' behaviour in the study. More often issues arose that opened up more questions that could not be answered in this research.

4. RECOMMENDATIONS FOR FURTHER RESEARCH

There are only a few research studies that focus on the educative perspective on learners learning analogue clock time in the primary school and no recent studies in the last decade in South Africa. While this study is limited in generalizability due to my small case study approach the research study illuminates pathways for further research. These include for example researching this topic in a wider range of contexts, different languages and across grades in school.

5. REFLECTION ON THE RESEARCH PROCESS

I have learnt about the important role the physical analogue clock plays in teaching and learning clock time. I am now more aware that teaching and learning analogue clock time requires careful sequential planning and implementation of activities and not an ad hoc approach. It is very important for the teacher to know and understand what makes it difficult for learners to master clock knowledge and skills.

I recognised the importance of teaching explicitly technical concepts of the physical clocks configuration to the learners before continuing to elapsed time tasks. I noticed during the intervention programme that the low ability learners became confident clock readers when exposed to a variety of activities using the physical clock. The importance of teaching the foundational concepts embedded in the physical clock is vital for the learners to make sense of clock time.

Here teachers should pay more attention to the technical aspects such as the importance of the 12-label; the double nature of the numbers on the clock and relational operation of each of the two hands on the clock. Teachers should be mindful that learners are flexible to make meaning of the clock and even extend it if the basic operations and functions of the clock are meaningfully taught to them.

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APPENDIX 1: BASELINE ASSESSMENT TASK



RHODES UNIVERSITY

Where leaders learn



PRIMêRE SKOOL LEERDERS NAVORSING FOKUS: ANALOGIESE TYD

RESPONDENT SE NAAM:

GESLAG (MERK MET X) MANLIK VROULIK

GRAAD 4 OUDERDOM IN JAAR

SKOOL: ALEXANDRIA PRIMêR

KRING 4 DISTRIK GRAHAMSTOWN

JAAR 2013

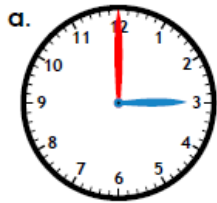
Fase 1:

Vraag 1: Voltooi die tel aktiwiteit.

a) 0; 5; 10; _____; _____; _____; _____; _____; _____; _____; _____; _____

b) 60; 55 ;50 ; _____; _____; _____; _____; _____; _____; _____; _____; _____

Vraag 2: Watter horlosie toon die analogiese horlosie. Merk met ‘n X indien Ja of Nee



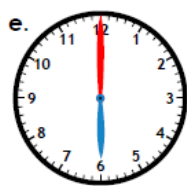
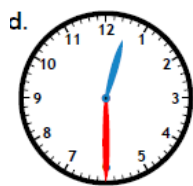
JA	NEE
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JA	NEE
----	-----

Vraag 3: Hoeveel arms is daar op ‘n analogiese horlosie? Merk met ‘n X op die korrekte getal.

1 2 3 4

Vraag 4: Watter arm is die uurwyser op die analogiese horlosie? Merk die kleur met ‘n X.

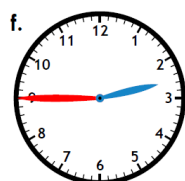


ROOI	BLOU
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ROOI	BLOU
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ROOI	BLOU
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ROOI	BLOU
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ROOI	BLOU
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ROOI	BLOU
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ROOI	BLOU
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ROOI	BLOU
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Fase 2:

Vraag 5: Orden die aktiwiteitevolgens 'n pasliketyd.

Skool kom uit; staan op en was; eet pouse; sport oefening; gaan skool toe

1.....

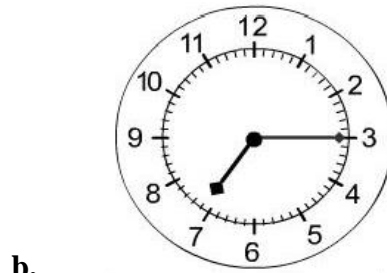
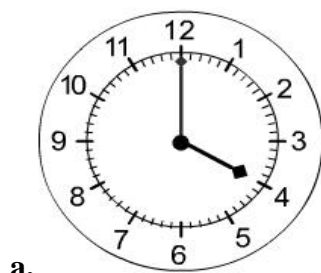
2.....

3.....

4.....

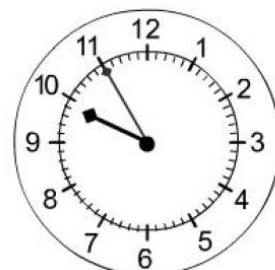
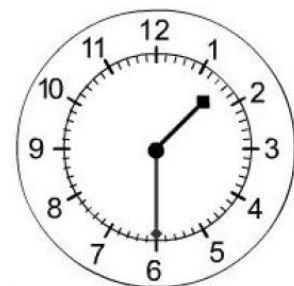
5.....

6. Sê hoe laat dit is:



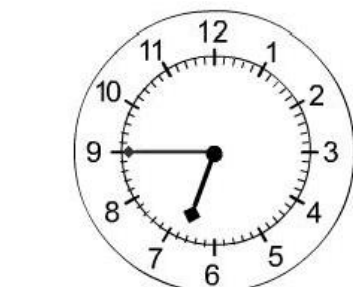
a.

b.



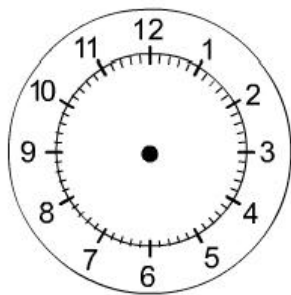
c.

d.

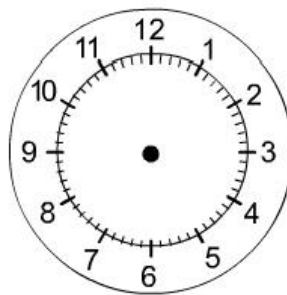


e.

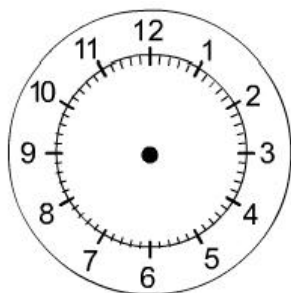
7. Teken hoe laat dit is op die klok.



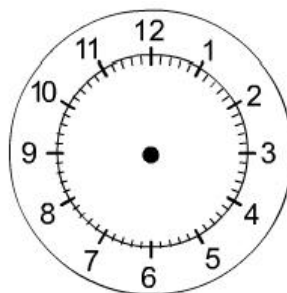
a) Twaalfuur



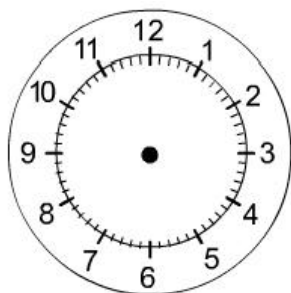
(b) Half twee (half past one)



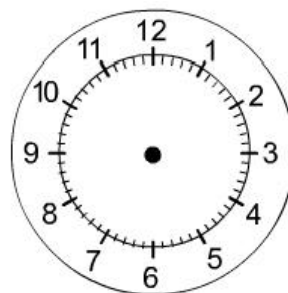
c) Twintig minute oor agt



(d) Kwart oor vier



e) 40 min oor ses



(f) Kwart voor een

Fase3:

Leerder wys asseblief hoe jy die tyd bereken het:

8. 'n Eier word presies om twee uur in die pot gekook. Die eier word kwart oor twee uit die pot gehaal. Hoe lank het die eier gekook?

9. Die eerste periode begin agtuur die oggend. Om half nege (half past eight) lui die klok vir die einde van hierdie periode. Hoe lank was die periode?

10. Ek wil agtuur by die skool wees. Dit neem my 15 minute om betyds by die skool aan te kom. Hoe laat het ek die huis verlaat?

11. Die bus kom twee uur by die aankoms plek aan. Die rit was 45 minute lank. Hoe laat het die bus vertrek?

Baie dankie vir julle samewerking.

APPENDIX 2: LETTER OF PERMISSION TO PRINCIPAL & CONSENT FORM



RHODES UNIVERSITY

Where leaders learn

Letter of Permission

The Principal
Alexandria Primary School
Alexandria , 6185



Dear, Mr A. Cannon

I am registered as a part-time Master Degree student at Rhodes University, Grahamstown (Student number g04m4816) for 2012 - 2013. I am studying for a Master's degree in Mathematics Education. I hereby request your (school) voluntary participation in my research. Your withdrawal from the research is possible at any stage of the research.

The aim of my research is to research and collect data pertaining to how learners make meaning when learning analogue clock time in grade 4. This is expected to emerge from interviews and document analysis I intend to carry out with teachers and learners. I therefore ask for your permission to audiotape and / or video records these interviews and learning interactions in an after school learning set up. The participants hence, learners and teacher's identity will remain anonymous. I will expose the final draft to be read by participants (teachers) to ensure that collected information is not misinterpreted.

Yours in education development

Mr R.G. Metelerkamp (0844724693)

Permission: _____

Principal: (signature) _____

Date: February 2013

APPENDIX 3: LETTER OF PERMISSION TO GRADE 3 TEACHER &
CONSENT FORM



RHODES UNIVERSITY

Where leaders learn

Consent form

Alexandria Primary School



I the undersigned participating teacher hereby give Mr R. G. Metelerkamp permission to involve me as mathematics teacher of the grade 3 class in his research for the completion of his Master's Degree in Mathematics Education at Rhodes University.

I understand that the data for analysis will be collected from interviews and document analysis; and this information obtained may be used in the final report.

Teacher: _____

(Signature): _____ Date: _____

APPENDIX 4: LETTER OF PERMISSION TO PARENTS/GUARDIANS & CONSENT FORM



RHODES UNIVERSITY

Where leaders learn

Consent form
Alexandria Primary School



Dear, Parent / Guardian

I, Mr R. G. Metelerkamp (Mathematics Teacher of Grade 4), hereby request your consent to involve your child in my research about analogue clock time. The purpose of my research seeks to understand how learners make meaning of telling time using analogue clocks. The research would require participants to meet in an after school class group.

I am registered as a part-time Master Degree student at Rhodes University, Grahamstown (Student number g04m4816) for 2012 - 2013. I am studying for a Master's degree in Mathematics Education. I hereby request your child's voluntary participation in my research. Your withdrawal from the research is possible at any stage of the research. The learners' identity will remain anonymous.

Please, provide written permission below and return the form to me. Be assured that the principal Mr A. Cannon is already positive towards this research.

Parent / Guardian (Signature): _____ (Permission granted)

Date: February 2013

APPENDIX 5: INTERVENTION PROGRAMME ACTIVITIES



RHODES UNIVERSITY

Where leaders learn

Leerder intervensie program

Leerder se naam: _____

Ouderdom: _____

Graad 4

Intervensie aktiwiteite

Naam van leerder: _____

Graad 4

Datum: _____

Ouderdom: _____

Aktiwiteit 1: Voltooi die volgende vrae oor jou ondersoek:

1. Aksie: Swaai die pendulum heen-en-weer vir 'n telling van 60 om te skat hoe lank een minute is.

Is een minuut lank of kort?

2. Aksie: Hou jou asem vir 'n telling van 10.

Het die tyd lank of kort gevoel?

3. Aksie: Maak jou oë toe vir 'n telling van 15.

Het die tyd lank of kort gevoel?

4. Aksie: Sê jou naam aan een vir 'n telling van 30.

Het die tyd lank of kort gevoel?

5. Aksie: Staan op een been vir 2 minute.

Het die tyd lank of kort gevoel?

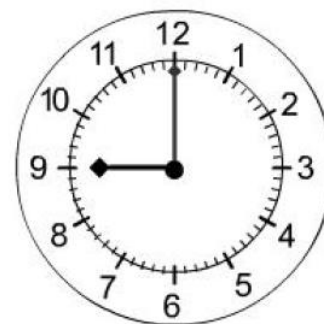
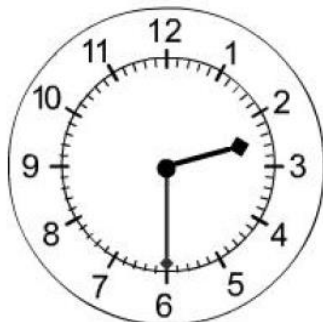
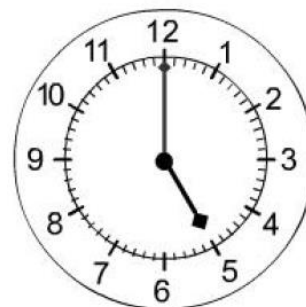
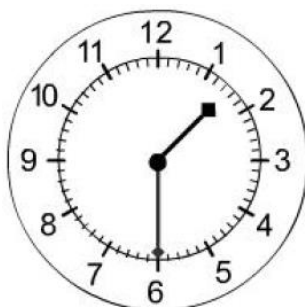
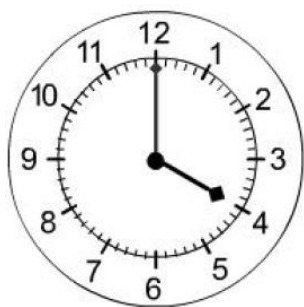
6. Aksie: Tyd lees speletjie (Pick the card)

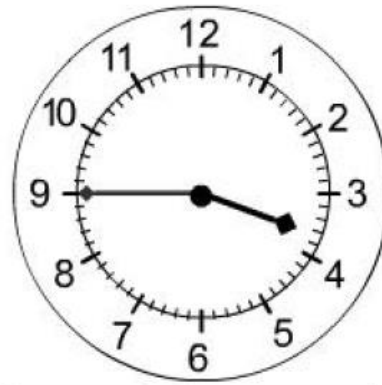
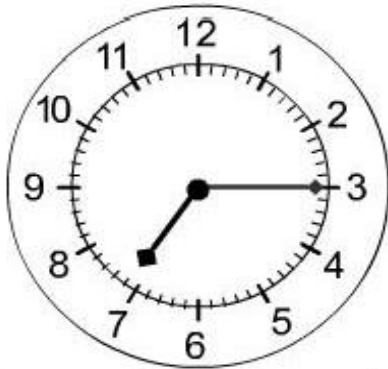
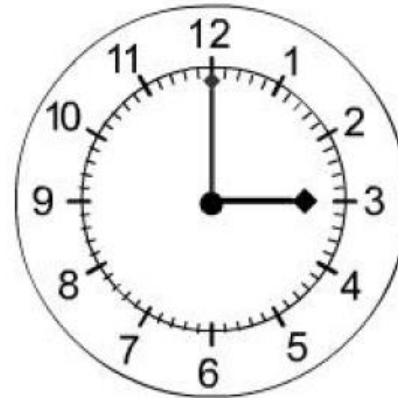
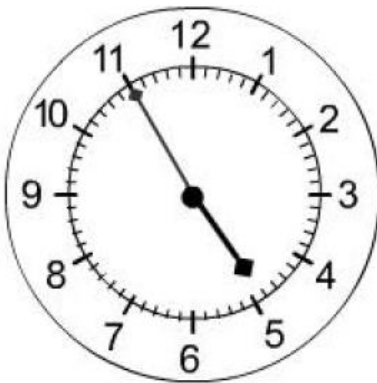
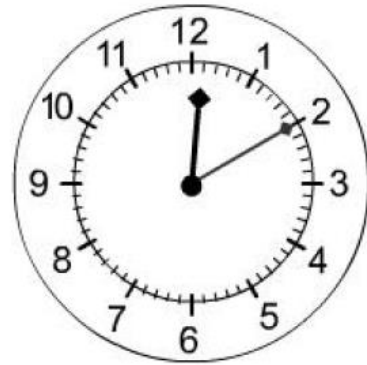
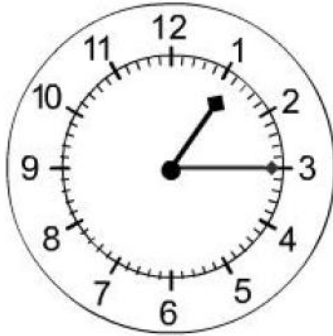
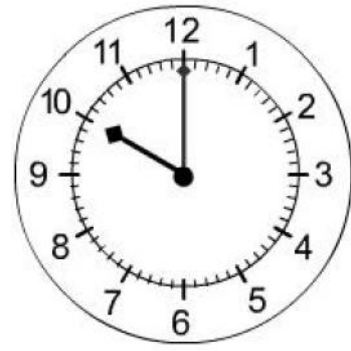
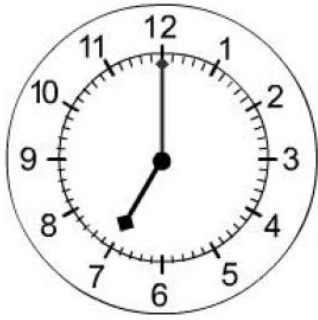
Elke leerder neem 'n kaartbeurtlings. Die leerder sê die tyd en wys dit op die horlosie aan almal in die groep.

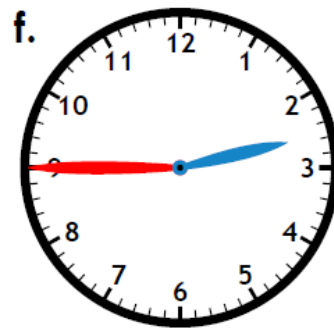
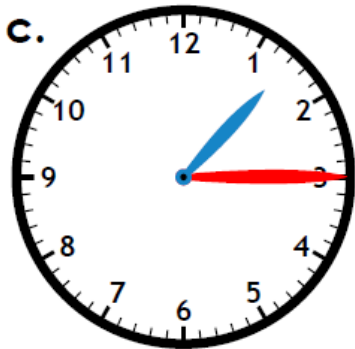
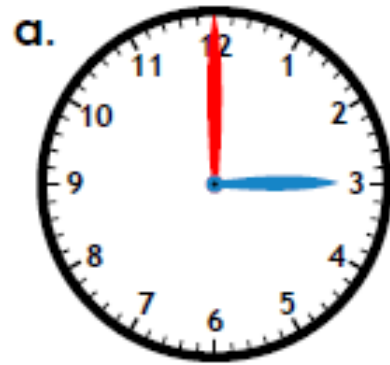
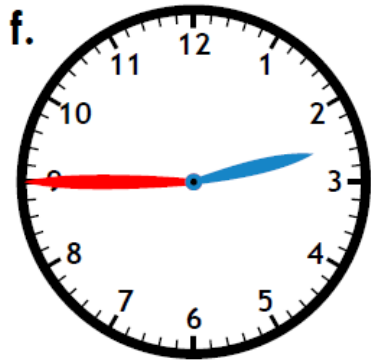
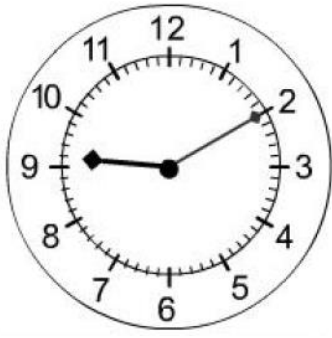
Refleksie: Ek het geleer dat

.....

Kaart speletjies







Intervensie aktiwiteite

Naam van leerder: _____

Graad 4

Datum: _____

Ouderdom: _____

Aktiwiteit 2: Volg die instruksies noukeurig.

1. Aksie: Maak 'n klokuitpapierbordjies en plaaseersdie kort wysereerste en dan die lang wyser daarop.

- a.) Die kort arm toon die _____ wyser.
- b.) Die lang arm toon die _____ wyser.
- c.) Daar is _____ verdelings op die horlosie se gesig.

2. Aksie: Voltooi die volgende vrae:

- a.) Die getal 1 op die horlosie se gesigtel 1 uur en ook _____ minute.
- b.) Die getal 3 op die horlosie se gesigtel 3 uur en ook _____ minute.
- c.) Die getal 6 op die horlosie se gesigtel _____ en ook _____ minute.
- d.) Die getal 9 op die horlosie se gesigtel _____ en ook _____ minute.
- e.) Die getal 12 op die horlosie se gesigtel _____ en ook _____ minute.

3. Vaslegging (Groepwerk): Klokspeletjie

- Neem 'n kaarten lees die tyd.
- Wys die korrekte posisie van die lang en kort arm op die horlosie gesig
- Kyk of jou maat korrek is en gee vir hom / haar 'n punt
- Kyk wie het die meeste punte

Refleksie: Ek het geleer

.....

Kaart speletjie

Agt uur	Vier uur	Twintig voor twee	5 oor 10
11 uur	Half tien	20 minute oor 10	40 minute oor vier uur
25 minute voor 7 uur	Kwart oor agt	37 minute oor 11	Tien voor tien

Intervensie aktiwiteite

Naam van leerder: _____

Graad 4

Datum: _____

Ouderdom: _____

Aktiwiteit 3: Lees en sê die tyd op die analogiese klok.

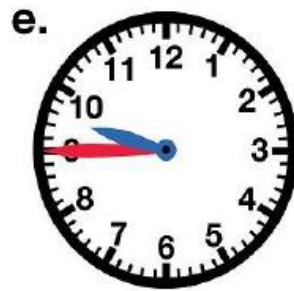
1. Aksie: Skryf die tyd op twee verskillende maniere neer. Voorbeeld(a.) hoe dit gedoen word.



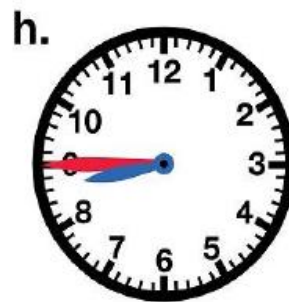
15 minute oor 2
Kwart oor twee

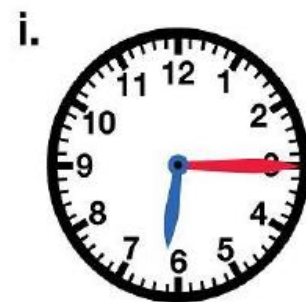












Intervensie aktiwiteite

Naam van leerder: _____

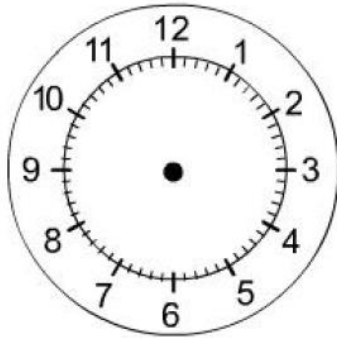
Graad 4

Datum: _____

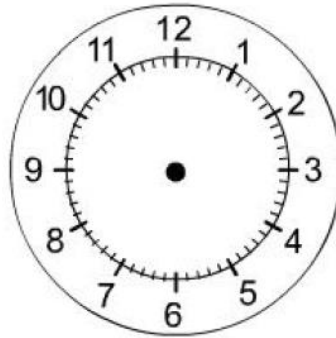
Ouderdom: _____

Aktiwiteit 4: Teken die tyd op die analogiese klokke. Gebruik die model klok om jou te help.

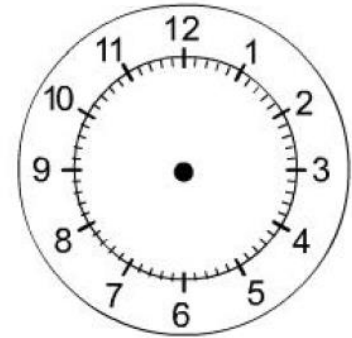
Wanneer jy klaar is lees jou tyd hardop en wysdit op die model klok.



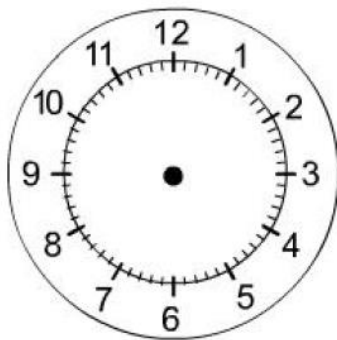
(a) Vyfuur



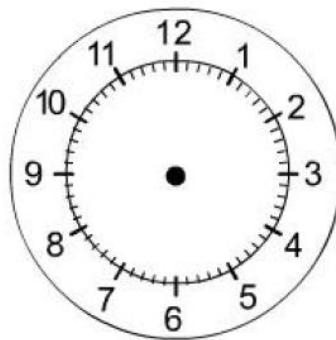
(b) Vyf minute oor vyf



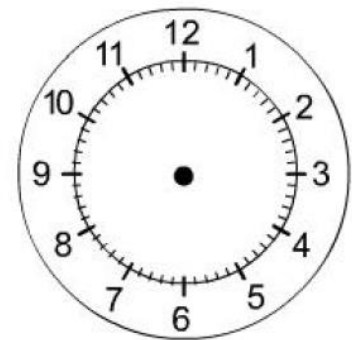
(c) Kwart oor vyf



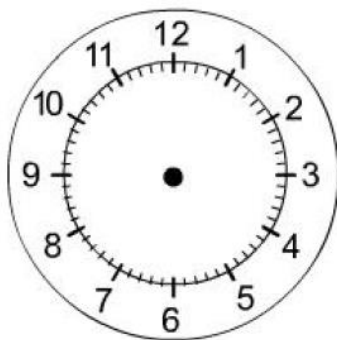
(d) Half ses



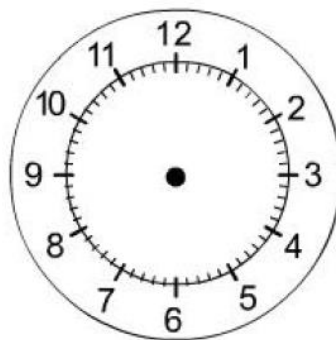
(e) 32 min oor 8



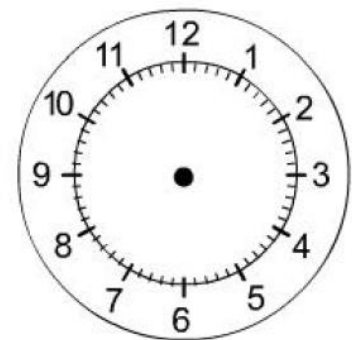
(f) veertien minute voorneg



(g) 16 minute oor 12 uur



(h) sewe minute nadrie



(i) kwartvoordrie

Intervensie aktiwiteite

Naam van leerder: _____

Graad 4

Datum: _____

Ouderdom: _____

Aktiwiteit 5.1: Verloop van tyd. Die “uur reël”.

1.

Klok A



Klok B



Wat

is die tyd op

A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?.....

2.

Klok A



Klok B



Wat is die tyd op A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?.....

3. Klok A



Klok B



Wat is die tyd op A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

4. Klok A



Klok B



Wat is die tyd op A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

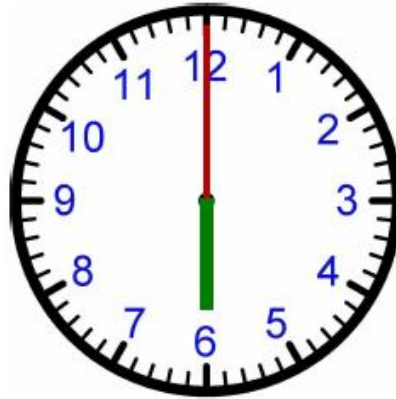
.....

5.

Klok A



Klok B



Wat is die tyd op A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

6.

Klok A



Klok B



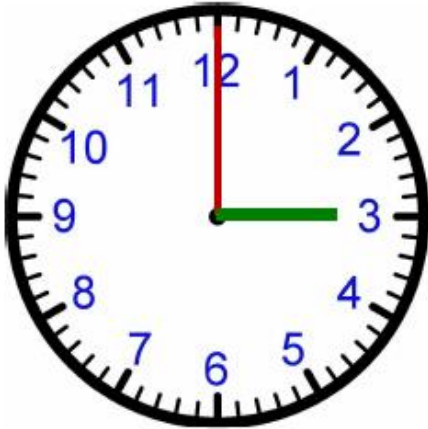
Wat is die tyd op A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

7.

Klok A



Klok B



Wat is die tyd op A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

8.

Klok A



Klok B



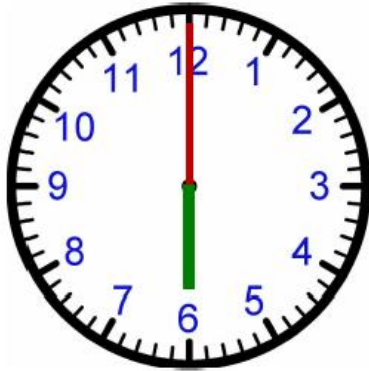
Wat is die tyd op A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

1.

Klok A



Klok B



Wat is die tyd op A?Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

2.

Klok A



Klok B



Wat is die tyd op A? Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

3.

Klok A



Klok B



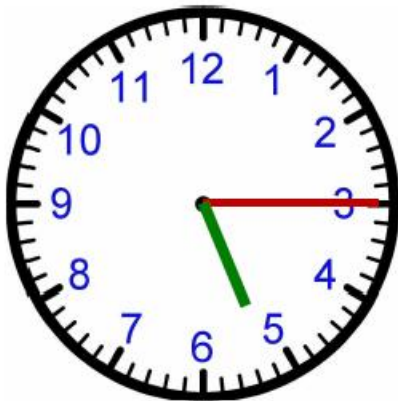
Wat is die tyd op A? Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

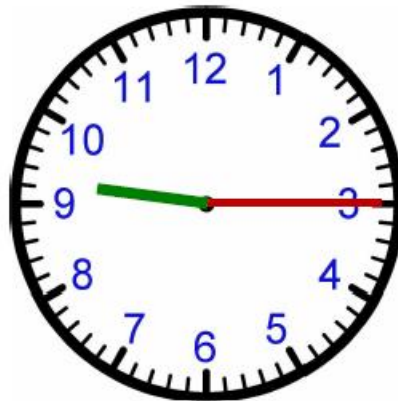
.....

4.

Klok A



Klok B



Wat is die tyd op A? Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

5.

Klok A

Klok B



Wat is die tyd op A? Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

6.

Klok A

Klok B



Wat is die tyd op A? Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

.....

7.

Klok A



Klok B



Wat is die tyd op A? Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

8.

Klok A



Klok B



Wat is die tyd op A? Wat is die tyd op B?

Hoeveel tyd het verloop tussen klok A en B?

Naam van leerder: _____

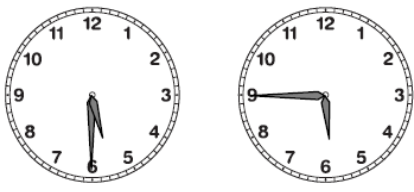
Graad 4

Datum: _____

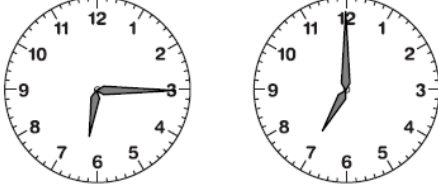
Ouderdom: _____

Aktiwiteit 5.2: Verloop van tyd. Die “uur reël”. Gebruik die model klok.

1.

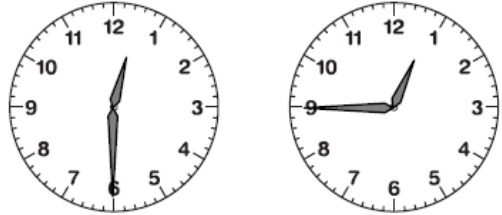


Die tweedeklok is _____ minute voor
voor die eerste klok.



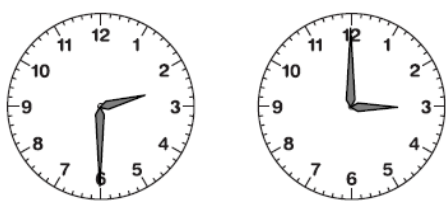
Die tweede klok is _____ minute
voor die eerste klok.

3.



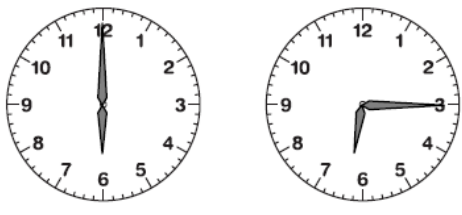
Die tweede klok is _____ minute voor
die eerste klok.

4.



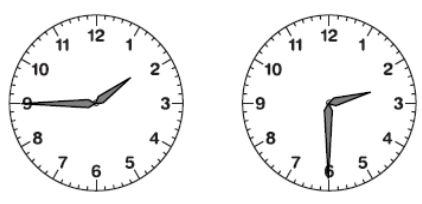
Die tweede klok is _____ minute
voor die eerste klok.

5.



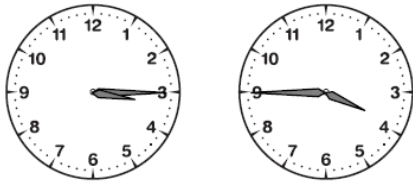
Die tweede klok is _____ minute voor
die eerste klok.

6.



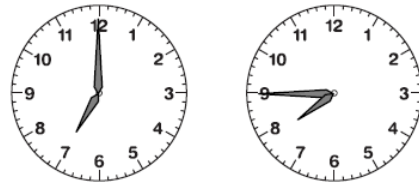
Die tweede klok is _____ minute
voor die eerste klok.

7.



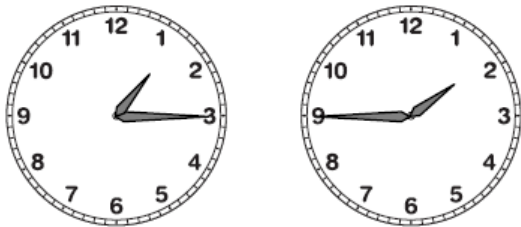
Die tweede klok is _____ minute voor
voor die eerste klok.

8.



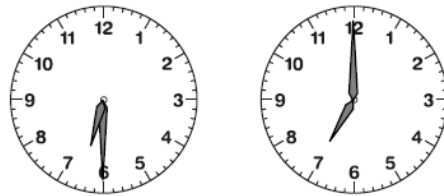
Die tweede klok is _____ minute
die eerste klok.

9.



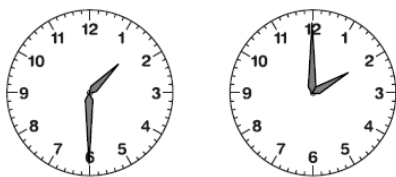
Die tweede klok is _____ minute voor
die eerste klok.

10.



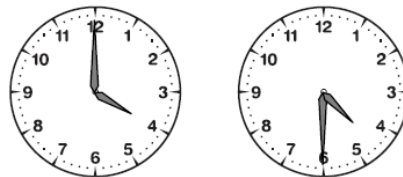
Die tweede klok is _____ minute voor
die eerste klok.

11.



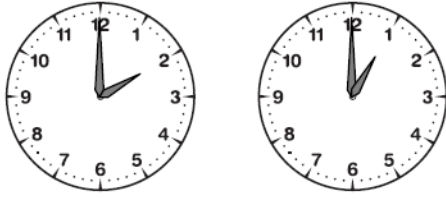
Die tweede klok is _____ minute voor
voor die eerste klok.

12.



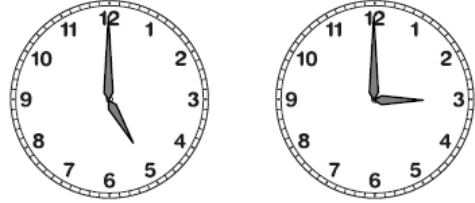
Die twee klok is _____ minute
die eerste klok.

13.



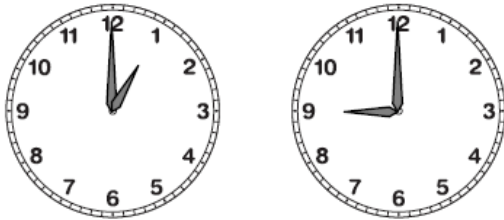
Die tweede klok is _____ minute agter
eerste klok.

14.



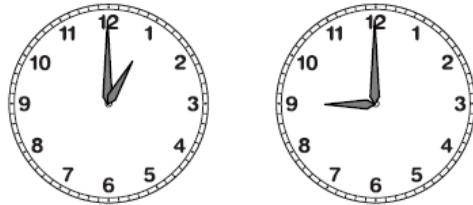
Die tweede klok is _____ minute die
agter die eerste klok.

15.



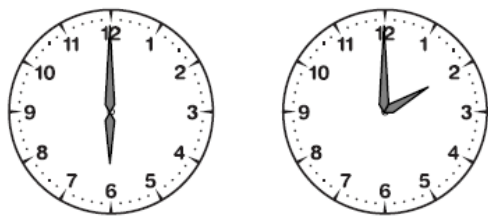
Die tweede klok is _____ minute agter
agter die eerste klok.

16.



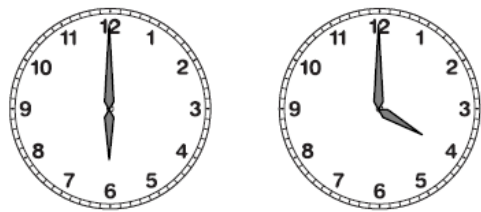
Die tweede klok is _____ minute
die eerste klok.

17.



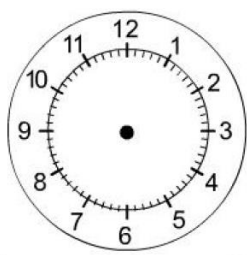
Die tweede klok is _____ minute agter
agter die eerste klok.

18.

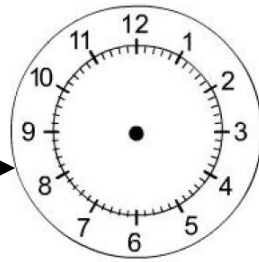
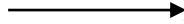


Die tweede klok is _____ minute
die eerste klok.

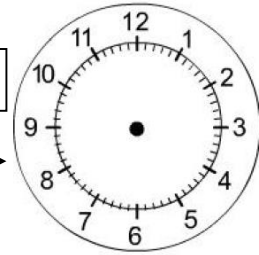
d.



15 minute oor drie

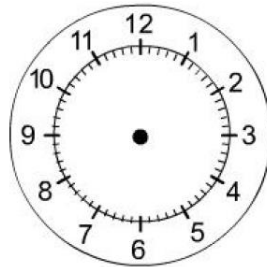


25 minute oor 3

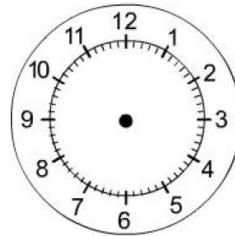


35 minute oor 3

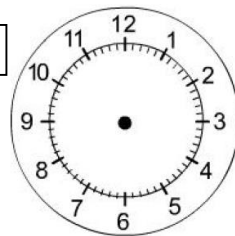
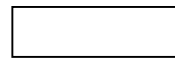
e.



Tien oor agt

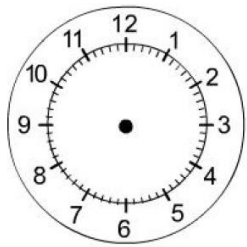


half nege

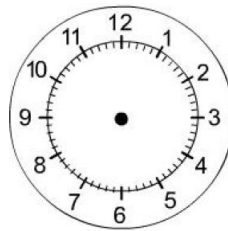
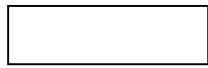


kwart voor nege

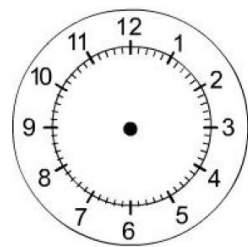
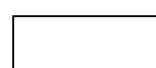
f.



Kwart oor twaalf



45 minute oor twaalf



een uur

Naam van leerder: _____

Graad 4

Datum: _____

Individueel

Ouderdom: _____

Aktiwiteit6: Verloop van tyd

Aksie: Bereken hoeveel tyd verloop het vir elke storie.

1.) Ek verlaat die huis om sewe uur en kom kwart oor nege uur terug. Hoe lank was ek weg?

2.) Ons verlaat die huis om 8 30 die oggend en kom 10 uur in Port Elizabeth. Hoe lank het ons na Port Elizabeth gery?

3.) Die “Anaconda”fiek op t.v. begin 8 uur. Dit is nou kwart voor 8. Hoe lank sal jy wag?

4.) Die “Oh Schucks” film op t.v. begin sewe dertig. Dit speel vir 1 uur en 5 minute lank. Hoe laat sal die film eindig?


5.) My t.v. schedule vir 'n program. Bepaal hoe laat Dragon Ball Z sal stop.

My T.V. program	BEGIN	STOP	HOE LANK
Dragon Ball Z	Half vyf		35 minute

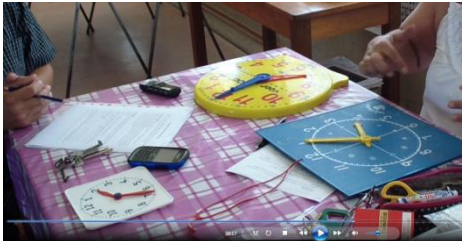
6.) 'n Taxi rooster: Bepaal die vertrek tyd.

VERTREK	AANKOMS	TYD (GERY) VERLOOP
	Twee uur	45 minute

APPENDIX 6: TRANSCRIPTION OF INTERVIEW WITH GRADE 3 TEACHER

Teacher	03:31- 04:11	Hoe hulle dit leer nie hoe voel ek oor hoe hulle leer. Ah, analogiese tyd vir kinders te leer is na volgens my is moeilik jy weet seker ek. Ek het al almal gevra oor analogiese tyd vir die kinders te leer ne. Om ure te leer is heel fine 9 uur 10 uur 11 uur 12 uur. Maar die ander, is sulke, die taal, in Afrikaans is daar sukke aspekte soos oor en voor. In Engels is dit so maklik past en to maar in Afrikaans is dit oor en voor. En die half konsep?	Teacher reads the question before speaking. She answers, moves her hands and looks as though she feels passionately about this.
Roger	04:12- 04:14	So kan jy voorbeelde (sp) gee? N voorbeeld van.	
Teacher	04:15- 05:13	Aah. In Engels gaan jy sê dit is half past 1, wat logies is. Nou die kinders leer by die huis n taal ne, hulle leer by die huis die tyd, by die huis ek leer die is half past 1. Nou in Afrikaans moet jy nou vir die kind se die is half twee. Wat ek gewoonlik maak is dat ek se staan stil en kyk nou dit is n half uur na twee uur toe. Dit is wat ek vir hulle se want as jy net skielik vra hoe laat dit is dan gaan hy vir jou sê half past 1 en ons leer nou mos in Afrikaans. As ek se staan stil ek moet dit in Afrikaans vrae. Hoe laat is dit som sal antwoord dit is half twee omdat dit is half na 2 uur toe is. In Afrikaans. Ek weet nie daars my klok.	Teacher picks up the clock. Roger gets up to fetch it for the teacher. Teacher sits back down.
Roger	05:14- 05:15	Hier is Juffrou's se klok.	
Teacher	05:16- 05:54	Hier is my klok. Hy is oor en voor maar die kinders raak altyd met voor en oor, die kind sien half is reguit klein gemerk. Die $\frac{1}{4}$. Ek het die $\frac{1}{4}$ in geskryf maar daar is kinders wat raak met oor, voor en die half. Hoe laat is dit nou en hulle sal se dit is 1 uur. Hoe laat is dit nou. Draai Draai Draai. En se dit is 7 uur. So dit is die minute wyser en die uur wyser waar die in kom. Dit is oor, voor en half.	

LINE 20 BELOW

20	Teacher	08:07- 08:32	<p>Jy kan ok sien daai (?) oomblik ne as ek sê hoe laat is dit en hy kyk die ure en sê per ongeluk een en dan sê ek nee man dit is minute ons gaan na die een toe en hoeveel gaan jy tel en dan kan ons sien hoe, vyf juffrou, 5 oor 7. Dit is die (INAUDIBLE) , jy kan ook sien hy klik nou en hy verstaan nou wat dit is daai tipe van n ding.</p>	<p>Teacher clicks.</p> 
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APPENDIX 7: THE GRADE 3 TEACHERS PREDICTION

In the section below I used a rating scale to analyse and interpret the teacher response on how the learners might perform in the baseline assessment task. I collated a table to present a general glimpse of the teachers' prediction.

Table 4.5: Rating scale of the teachers' prediction of the learners' performance in BAT

Question	Type of question	Teachers' Confidence Rating Scale 1-3		
		1- Less than half	2- Half	3- More than half
1	Counting exercise, forwards and backwards.			X
2	Distinguish the visual representations between analogue and digital clock.	X		
3	Personal perception of the arms on the analogue clock			X
4	Visual recognition of the hour representation.			X
5	Ordering of daily events in acceptable order		X	
6	Read time on the clock			
A	Vier uur			X
B	Kwart oor sewe			X
C	Half twee		X	
D	Vyf voor tien		X	
E	Kwart voor sewe	X		
7	Draw the time on the clock			
A	Twaalf uur			X
B	Half twee (half past one)		X	
C	Twintig minute oor agt			X
D	Kwart oor vier			X
E	40 min oor ses	X		
F	Kwart voor een	X		
8	Calculation duration of events			X
9	Calculation duration of events			X
10	Calculation of stop, start and / or duration of events.	X		
11	Calculation of stop, start and / or duration of events.	X		
Average %		30 %	20 %	50 %