SCHOOL SCIENCE FOR SIX-YEAR-OLDS:

A NEO-VYGOTSKIAN APPROACH TO CURRICULUM ANALYSIS

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COMPULSORY DECLARATION

This work has not been previously submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation from the work, or works, of other people has been attributed, and has been cited and referenced.

Signed by candidate

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Date: 9th January 2014

ABSTRACT

The purpose of this study is to describe the form of knowledge that is made available to six year olds as ‘Science’ in key South African Grade R curriculum texts. The study draws on a neo-Vygotskian conceptualisation of forms of knowledge and child development to develop a language of description in terms of which the selected texts are analysed. Representations of knowledge in the curriculum texts are described in relation to the notion of a simple scientific concept, an idea that was derived from a neo-Vygotskian conceptualisation of knowledge. A simple scientific concept is consistent with scientific criteria and functions as an entry level concept in relation to scientific knowledge.

Findings indicate that the Grade R science curriculum represents knowledge in terms of everyday concepts and ‘potential’ scientific concepts, i.e. concepts that have the potential to prompt the Grade R educator to translate an everyday concept into a simple scientific concept. However, the curriculum does not represent any concepts in ways that conform to the criteria for scientific concepts, including simple scientific concepts.

The study concludes that the official recontextualisation of scientific knowledge into Grade R school science is problematic because the Grade R science curriculum represents knowledge mostly in everyday terms. The implications are that Grade R learners are not given the opportunity to acquire the form or content of scientific knowledge or to develop the cognitive skills required for formal schooling.

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This study is my contribution to the body of knowledge of early childhood development.

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CHAPTER 1: Introduction

Our knowledge can only be finite, while our ignorance must be infinite (Karl Popper in *Conjectures and Refutations*[1])

1.1. INTRODUCTION

Although substantial changes have been made in South Africa with regards to the national curriculum over the last twenty years and the greatest single allocation in the national annual budget goes to education, quality in South African schools remains problematic (NEEDU, 2013; DBE, 2012e; TIMSS, 2011). Approximately 60% of children do not complete their schooling (Klinck, 2013) and high school learners in South Africa are underperforming in science and mathematics (Klinck, 2013; TIMSS, 2011; DBE, 2011d). Although there is much discussion and concern about the matter, there seems to be little understanding as to why. If a failure to thrive academically is rooted in early learning an investigation into the 'what' of early science may shed light on why older children are struggling to acquire more complex knowledge concepts in later grades. I chose science as the object of my study because science integrates knowledge, mathematics, literacy and critical thinking skills. Thinking about this idea in relation to my 37 years of empirical experiences in South African Grade classrooms as a Grade R educator, pre-primary school manager and early childhood development (ECD) teacher trainer) led to the question which initiated this study: 'What is science for six-year-olds?'

As will be discussed more fully below, there is scant evidence of science in the Grade R classroom, most Grade R educators know little about science, and literacy and mathematics dominate in the South African Grade R curriculum. If the learning of early knowledge underpins later academic success then a lack of science in the first year of school is problematic. Research supports this notion. Recent research suggests that young children are more cognitively competent and able to think abstractly than indicated by developmental theorists in the early 1900s (Winkler-Rhoades, Carey & Spelke, 2013; Haynes & Murris, 2012; Fleer, 2005; Egan, 2002). Neuroscience has confirmed that most of the brain's physical development takes place in the preschool years and that 'Beginning at the

[1] Quoted in: B. Clegg. 2003. *Infinity. The Quest to Think the Unthinkable*

moment of conception heredity potential unfolds in concert with the environment' (Shonkoff & Phillips, 2000: 39). A quality early education supports academic, personal and social competencies in adulthood (High/Scope Perry Preschool Study, 2005). Learning about science and knowledgeable teachers both contribute qualitatively to early education (Sylva et al, 2004).

The focus of this study is on school science knowledge for six-year-olds. The study takes the form of a document analysis of the Grade R science study area *Beginning Knowledge* (Department of Basic Education [DBE], 2011a). This component of the official Grade R science curriculum guides the teaching of science to most six-year-olds in South Africa, who are in public Grade R classrooms (DBE, 2013).

The study adopts a neo-Vygotskian[2] approach as the theoretical lens through which to view science for six-year-olds. This approach assumes that some approaches are more appropriate than others when it comes to the teaching and learning of scientific knowledge. These considerations led to a single research question: *How does the South African Grade R curriculum represent school science knowledge for six–year-olds: a neo-Vygotskian perspective?*

This chapter introduces the research topic and sets out the study as follows. The rationale, explains why this study will make a valid contribution to education and society. A lengthy contextualisation follows which discusses the notion of 'science' from the scientist's laboratory to the Grade R classroom. The neo-Vygotskian perspective as the theoretical lens for this study is explained in more detail followed by a brief description of the research design and methodology. The chapter concludes by outlining the remaining chapters of the study.

1.2. RATIONALE

> The object of the common school system in Massachusetts was to give to every child in the Commonwealth a free, straight solid path-way by which he could walk directly up from the ignorance of an infant to a knowledge of the primary

[2] Vygotsky and his followers

> duties of a man; and could acquire a power and an invincible will to discharge them. Have our children such a way? Are they walking in it? Why do so many, who enter it, falter therein? Are there not many, who miss it altogether? What can be done to reclaim them? What can be done to rescue faculties, powers, divine endowments, graciously designed for individual and social good, from being perverted to individual and social calamity? These are the questions of deep and intense interest which I have proposed to myself and upon which I have sought for information and counsel (Mann, 1838, in the National Education Evaluation & Development Unit [NEEDU], 2013: 8).

Although written 175 years ago, Mann's statement resonates with South Africa's current educational concerns and my own reasons for embarking on this study. Despite nearly 20 years of post-apartheid education, South Africans are still struggling to provide a quality education for all children in the interests of bettering society.

My initial interest in science and six-year-olds grew out of the disjuncture between my own pedagogical experiences and my observations in Grade R classrooms. As a teacher I understood early science as an exciting way to teach children mathematics, science, literacy, and critical thinking; but as a teacher trainer I saw little evidence of science in the Grade R classrooms I visited. While educators refer to 'maths and science' as if they are one thing made up of two equal parts, the reality is that in South Africa, mathematics and literacy dominate pedagogy in the early school years (DBE, 2011a). Preschool teachers have a limited view of young children as science learners, and most do not have the required scientific knowledge and language skills to teach science (Biersteker, 2012; Olgan, 2008; Kallery & Psillos, 2001). This is counter to the idea that science contributes to developing cognition (Davydov, 2008; Karpov, 2005; Sylva et al, 2004) and that there is a growing focus on developing cognition in preschoolers in industrialised countries (DBE, 2013; DBE, 2009; Fleer & Raban, 2007).

The practical goal of this study is to inform our understanding of issues related to quality in the teaching of early science. The study is premised on the idea that early science contributes towards a quality early education which, in turn, contributes to school and adult competencies. A seminal 20th century longitudinal study on disadvantaged African-American preschool children found that a quality preschool education provided long-term individual and societal benefits in adulthood (High/Scope Perry Preschool Study, 2005; Schweinhart, 2003). These benefits include scoring higher on an IQ test, being more likely to graduate from college, and securing well-paid employment. A more recent five year study on preschool education (Sylva et al, 2004) has also identified the merits of a quality early education, especially for disadvantaged children. A quality preschool education contributes to 'better intellectual and social/behavioural development for children' and children make more progress when their teacher is well -qualified (Sylva et al, 2004: ii–iv). A report by the Human Sciences Research Council confirms the link between economically disadvantaged school communities and low quality educational outcome:

> As expected, there was a relationship between the poverty index of the school and achievement levels of the better resourced Quintile 3, 4, and 5 schools[3]. Quintile 5 schools achieved a much higher average achievement score that the other quintiles (Human Sciences Research Council [HSRC], 2011: 9).

Early science contributes qualitatively to early education and therefore to the development of later competencies. Sylva et al's (2004) study on preschools also found that 'Centres which put particular emphasis on literacy, *maths, science/environment* and children's 'diversity' ….promoted better outcomes for children in their subsequent academic attainment …' (my italics, Sylva et al, 2004: iv). According to Mantzicopoulos, Patrick and Samarapungavan (2008) limited exposure to science in the early years and less than ideal pedagogical practices result in negative perceptions and beliefs in older school children which, in turn, create barriers to the later learning of science. Mantzicopoulos et al posit that if we are to create more science graduates, and sustain in learners a lifelong interest in science, early science needs to be targeted because:

> ... it is through the active engagement with science that children develop concepts of themselves as science learners and participants in the process of science, construct understanding of science as a discipline, and come to view science as interesting and worth pursuing (Mantzicopoulos et al, 2008: 379).

[3] The South African Education Department rates and then groups schools in quintiles. The term 'Quintile 1' is conferred on the poorest, least resourced (in terms of fee payment, materials and human resources) South African schools. A quintile 5 school category refers to the most well-resourced schools.

French (2004), and Ginsberg and Golbeck's (2004) idea that young children are interested in 'doing' simple science is supported by Mantzicopoulos et al who concluded that six-year-olds are mentally ready for the learning of science. Whilst a minority of six-year-olds understood what constitutes science at the beginning of the kindergarten year 'Responses to questions later in the year about kindergarten science reflect a growing understanding that science is a content area with its own instructional content, vocabulary, processes, and activities' (2008: 379). In addition, young children are more likely to be exposed to mathematics and literacy in the home than to science (Mantzicopoulos et al, 2008), which suggests that children start school with a deficit in science which needs to be addressed if young children are to build a sound foundation for later school science competency.

In spite of research that suggests that six-year-olds can 'do' science, and that early science leads to later competencies, the South African Foundation Phase curriculum provides only one hour a week for the learning and teaching of science (DBE, 2011a). A baseline survey of 41 Western Cape preschool and Grade R classrooms showed little classroom evidence of science, and most of the educators interviewed indicated that they knew little about science (Biersteker, 2012). Arguably, a late and under-resourced start to science has contributed to the following:

1. 'The quality of the educational system is very poor (146th), with low primary and tertiary enrolment rates' (World Economic Forum, 2013: 16).
2. South Africa scored very low internationally with regards to mathematics and science (TIMSS, 2011[4]; Centre for Development and Enterprise, 2004). Even though the 2011 Grade 8 TIMSS test was administered to South African children in Grade 9, the results remain discouraging: of the 45 countries that participated '… three countries (Botswana, South Africa and Honduras) continued to perform at the lowest end in both mathematics and science' (HSRC, 2011: 1).
3. In the 2011 matric finals 66.2% achieved less than 40% in Physical Science (deduced from DBE, 2011d).

The above implies that there are, and will be, too few mathematics and science graduates[5] contributing to South Africa's socio-economic well-being.

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[4] South Africa did not participate in the 2007 TIMSS
[5] Engineering, medicine, agriculture, physics, chemistry, technology

While research has indicated that there are many reasons why we should be paying close attention to early education, South African universities and colleges focus almost exclusively on producing teachers for primary and high schools. Schooling for six-year-olds differs significantly from Grades 1, 2 and 3 in terms of the developmental sensitivity and pedagogical demands[6] but there are no university four year full time teacher education courses that focus on preschool and Grade R, no Grade R graduate teaching posts are available in public schools, and the minimum qualification required of a preschool principal or Grade R teacher is currently a Level 4 certificate in Early Childhood Development (ECD) education.

Although initiated by personal and practical goals, this study aims to make three contributions to the field of scholarship relating to early science by:

- Describing the Grade R science curriculum in a way that enables us to consider the degree to which the curriculum potentially gives learners access to science concepts and processes.
- Recontextualising the essential principles underpinning a neo-Vygotskian approach into a conceptual framework on science knowledge for six-year-olds.
- Developing a language of description for evaluating science curriculum concepts for six-year-olds.

1.4. CONTEXT

The term 'science' is used in many contexts and means many things to different people. The purpose of this section is to clarify the three notions of science that pertain to this study and to set out the context in which this study is located. The next three sections explain the following:

- the scientist's view of 'science'
- 'school science' as represented in the South African primary school curriculum. From a general understanding of school science, the explanations narrow down to the school science for six-year-olds.

[6] Discussed in Chapter 2, the literature review.

1.4.1. The discursive context: different understandings of science

There is a distinction between scientific knowledge as the *production and organisation* of knowledge by scientists, and school science as the *reproduction and acquisition* of particular aspects of scientific knowledge within the schooling context. The common notion of either idea above as scientifically 'truthful and correct' and beyond contestation is a societal myth. Professor John Bolton, a botanical scientist from the University of Cape Town, pointed out that there are no simple, complete and universally agreed upon scientific concept definitions[7]. The matter of classification remains contestable between scientists particularly in the light of today's technological advances in determining DNA. Dr Bolton explained this idea by providing the following example: there is no 'correct' scientific definition of the concept *plant* because scientists cannot agree on the essential characteristics of *plant*. Some scientists will argue that kelp is a plant because photosynthesis occurs in kelp; others will argue that kelp is not a plant because plants grow on land. The reality for scientists is that knowledge is not a complete, orderly and predictable entity. However, in spite of this disputation, it is the intention of scientists to strive as an academic community to come to a common agreement with regards to understanding the world. At times concept definitions are 'settled' but with new discoveries these definitions are often disputed and changed[8].

In terms of children acquiring scientific knowledge, Sharma and Anderson (2009: 1253) point out that:

> Scientists 'do' science, while students 'learn' science, but what scientist do and students learn in the name of science is not the same thing. In order to be taught to students the "scientists' science" has to be recontextualised into "school science".

Larkin observes that school science in the West is moving closer to the scientists' idea of science (Larkin, 2013), but, in my opinion, Bernstein's caution against thinking that the knowledge of scientists is 'knowable', i.e. already known, is still valid. School knowledge is still often represented as 'impermeable' and 'settled' to children as part of 'the long socialisation into pedagogic code' (Bernstein, 2000: 11). While definitions provided by

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[7] The matter of classification and what constitutes a simple scientific definition was discussed in a telephone conversation between the researcher and Professor John Bolton on the22nd October 2012.

[8] E.g. Pluto, which was considered one of nine planets in our solar system in the 20th century, is no longer classified as a planet in 2013.

curriculum, dictionaries and school encyclopaedia are generally derived from 'settled' scientific knowledge, they are also likely to be scientifically disputable

According to early science researchers around the world there is now a focus on science pedagogy and young children (Maier, Greenfield & Bulotsky-Shearer, 2012; Fleer, 2010, 1995, 1993; Mantzicopoulos et al, 2008; French, 2004). The literature shows that, regardless of their theoretical approach, the proponents of early science[9] generally agree on the following:

- A knowledgeable adult, concrete objects and experiences, and language play an essential role in learning in the early years.
- Young children are more cognitively competent than described by early 20th century researchers but there are biological limitations to what young children can learn.
- There is insufficient research on science and young children
- Opportunities for the learning of science are limited in most preschool and kindergarten curricula.

1.4.2. Science in the South African schooling context

In South Africa, school science has undergone three changes in twenty years. The first *National Curriculum Statement* (NCS 2005[10]) which was introduced in 1997 was based on outcomes-based curricula. The NCS 2005 was reviewed, simplified and implemented as the *Revised National Curriculum Statement* (RNCS) in 2002. In 2011 the RNCS was replaced by the *Curriculum and Assessment Policy Statement* (CAPS). In the CAPS Foundation Phase (Grades R-3) Life Skill curriculum science comprises the subject area *Beginning Knowledge*

(DBE, 2011a). In the CAPS Intermediate Phase (Grades 4-6) *Beginning Knowledge* is replaced by the school subject *Natural Sciences and Technology* (DBE, 2011b). School science comprises two basic disciplines, i.e. biology, defined by Morris as 'the study of the properties and history of living organisms and of their interactions with the non-living world' (1992: 261), and physics, i.e. 'the scientific study of matter, energy, motion and force' (Morris,

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[9] Examples of early science programs founded on research studies: The 2005 Scientific Literacy Project (Mantzicopoulos, P., Patrick, H., & Samarapungavan, A.); ScienceStart! (French, L, 2004); Preschool Pathways to Science (PrePS© (Gelman, R. & Brenneman, K., 2004), Tools of the Mind (Bodrova E. & Leong, D. J., 2001) and the Golden Key schools (Kravtsova, E, n. d.)

[10] Does not pertain to the publication date; refers to the curriculum's intention to be implemented in all South African schools by 2005.

1992: 1643). Each discipline is structured as two parts: knowledge content and scientific processes. At times one aspect is foregrounded in preference to the other, e.g. the *Revised National Curriculum Statement Grades R–9 (Schools): Natural Science* was process orientated (DBE, 2002). Researchers into sub-Saharan school science note the following: Scientific investigations and practical work lead to conceptual understanding (Ramnarain & Kibirige, in Ramnarain, 2010: 10-11). School science is a combination of '*scientific knowledge* (ideas, facts, principles, laws and theories of science)' and 'the process of science ...gathering data and constructing new scientific knowledge'. Most teachers 'do not have a proper understanding of what science is and how scientific knowledge comes to be' (Vhurumuku in Ramnarain, 2010: 25).

The following definitions of 'science' illustrate current approaches to school science in South Africa. The first definition, an official perspective, acknowledges the historical nature of science knowledge, link the scientific to the school context, and view school science as two related parts, i.e. content and process.

> What is today known as 'science' has roots in African, Arabic, Asian, European and American cultures. It has been shaped by the search to understand the natural world through observation, codifying and testing ideas, and has evolved to become part of the cultural heritage of all nations. It is usually characterised by the possibility of making precise statements which are susceptible to some sort of check or 'proof' (DBE, 2011b: 8).

This broad historical notion of science is refined in the Foundation Phase Life Skills curriculum to two ideas, i.e. '*Natural Science concepts;* life and living, energy and change, matter and materials; planet earth and beyond' and '*Scientific process skill;* the process of enquiry which involves observing, comparing, classifying, measuring, experimenting, and communicating' (DBE, 2011a: 8). By contrast, the second definition provided by a South African preschool/Grade R maths and science manual refers only to process:

> Science is the process of investigating the world around us; using observation, experiment and analysis to:
>
> - discover pattern
> - make and test predictions
> - build model; and

- to communicate what has been learned (Curriculum Development Project Trust, 2009: 9)

The remainder of this section focuses on the current official approach to school science for most six-year-olds in South Africa. Grade R is the school year preceding entry into formal schooling in Grade 1[11]. The study uses the term 'Grade R science curriculum' to refer to the *National Curriculum Statement (NCS), Curriculum and Assessment Policy Statement Foundation Phase Grades R – 3: English Life Skills* subject area *Beginning Knowledge* (DBE, 2011a). As children in Grade R are officially in the sixth year of biological development[12], the study also uses the term 'six-year-olds'. Like the CAPS curriculum, this study employs the notion of a generic six-year-old and views most six-year-olds as having the capacity to be confident and able to self-regulate, abide by rules, co-operate, remember, pay attention, solve problems, reason, classify, predict, evaluate, and sequence[13] (WCED, 2011: 15-21). All these qualities relate to Vygotsky' (1962), Luria' (1976) and Davydov's (2008) ideas on the abilities required for abstract learning.

In the Grade R classroom there is little time for, or information on science. The stipulated weekly time allocation in the Grade R curriculum is ten hours for *Literacy*, seven hours for *Mathematics,* and one hour for the science subject area *Beginning Knowledge* (DBE, 2011a). A significant factor differentiates Grade R from Grades 1-12: while children in Grades 1-12 are taught by university or college education graduates, there are no departmental Grade R posts currently available in public schools[14] to date. A survey of Grade R classrooms showed that

most six-year-olds are taught by ECD practitioners with a certificate in early childhood development (Biersteker, 2012). Graduate Grade R teachers are likely to be employed by well-resourced independent schools.

In the next chapter this study introduces, into the current South African school science context described above, a neo-Vygotskian perspective that takes a particular approach to

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[11] The term Grade R is similar to the terms kindergarten, reception year or infant schooling. Grade R, unlike Grade 1, is not yet compulsory in terms of school attendance, and there is no formal assessment of learners.

[12] In Grade R classrooms that have low learner registration children who are four turning five are encouraged to attend (Biersteker, 2012).

[13] As described in the *Western Cape Education Department (WCED), 2011. Foundation Phase training manual: Grade R.*

[14] The Grade R graduate teachers who were employed under the pre-1994 dispensation remain in their posts but when they resign the post falls away. There are no 'new' state Grade R graduate teaching positions available to date.

scientific knowledge and school science. In contrast to the earlier definitions of science, the neo-Vygotskians understand that 'Science aspires to pass from the description of phenomena to the disclosure of essence as their internal bond'[15] (Davydov, 1990: 36).

1.5. THEORETICAL FRAMEWORK

This section explains the reasons for selecting a neo-Vygotskian approach, identifies the theorists and commentators selected for this study, and rationalises the focus on six-year-olds.

I selected a neo-Vygotskian perspective for the following five reasons:

- The neo-Vygotskians are well positioned in a field which considers Vygotsky, Piaget and Bruner as three major influences in the theorising of children's cognitive development (Moll, 1989). Vygotsky's ideas on knowledge have been brought into the 21st century by the neo-Vygotskians. Vygotsky had a limited language of description and after his premature death at the age of 38 it was the neo-Vygotskians who addressed the shortcomings and expanded on his ideas on scientific knowledge (Daniels, 2008; Karpov, 2005). This study locates itself within this historical legacy, which has provided me with a language of description for understanding school science for six-year-olds.
- A neo-Vygotskian perspective provides a fresh view on early science, in contrast to most studies which are rooted in discovery based approaches (Van der Merwe, 2009; French, 2004; Gellman & Brenneman, 2004; Ginsberg & Golbeck, 2004; Lind, 1998; Skamp, 1998; Doris, 1991). Egan (2002) argues that educational approaches in the West have been dominated by the theories of Spencer, Dewey, and Piaget and he questions the relevance of long-held pedagogical 'truths' such as the concrete and known must always precede the abstract and unknown, children are born naturally curious, and young children cannot grasp abstract concepts. Egan's view is supported by research showing that young children are more competent than indicated by early 20th century developmental theorists. 'Indeed, the research has so effectively introduced new insights into what children can do, that we can now chant a litany of competence, competence everywhere' (Ginsberg & Golbeck, 2004: 191).

[15] This idea is fleshed out in the literature review.

- Vygotsky and the neo-Vygotskians take a developmental view of school science, i.e. the learning of scientific knowledge is '... one of the most significant sources of the school children's psychical development' (Davydov, 2008: 191). This idea correlates with my own experience of using science to teach six-year-olds mathematics, knowledge and literacy skills, and relates to Sylva et al's (2004) findings that science contributes qualitatively to cognitive development in the early years.
- Empirical studies have confirmed the positive impact of a neo-Vygotskian approach on preschool and early primary school children's conceptual acquisition (Harrison, 2011; Fleer, 2010; Bodrova & Leong, 2001).
- There are contextual parallels between South African education post 1994 and a neo-Vygotskian approach. Both emerged after a period of societal upheaval in which the new dispensation strove to create a more egalitarian society in an economical and culturally diverse country. The neo-Vygotskians' efforts to complete and extend Vygotsky's ideas are mirrored in the South African education department's striving to provide a quality workable curriculum by addressing the gaps and shortcomings in the last two decades[16] .

As there are many neo-Vygotskians, this study has selected certain scholars and commentators to represent a neo-Vygotskian approach to scientific knowledge and has grouped them according to Karpov's (2005) and Daniels' (2008) idea that there are three historical 'generations' or 'waves' of Vygotskian theorists: Vygotsky, the first generation neo-Vygotskians, and the second generation neo-Vygotskians.

1.5.1. Vygotsky

Lev Vygotsky's (1896 – 1934) work and theories on human development are the foundation of the neo-Vygotskians work. Vygotsky's thinking was influenced by European thinkers[17] and the social and cultural ideological changes that emerged from the Russian revolution. Vygotsky's seminal publications, *Thought and language* (1962) and *Mind in society* (1978), engaged with Piaget's theories[18] and drew on the ideas of Pavlov, Tolstoy and Marx (Daniels, 2008; Luria, 1979). Vygotsky's critique on the shortcomings of his own work on scientific concept development signalled the direction of the neo-Vygotskians' work (Vygotsky in Van der Veer & Valsiner, 1994). As a neo-Vygotskian approach is rooted in

[16] From the first 1997 National Curriculum Statement (NCS, 2005) to the Revised National Curriculum Statement (RNCS, 2002) to the current CAPS (2011) curriculum

[17] Hegel, Wundt, Spinoza, the Gestalt psychologists, Piaget, Freud, Kant, and Engels (Luria, 1979, Daniels,

[18] Vygotsky acknowledged the debt in his statement 'Psychology owes a great deal to Jean Piaget' (Vygotsky,

Vygotsky's theories, each notion or argument put forward in this study generally begins with Vygotsky's ideas.

1.5.2. The first generation neo-Vygotskians

This study is primarily informed by Davydov's 1990 and 2008 texts that are uniquely positioned in the neo-Vygotskian context. As a Russian student of Vygotsky who lived and worked in the West, Davydov's work spans between the two generations of neo-Vygotskians. Although Davydov's work pertains to schoolchildren his conceptual ideas offer considerable insight into understanding knowledge. Luria (1979, 1976, 1971) and Zaporozhets' and Elkonin's 1971 collation of preschool studies by various first generation neo-Vygotskians also contributed to understanding early knowledge in this study.

1.5.3. The second generation neo-Vygotskians

Vygotsky's ideas emerged and were taken up by the West in the 1970s. As current Vygotskian scholars are diverse in their thinking and must be seen in their own cultural context (Daniels, 1996), this study focuses on Hedegaard (2002) and Fleer (2010). Hedegaard's work with young schoolchildren builds on Vygotsky's theory of the zone of proximal development (ZPD) and his idea of double stimulation. Hedegaard also acknowledges that she was 'heavily influenced' by Davydov's work (Hedegaard, 2002). Fleer's work on preschool science applies Vygotsky's and Hedegaard's ideas to understanding the learning of science in the preschool context (Fleer, 1993, 2005, 2009, 2010, 2011). The first and second neo-Vygotskians are, however, united in their approach by:

> ...the principles of the psychological theory laid down in the 1920's and 1930's by Vygotsky, and which they followed in elaborating the problems of Russian psychology. Vygotsky's scientific school was created, developed, and continues to develop, based on these principles (introduction to Davydov, 2008: 2).

Narrowing the focus of this study to six-year-olds has been purposeful. Although Fleer (2010) employs a neo-Vygotskian approach to researching preschool science, most neo-Vygotskians have located their work in the formal school domain, e.g. Davydov (2008, 1990), Hedegaard (2002), Bodrova and Leong (2001). The sixth year, which straddles learning in preschool play settings and learning through formal instruction, is therefore under-researched in terms of science knowledge (Fleer, 2009).

1.6. RESEARCH DESIGN

I adopted a text analysis of the Grade R science curriculum because this document informs the 'what' of science for the teaching of most six-year-olds in South Africa (General Household Survey, 2012)[19]. Although research studies usually employ document analysis as a complementary corroborating method, a stand-alone document analysis has been used as an effective and efficient methodology (Bowen, 2009). I found Maxwell's (2010) idea of creating a connecting strategy between the theory (the neo-Vygotskians' ideas) and the empirical (Grade R science curriculum) useful. The design of the analytic indicators, the rating scale, benchmarks and knowledge type descriptions all draw on a principle-based conceptual framework that was developed from a literature review on the neo-Vygotskians' understanding of knowledge. Rooting the design in the conceptual framework generated a language of description for analysing the Grade R science curriculum knowledge concepts in relation to a neo-Vygotskian approach to school science knowledge for six-year-olds.

1.7. STUDY OUTLINE

Chapter 1 introduced the reader to the study. The literature review, which follows, provides a broad theoretical understanding of Vygotsky's and a neo-Vygotskian approach to knowledge, before narrowing down to a specific understanding of school science knowledge for six-year-olds. A conceptual framework reflects the neo-Vygotskian idea of a simple scientific concept as a unit of science knowledge for six-year-olds. In Chapter 3 the conceptual framework is translated into an analytic framework for the analysis of the Grade R science curriculum. Chapter 4 generates analytic descriptions of the Grade R science curriculum in terms of the neo-Vygotskian idea of a scientific concept for six-year-olds. The conclusion completes the study by discussing the findings, deriving implications, and making recommendations with regards to school science for six-year-olds.

[19] The survey indicates that most six-year-olds are in public schools.

CHAPTER 2: Literature review
A neo-Vygotskian approach to understanding scientific and everyday knowledge

Thoughts without content are empty, perceptions without concepts are blind (Emanuel Kant, *Critique of Pure Reason* in Wellington, 1989: 1)

2.1. INTRODUCTION

The task of this chapter is to develop a conceptual framework derived from neo Vygotskian theory for the purpose of developing a language of description for an analytic account of the representation of school science knowledge for six year olds in selected curriculum texts. As the neo-Vygotskians are a group of diverse scholars I have located this study primarily in the work of Hedegaard, Davydov and Fleer because they are the current leaders in the field of school knowledge.

The chapter begins with a brief historical overview that traces the development of ideas on knowledge from Vygotsky's theory to a current neo-Vygotskian perspective on school science. This overview is followed by an explanation of Vygotsky's and the first generation neo-Vygotskians' notions of the concept as a unit of knowledge[20]. Specific attributes that distinguish a scientific concept from other concepts are identified. The next section pertains to the second generation neo-Vygotskians and narrows down to a particular view on school knowledge and school science as purposefully selected aspects of scientific knowledge. At this point, the discussion is summarised into a list of neo-Vygotskian 'principles' for scientific knowledge. I then consider these 'principles' in relation to the cognitive development of six-year-olds, and develop the notion of a simple scientific concept as a unit of knowledge on the scientific knowledge continuum. Simple scientific concepts relate to and underpin mature concepts[21] but are differentiated from scientific concepts by being couched in terms that six-year-olds can understand. The chapter concludes with a conceptual framework that theorises the idea of school science knowledge for six-year-olds i.e. the simple scientific

[20] As with all theory development the neo-Vygotskians' use of 'scientific concept' differs from Vygotsky's own use of the term. This is discussed in the chapter.

[21] The terms 'emergent' and 'mature' are inherent in the concept itself i.e. they relate to the simplicity or complexity of the concept itself and not to the child's developing understanding of the concept.

concept.

2.2. HISTORICAL OVERVIEW

This section expands Chapter 1’s introductory comments on a theoretical approach to knowledge with a historical overview of the development from Vygotsky in the early 1900s to Hedegaard and Fleer at the beginning of the 21st century. Two ideas on human knowledge remain constant:

- Knowledge creation involves other humans i.e. it is a social process
- The knowledge that children learn today has been developed by previous generations i.e. it is historical in nature.

Vygotsky understood human knowledge as a criteria-based structural division into two types which he termed everyday knowledge and scientific knowledge. Everyday knowledge is commonsense, the everyday know-how that humans need in order to go about their daily living e.g. how to raise a baby or prepare a meal. Scientific knowledge, on the other hand, is historically constructed over time by scientists into universally agreed upon meanings e.g. $E=mc^2$. Scientific knowledge comprises individual units, scientific concepts, which possess particular characteristics and can only be acquired through schooling. Once scientific concepts are acquired they become individual constructs because each child internalises and shapes their understanding of the scientific concept according to their context, prior knowledge and experience.

After Vygotsky’s premature death in 1933 the first generation neo-Vygotskians[22] confirmed, with empirical data, Vygotsky’s idea of everyday and scientific knowledge as the two basic types of knowledge (Davydov, 2008, 1990; Karpov, 2005; Luria & Yudovich, 1971).The first generation neo-Vygotskians also extended Vygotsky’s ideas by redefining a concept as’... a combination of scientific concepts and relevant procedures ...’ (Karpov, 2005: 182). Procedural knowledge comprises the related mental processes and activities involved in the acquisition of scientific knowledge content (Karpov, 2005). The notion of procedural knowledge is governed by two of Vygotsky’s seminal ideas: the zone of proximal development (ZPD) as ‘the learning space difference between what a child already knows and what he/she can potentially learn with the support of a knowledgeable adult or older

[22] Vygotsky’s Russian colleagues and students e.g. Davydov, Luria, Zaporozhets, Elkonin

child' (Vygotsky, 1962: 112), and the law of equivalence that posits 'any concept can be formulated in terms of other concepts in a countless number of ways' (Vygotsky, 1962: 112). Davydov's idea that 'It is therefore entirely reasonable to use the term "knowledge" to simultaneously denote both the result of thinking (the reflection of reality) and the process of obtaining it (i.e. the thinking action)' (Davydov, 2008: 121) is illustrated in the following example. When a child learns about the concept 'metamorphosis' by observing and documenting the lifecycle of a silkworm (reflection on reality), the child is also developing the mental processes of comparing, predicting, theorising, reflecting, and drawing conclusions (the thinking action). In this example the procedural knowledge pertains to the mental processes and the activity of observing and documenting the silkworms. This example also illustrates the neo-Vygotskian idea that the acquisition of scientific knowledge is developmental.

Vygotsky and the first generation neo-Vygotskians' work emerged in the West in the late 1960's and influenced Western scholars (Siraj-Blatchford, 2009; Bernstein, 2000; Rogoff, 1990; Bruner, 1968) which led to a second wave of Vygotskian scholars. Although the second generation neo-Vygotskian perspective is deeply rooted in Vygotsky's socio-historical approach and influenced by the first generation neo-Vygotskians' ideas, the second generation neo-Vygotskians took understanding scientific knowledge in a new direction by foregrounding the role of context (Hedegaard, 2002; Rogoff, 1990). The current neo-Vygotskian understanding of 'school knowledge' is that it comprises differentiated knowledge forms and thinking within a particular context of acquisition (Davydov[23], 2008; Hedegaard, 2002). 'School science' refers to selected historical scientific knowledge that has been recontextualised for the purposes of teaching school children about the natural sciences (Hedegaard, 2002).

2.3. THE CONCEPT AS THE BASIC UNIT OF KNOWLEDGE

This section considers Vygotsky's and the first generation neo-Vygotskians' ideas on the concept[24] as the fundamental unit of knowledge. The rationale for this entry point is to establish a clear understanding of the foundation on which this study's notion of school

[23] Davydov's longevity in the field spans between the first and second generation neo-Vygotskians.

[24] Although Vygotsky and the neo-Vygotskians use the term 'concept' at times to refer to a scientific concept, this study uses the term 'concept' to refer broadly to all types of concepts. When referring to a specific type of concept an adjective such as 'scientific', 'everyday', 'empirical' or 'theoretical' precedes the term 'concept'.

science for six year-olds rests. This examination necessitates the adoption of a 'drill down' approach beginning with Vygotsky's ideas. As knowledge is a complex and integrated construct, it is difficult to separate each aspect and at times the discussions on the constituents of knowledge 'lean over' into concept acquisition.

2.3.1. Vygotsky: the concept as the basic unit of knowledge

As mentioned above, the neo-Vygotskians' ideas on knowledge originated from Vygotsky's view of knowledge as two opposing but complementary structures that he termed everyday and scientific knowledge (Vygotsky, 1978, 1962). According to Vygotsky all knowledge comprises basic units known as concepts which, depending on how they were acquired[25], are differentiated into either everyday (also known as spontaneous or non-scientific) or scientific (also known as true, authentic, academic or non-spontaneous) concepts.

Scientific concepts are inherently different from everyday concepts, and can be distinguished from everyday concepts by certain features. These features have been summarised from Vygotsky's *Thought and Language* (1962) text:

- Scientific concepts are organised into hierarchical academic knowledge systems.
- As scientific concepts are placed within a hierarchical structure, they are mediated by other concepts. 'Thus the very notion of scientific concept implies a certain position in relation to other concepts, i.e. a place within a system of concepts' (Vygotsky, 1962: 93).
- Scientific concept formation requires higher order thinking abilities and involves cognitive processes such as abstraction, systemisation and generalisation.
- Scientific concepts are couched in a particular academic language.
- Scientific concepts are acquired through schooling.

Systematisation and generalisation are essential features of a scientific concept. Firstly, '... the *absence of a system* is the cardinal psychological difference distinguishing spontaneous from scientific concepts' (Vygotsky, 1962: 116). Secondly, generalisation functions like co-ordinates on a map to indicate precisely where a concept is positioned within the entire system of concepts (Vygotsky, 1962). Vygotsky makes the link between systematisation, generalisation and hierarchical ordering:

[25] This idea of determining a concept according to acquisition was challenged by the neo-Vygotskians who considered context in knowledge acquisition.

> If consciousness means generalization, generalization in turn means the formation of a superordinate concept that includes the given concept as a particular case. A superordinate concept implies the existence of a series of subordinate concepts, and it also presupposes a hierarchy of concepts of different levels of generality. Thus the given concept is placed within a system of relationships of generality (Vygotsky, 1962: 92).

Vygotsky uses the example of a flower and rose to explain generalisation and therefore systematisation. At first a young child will use one word e.g. 'flower' to indicate all types of flowers which is 'a generalization of the most primitive type'. As the child develops the child realises that the word 'rose' is subordinate to the word 'flower', in that the term 'rose' is only applicable to a certain group of flowers whereas 'flower' can be used generally to indicate all groups of flowers. Generalisation and systematisation relate to Vygotsky's law of equivalence which governs all concepts and posits that a concept is known by its relationship to other concepts[26] (Vygotsky, 1962). In simple terms: humans acquire new knowledge by comparing the new idea to what they already know.

The following example employs Einstein's theory of relativity formulation, $E = mc^2$, with two purposes in mind i.e. 1) to further clarify the notion of hierarchy and systematisation, and 2) to demonstrate how the application of Vygotsky's scientific characteristics determines whether a concept is a scientific or an everyday concept. Each symbol in the equation $E = mc^2$ is part of a mediated hierarchy of meaning located within a system of science knowledge. Before the equation $E = mc^2$ is understood, the individual meanings of the symbol 'm' as a sign that represents mass, the symbol 'c' which as a sign for the speed of light in a vacuum, and the mathematical notion of squaring need to be understood. But, before the concept of mass is understood, the concepts of weight, gravity, density and size need to be understood. Prior to weight being understood, the notions of heavy and light need to be comprehended. When the individual symbols are put together, their collective individual meanings become subsumed into a different concept known as 'energy' and represented by the symbol for 'E'. Understanding abstract notions, such as mass, speed of light, and mathematical squaring, requires higher order thinking skills. The concept, $E = mc^2$, employs a particular type of symbolic academic language which, if not understood, renders

[26] Relates to Piaget's (1997) idea of assimilation and accommodation

the equation incomprehensible. $E=mc^2$ is a complex abstract notion that cannot be understood in the absence of schooling by a knowledgeable adult. As all of Vygotsky's characteristics of a scientific concept apply to Einstein's formulation, it can be concluded that $E = mc^2$ is indeed a scientific concept.

If we think a little further about Vygotsky's stated criteria, the core factors that differentiate and identify scientific concepts from everyday concepts are abstraction and systematisation. In providing a clear understanding of the attributes that identify scientific concepts, Vygotsky gives clarity to the notion of everyday knowledge. Scientific knowledge is constituted of concepts that are ordered in relation to other scientific concepts, described in specialised terms, and the essential attributes are not easily discernable. Everyday knowledge, on the other hand is comprised of randomly organised isolated ideas that are easily perceived through the senses. Kozulin (1990) has pointed out that everyday knowledge shares some attributes belonging to scientific knowledge e.g. everyday concepts can demonstrate order and systematisation.

Although everyday and scientific knowledge comprise two fundamentally different types of concepts, they co-exist and are inseparably related except in young unschooled children. Everyday concepts are acquired by going about our daily living and are based on experience, observation and hearsay. When we are taught and acquire a scientific concept our everyday knowledge is restructured in accordance with the new scientific knowledge. Scientific concepts are acquired in relation to our everyday understanding of the world and cannot, in the absence of the everyday, exist (Vygotsky, 1962). Establishing the relationship between everyday and scientific knowledge is particularly relevant to this study which concerns science as the academic and abstract, and six-year-olds who are immersed in everyday knowledge and thinking.

2.3.2. First generation neo-Vygotskians: the concept as the basic unit of knowledge

The first generation neo-Vygotskians' ideas on knowledge were wrought from their empirical fieldwork which confirmed, challenged or extended Vygotsky's theoretical notions. This section's understanding of a concept was mostly derived from Davydov's (2008, 1990) detailed descriptions of the concept as the basic unit of knowledge. Davydov's definition of a concept below confirms Vygotsky's idea that a word can embody a concept. At the same time Davydov extends the idea of a concept to the mental processes integral to internalising the content:

> A combination of two, three, or more abstract and general attributes which is formed by the significance of a certain word (most often by means of a *definition*) is usually called a *concept*. Generalization and abstraction are indispensable conditions for forming it. The group of generalized attributes of an object is the *content* of the concept (Davydov, 1990: 7).

All concepts possess essential and non-essential attributes. Essential attributes are the primary attributes of an object or phenomena which uniquely define and distinguish the said object or phenomenon from other objects or phenomena (Davydov, 1990). Davydov illustrates this notion with the following example. The two essential attributes of a triangle are three straight sides and three angles. Having either one but not both of these attributes does not necessarily make it a triangle. The non-essential attributes would be the colour and size of the triangle. If the essential attributes change then the triangle is no longer a triangle; if the non-essentials change the triangle still remains a triangle. The notion of essential attributes or properties as essential, inherent, and constant is one of the rules governing a scientific concept.

Davydov extended Vygotsky's idea of a concept by describing the internal structure of a concept. Davydov uses the example of a car to explain that 'Every concept has its *content* and its *scope*' (Davydov, 1990: 19). The content of a concept is all the essential and non-essential attributes of the object or phenomenon. For example[27]: the essential attributes of a car are that it has more than two wheels, an engine and can carry one or a small number of people from one place to another. Some of the non-essential or secondary attributes of a car are the colour, shape and the size of the car. A car remains a car if the colour, shape or size changes but if there were no wheels or an engine and it carried a large number of people, objects or animals it would be something other than a car. This precise identification of the essential attributes is called defining and is a major mental operation. Davydov elaborates the idea of defining further. If all the essential attributes of a car had to be named it would be a lengthy and cumbersome operation. One of the defining techniques used to overcome this problem is the establishment of the concept's closest genus and the

[27] Although the second example appears repetitious, it reinforces the basic structural principles governing a concept

type of attribute that best distinguishes it from other concepts in the same genus. Therefore the definition of a car (concept) is it is a vehicle (genus) that has more than two wheels, an engine and can carry one or a small number of people from one place to another (essential attribute type). A bus (concept) is also a vehicle (genus) but it differs from the concept 'car' because the essential attribute (type) 'carries many people' is different.

Davydov explains the notion of scope in a concept: 'Within a system of concepts one can pass from a concept of broader scope to a concept of a narrower scope, and vice versa' (Davydov, 1990: 20). Narrowing a scope is termed delimitation of a concept and it is the addition of attributes to the concept type. The reverse, broadening the scope, is termed generalisation of a concept and is the taking away of an attribute or attributes from the concept type. An example of delimitation of the concept 'car' is if additional attributes such as 'a retractable roof, a high speed engine, two-seater, and is more expensive' were added to the concept type of car, then the scope of the concept could be narrowed to 'sports car'. An example of generalisation of the concept 'car' is if we take away 'more than two wheels' from the attribute type of the concept 'car', it would broaden and change the original concept 'car' to include motorised scooters, motor bikes and electric bicycles. The next section moves from a general understanding of what constitutes a concept to understanding scientific knowledge.

2.4. THE NEO-VYGOTSKIAN APPROACH: SCIENTIFIC KNOWLEDGE AND SCHOOLSCIENCE

The next two sections pave the way for understanding school science knowledge for six-year-olds. The first section explains the first generation neo-Vygotskians' extension of Vygotsky's ideas on scientific knowledge into knowledge content and related cognition. The second section describes the further elaborations by the second generation neo-Vygotskians on the role of context.

2.4.1. First generation neo-Vygotskians

The neo-Vygotskians' understanding was shaped by their critique of Vygotsky's differentiation of everyday and scientific concepts according to how they were acquired rather than on the content of the concept:

> The distinction, as it was presented by Vygotsky, rested on the difference in the sources of acquisition of concepts – an asystematic individual experience in the first case, and systematic classroom instruction in the second. Such a basis for discrimination seemed to be inadequate... (Kozulin, 1990: 256).[28]

As a result the first generation neo-Vygotskians extended Vygotsky's notion of a scientific concept into a two part structure: content knowledge and procedural knowledge i.e. the processes involved in internalising the content knowledge. Each part is discussed, in turn, below:

2.4.1.1. Content knowledge

A concept is considered scientific when the concept's essence i.e. the essential attributes which may not be visible but which are integral to the concept, are unambiguously defined and understood. Davydov explains:

> Science strives to advance from the mere description of phenomena to the discovery of the essence of their internal connection. It is well known that essence has a content that is distinct from the immediate given properties of objects or phenomena (Davydov, 2008: 76).

Davydov acknowledged the complexity of understanding 'essence' by pointing out that the terms 'general' and 'essential' are synonymous i.e. 'The *general* as something recurring or stable is a definite invariant of the diverse properties of objects of a given sort – that is, it is *essential'* (Davydov, 1990: 8). The problem that arises is the difficulty in establishing the essential and the non-essential. For example: the Grade R science curriculum describes 'Birds' in terms of 'General characteristics of a bird – feathers, two legs, beak, lays eggs' (DBE, 2011a: 21). All these attributes are general to birds but which are essential? The only essential attribute that unambiguously defines a bird from another object is the characteristic 'feathers'. Although insects have wings and lay eggs, the tortoise has a beak, and mankind is also bipedal, no other animal is covered in feathers. Because of the complex and contentious nature of scientific definitions and because this study concerns school science for six-year-olds this study considered Davydov's idea:

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[28] The reason was that the study of human knowledge requires 'an appropriate epistemological study, which, according to Davydov, Vygotsky neglected ...' (Kozulin, 1990: 256). One of the problems was that there was no language available in Vygotsky's era to describe the new conceptual ideas (Daniels, 1996).

> Unfortunately, in the literature on educational psychology there is not special analysis of this problem. So far as one can judge by the actual division of essential and nonessential attributes in educational material, the former means such general qualities as are *inherent* (inseparable) in a certain range of objects, *differentiating it unambiguously* from any other objects (Davydov, 1990: 8).

A school science concept for six-year-olds should ideally contain a number of essential and general attributes. For example: the notion of a bird = feathers (essential characteristics) + two legs + a beak + lays eggs (general characteristics) becomes a simple scientific definition as in 'We know an animal is a bird if it has feathers all over its body. Birds also lay eggs and have wings, a beak and two feet'. This definition conforms to Davydov's description of a scientific concept[29]:

> In a concept the constituent features are; first, the presence of essential attributes permitting one class of objects to be distinguished unambiguously from others; second, a verbal expression of the meaning; third, this meaning need not be connected with the presence of visual images, but can have an abstract character (Davydov, 1990: 22).

However, the Grade R curriculum's representation of the topic concept 'Birds' is incomplete because 'Scientific knowledge, however, cannot be reduced to the verbal definitions of scientific concepts but should include procedural knowledge relevant to these concepts as well' (Karpov, 2005: 182).

2.4.1.2. Procedural knowledge

Procedural knowledge pertains to the mental processes and activities integral to acquiring scientific content (Karpov, 2005). A list of procedures cannot be provided for each is unique to the concept: 'For example: the procedures that are relevant to Archimedes' law are the methods of calculating the density of different objects and comparing these densities with the density of water' (Karpov, 2003: 47). Procedural knowledge is, in simple terms, knowing what to do with the content of a concept in order to master the concept. Davydov explains:

> Mastering a concept means not only knowing the attributes of the objects and phenomena embraced by the given concept but also *being able to apply the*

[29] As the neo-Vygotskians often employ the term 'concept' to denote a scientific concept, I have taken Davydov's notion of 'concept', which includes essential attributes, to refer to a scientific concept.

> *concept in practice*, being able *to operate* with it. And this means that concept mastery includes *not only a path from the bottom up – from separate and particular cases to their generalization, but also the opposite route from the top down, from the general to the particular and separate*. Knowing the general, one must be able to see it in the particular, concrete case, with which one has to deal at the given moment (Davydov, 1990: 11).

E.g. a six-year-old demonstrates her/his mastery of *birds*[30] by 'operating' with the simple scientific definition of *birds* i.e. employing the essential attributes 'feathers all over its body', 'lay eggs', 'have wings, a beak and two feet' to sort a set of plastic animals into two groups i.e. 1) *birds* and 2) *other animals that are not birds*.

Procedural knowledge always involves generalisation because it is the basis of all learning (Davydov, 1990). Underpinning all learning is classification because '… ultimately every thought from the most abstract and complex deductions to elementary intuition, consists in establishing similarity and dissimilarity between two sensations' (Vygotsky quoted in Davydov, 1990: 26). Generalisation and classification therefore are at the heart of procedural knowledge. Although the basic features of generalisation i.e. identifying an invariant, word naming, grouping according to one or two attributes, are intrinsic to elementary (everyday) and theoretical (scientific) concepts (Davydov, 1990: 13), procedural knowledge pertains to a particular type of generalisation that is specific to the acquisition of scientific concepts. The following paragraph illustrates the difference between the two types of generalisation.

Davydov's description below of generalisation by six-year-olds' pertains to the acquisition of an everyday concept:

> ...is done on the level of conceptions as simple "recollections"[31] of something previously seen. This generalization is by no means complete or precise; in it elements of the essential attributes of objects are mingled with the nonessential ones. Its content is the purely external, striking attributes with an everyday significance, on the basis of which children orient themselves when they perform operations with objects (Davydov, 1990: 12).

[30] In an effort to reduce wordiness, Italics are used to refer to a scientific or school science concept.
[31] Reproduced exactly as in the text; appears to be an editing error.

However, when six-year-olds start to classify according to the essential attributes of a simple scientific concept (such as the definition of 'birds' above), they start to engage with procedural knowledge. For example: A child is shown a set of animal picture cards and asked 'Which one does not belong: a hippopotamus, lion, sheep, giraffe, or zebra?'[32] If the child responds by choosing the card with a lion and explains his/her choice in terms of the essential attributes of *herbivore*[33], the response involves a different mental process and procedure to the one described above by Davydov. In this example the child is not basing his or her understanding on 'simple recollections of something previously seen' nor on 'purely external, striking attributes'. The child is 'operating' with the concept *herbivore*. The use of academic terminology does not necessarily mean that a concept such as *herbivore* will be acquired by the children but the educator's ability to define a concept is the first step towards potential acquisition of concept.

Davydov (2008) elaborates further. Generalisation is the thread running through procedural knowledge which differentiates concept type and modes of acquisition. 'An empirical[34] conceptual generalization does not single out the essential features of the object itself – the internal connection of its different aspects' (Davydov, 2008: 76-77); '... by "theoretical knowledge" we mean contentful abstraction and generalization and theoretical concepts, taken as a unity' (Davydov, 2008: 115). The following example illustrates these two ideas. A young child acquires an everyday concept when she thinks that all birds can fly because she has observed birds flying. Although 'wings' are an essential feature of *bird,* 'the ability to fly' is not. However, if a child learns that all birds have feathers (an essential attribute), the child can look at a group of animals and identify the birds by their feathers. Even though a penguin and ostrich cannot fly the child understands that they are birds because they have the one attribute that is unique to *birds*, feathers. Schooling is mandatory for the acquisition of scientific knowledge because the essential features of a concept are generally not easy to discern. In the absence of essential attributes, content knowledge does not exist, and in the absence of content knowledge, procedural knowledge does not exist.

In summary: Vygotsky (1962, 1978) laid the basic theoretical foundation by differentiating

[32] This question is derived from a word game played in different ways with six-year-olds in Grade R.
[33] 'A lion eats meat; the other animals are herbivores and they only eat plants'
[34] Davydov employs different terms in his refining of Vygotsky's ideas on everyday and scientific knowledge. In general 'empirical' refers to everyday knowledge, 'theoretical' to scientific.

knowledge into two types, everyday and scientific. Scientific knowledge is a systematically ordered socio-historical entity comprised of transferable individual scientific concepts which are acquired through schooling[35]. Once acquired, scientific concepts restructure our everyday

understanding of the world. The first generation neo-Vygotskians elaborated Vygotsky's notion of scientific knowledge with the idea that a concept has two integral parts; content and procedural knowledge and that'... theoretical thought has its own particular *content,* which is distinct from the content of empirical thought ...' (Davydov, 1990: 120). The next section discusses how Vygotsky's and the first generation of neo-Vygotskians' idea of school knowledge, i.e. the academic concepts in school subjects such as mathematics, the social and the natural sciences[36], changed with the second generation neo-Vygotskians' notion of context.

2.4.2. Second generation neo-Vygotskians

This section outlines the current neo-Vygotskian perspective on 'school knowledge' and 'school science' before explaining Hedegaard's (2002) differentiation of school knowledge and Morais et al's (2004) notion of primary school science. Fleer's ideas about preschool science follow and provide insights into what constitutes science for six-year-olds who are developmentally and pedagogically in transition between two schooling stages (2010, 2009, 2005).

2.4. 2.1. School knowledge

Vygotsky's idea that scientific knowledge is acquired only within the schooling domain introduced the idea of a specialised context of acquisition. The idea of context was taken up by the second generation neo-Vygotskians who currently understand school knowledge as sanctioned, selected knowledge framed by a particular context for the purpose of schooling children (Fleer, 2010; Morais et al, 2004; Hedegaard, 2002; Rogoff, 1990).

At this point the chapter digresses slightly to point out that although the discussions above give the impression that knowledge types exist in silos, they do not. Everyday and scientific concepts co-exist, constantly influence each other and each is part of a single development

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[35] According to Karpov (2005).

[36] Interestingly, Davydov's 2008 book on children's school knowledge refers to mathematics, language, history and art but not natural science.

process (Vygotsky, 1962). Although it was necessary to first separate the everyday from the scientific in order to establish a clear picture of the essential characteristics of scientific concepts, it is not possible to consider what constitutes school knowledge without considering everyday knowledge. 'Though scientific and spontaneous concepts develop in reverse directions, the two processes are closely connected ...In working its slow way upward, an everyday concept clears a path for the scientific concept and its downward development' (Vygotsky, 1962: 108-109). Daniels elaborates: 'As they meld with everyday referents, scientific concepts come to life and find a broad range of applications' (Daniels, 1996: 11). The neo-Vygotskians confirmed Vygotsky's ideas on the interdependence of everyday and scientific knowledge. Although Davydov argued for theoretical and not empirical knowledge[37] to be taught at schools (Hedegaard, 2002), he acknowledged that in the schooling context the two forms of knowledge were not exclusive (Davydov, 1990). Hedegaard's (2002) 'double move' approach extends Vygotsky's idea of double stimulation to a pedagogical context which marries children's everyday knowledge to the learning of school knowledge.

2.4.2.2. School science

After the 'sputnik shock'[38] in the mid-twentieth century, the focus in the West turned to science and mathematics (Kozulin, 1990). The term 'science' became a general term commonly used by educators when referring collectively to the science related school subjects, biology, chemistry and physics. This study uses the term 'school science' to refer to aspects of scientific knowledge in the natural science domain that has been privileged and recontextualised for the specific purpose of transferring selected historically acquired knowledge to young children (Hedegaard, 2002).

2.4.2.2.1. *Hedegaard's notion of school knowledge*

Hedegaard's statement below echoes Vygotsky's idea that knowledge is socio-historical and points out the role of context in shaping knowledge:

> ...knowledge is determined by the problems and tasks that dominate a specific type of society. knowledge is not a mirror of the world but rather collective experiences that are created through solving pressing societal problems

[37] A type of everyday knowledge that is factually correct within a particular context e.g. it snows in winter.

[38] The Russians launching of a space rocket prior to the American launch signalled to the West that the Russians were ahead with regards to scientific knowledge and technology

> connected to a specific way of living. knowledge is connected to societal goals (Hedegaard, 2002: 26)[39].

Hedegaard expands on the notion of 'societal goals' by pointing out:

> In Western society, the dominating common goals are to maintain a standard of living based on technology, information, mediation, and democratic government (Ramirez & Boli, 1987b). Knowledge and thinking are controlled by these goals, and the educational system has the task of mediating these forms of knowledge and thinking methods to the next generation (Hedegaard, 2002: 26).

Hedegaard proposed that, because a knowledge form cannot be separated from the context that created that knowledge, there are specific mental processes related to particular forms of knowledge (Hedegaard, 2002). Three types are relevant to schoolchildren and each is accompanied by a distinct type of thinking. Empirical knowledge is acquired by paradigmatic thinking, narrative knowledge by narrative thinking, and theoretical knowledge by theoretical thinking (Hedegaard, 2002). Each is discussed in turn below.

Empirical knowledge and paradigmatic thinking

Hedegaard's notion of empirical knowledge and paradigmatic thinking addresses Kozulin's concern that 1) everyday knowledge may contain a degree of systemisation (1990), and 2) 'Theoretical views are organically infused with so-called empirical data' (1990: 90). Hedegaard explains: 'Empirical knowledge is knowledge about facts obtained through observation, description and quantification' (2002: 27). Although empirical knowledge can be compared to scientific knowledge in that it is constituted of organised factual concepts that seek to be an accurate representation of the world, empirical concepts belong to the realm of everyday knowledge because they are context dependent and do not require the identification of the essential attributes. The value of empirical knowledge is that it is '... a functional form of knowledge which does not necessarily disconnect the world into small units provided it is described in such a way that the context for the facts is explained' (Hedegaard, 2002: 21).The following example illustrates Hedegaard's notion of empirical knowledge and paradigmatic thinking in relation to six-year-olds, and demonstrates the difference between an empirical and a theoretical concept.

When six-year-olds learn about a*utumn* by observing the physical changes, comparing the

[39] Reproduced exactly as in the text. The absence of capital letter is a possible editing error

colour of leaves, looking for evidence of berries and fruits, recalling what type of clothes they wore last year when the weather turned colder, measuring the temperature change and counting the number of rainy days, they are concerned with empirical concepts and paradigmatic thinking. As the children are not being schooled in the essential attributes that are integral to *autumn* they do not acquire *autumn* as a scientific concept i.e. *autumn* pertains to a time in the year when the earth tilts away from the sun and this precipitates changes in the weather which lead to changes in human activity, and the earth's flora and fauna. Hedegaard's concern is that, because empirical knowledge uses a self-discovery approach and is context-dependent, it is academically unreliable in terms of scientific knowledge. Hedegaard cautions:

> The students should learn that empirical knowledge, like all forms of knowledge, is a result of the condition from which it is created. They should learn that empirical knowledge is not universal, but has to be understood as part of a context (2002: 33).

Narrative knowledge and narrative thinking

Hedegaard acknowledged the influence of Bruner in developing her notion of narrative knowledge and narrative thinking. According to Hedegaard: 'Narrative knowledge is created through the use of fiction in situative context where meaning is constructed through a story' (Hedegaard, 2002: 28).The narrative mode creates a meaningful learning context because it is characterised by 'expressions of feelings and intentions', a 'coherent wholeness', relates to children's everyday lives, and makes use of a 'what if?' situation within a story to create meaning (Hedegaard, 2002: 28-29). The following example demonstrates the *pedagogical* value of narrative knowledge and thinking in terms of six-year-olds acquisition of school science concepts.

The teacher first tells the well–known story of 'The Three Little Pigs' to her class of six-year-olds. The teacher then extends the story by saying she has received a letter from the three pigs. The letter says (teacher reads the letter out aloud) that the three little pigs have all grown up and the house of bricks is too small for the three of them so they need to build another house. However, as they do not want to make the same mistakes, the three pigs have written a letter to the children asking their advice on what are the best materials for building a house. After a general discussion, the children participate in activities which test the properties of materials with regards to strength, durability and stability. Simple predictions are made, materials collected and tested, and conclusions drawn after which the children and teacher write a letter back to the three pigs telling them of their findings and advising them on the best materials to use for building a weather and predator-proof house. The value of narrative knowledge and thinking is that it recontextualises the scientific and makes it meaningful to young children.

Theoretical knowledge and theoretical thinking

Hedegaard (2002) acknowledges Davydov as the primary influence in her understanding of theoretical knowledge and theoretical thinking as a dialectical schooling approach in which everyday and scientific knowledge meet each other in a meaningful way. Hedegaard linked Davydov's notion of the 'germ cell', a core scientific concept related to a particular subject domain (Hedegaard, 2002), with the method of experimentation and in particular, the 'imagined experimentation' and the 'what if?' narrative mode. According to Hedegaard, 'Theoretical knowledge can be conceptualised as 'symbolic tools' in the form of theories or models of subject-matter areas that can be used to understand and explain events and situations in (concrete life activities) and to organise action' (Hedegaard, 2002: 30). Hedegaard's idea appears to refer back, in part, to Vygotsky's original idea that scientific concepts served as semiotic tools in the acquisition of knowledge.

The following example illustrates Hedegaard's notion of theoretical knowledge and theoretical thinking in terms of six-year-olds. The teacher introduces six-year-olds to the scientific idea that 'All living things require water' i.e. a 'germ cell' concept, in Davydov's view. The teacher then asks the question 'What if there was no water in the world, what would happen to living things?' After discussing the possibilities the teacher and children participate in an experiment which begins with the question: 'What would happen if we plant some seeds and only give half of the seeds water?' Over a number of weeks the children observe the seeds and draw conclusions from their observations in relation to 'All living things require water'. The germ cell idea can also be extended to problem solving human concerns e.g. 'What can people do to save water?' Hedegaard cautions that theoretical knowledge should not be confused with abstract knowledge. Hedegaard's notion of theoretical knowledge is a combination of '... the general core aspect of a subject-matter area with a variety of concrete examples' (Hedegaard, 2002: 12)[40].

Morais, Neves and Pires' notion of primary school science

Morais, Neves and Pires (2004) view primary school science as'... pedagogical practices involving high levels of conceptual demand when they [the teachers] promote learning processes based on conceptualising and applying knowledge and developing of competences with investigative potential, such as in problem solving'(my insert, Morais, Neves & Pires, 2004: 2). Morais et al's understanding of school science confirms that 1) school science pertains to scientific knowledge, 2) school science is structured as two parts i.e. content and mental procedures and, 3) scientific concepts are acquired through schooling and the application of higher order thinking skills. This notion of school science is also applicable to subjects such as history, geography and mathematics.

2.4.2.2.2. *Fleer's notion of preschool science*

Marilyn Fleer's view of preschool science as '... schooled concepts learned through Western science education' (2009: 282) is based on the work of Vygotsky and employs, in particular, the ideas of Hedegaard (Fleer, 2010). Fleer explains below the difference between an everyday and scientific concept, and why she advocates the early learning of authentic, i.e. scientifically acceptable, concepts:

> At the everyday level, concepts are learned as a result of interacting directly with the world – developing intuitive understandings of how to do things, such as closing doors when it is cold, or opening windows when it is hot. Children put on jumpers when they feel cold, and will tell you that the jumper will keep them warm. These are important everyday concepts. But children may not know the science behind these actions. They may not know the scientific concept of insulation. However, everyday concepts cannot be easily transferred to other contexts. For example, knowing that a jumper helps you keep warm may not be useful if you are learning to surf. How do you keep warm in the water? But knowing about insulation will help you ask for and understand how a wet suit works. Knowing only about everyday conceptions limits children's thinking to embedded contexts and reduces their opportunities to apply concepts in new situations (Fleer, 2009: 283).

[40] Karpov (2005) and Davydov's (2008, 1990) use of 'theoretical knowledge' pertains to 'scientific knowledge' and therefore differs from Hedegaard's term.

2.5. SUMMARISING A NEO-VYGOTSKIAN APPROACH TO KNOWLEDGE AND SCHOOL SCIENCE

The essential neo-Vygotskian ideas on knowledge discussed above are compiled into a list of ‘principles’ below. The list has three purposes. The list summarises the findings of this chapter, provides a concise description of a neo-Vygotskian approach to knowledge, and informs the creation of a conceptual framework that theorises what constitutes school science knowledge for six-year-olds.

1. A concept is a unit of knowledge. A knowledge concept is constituted as two parts: 1) content, and 2) the mental processes and activities related to internalising the content
2. Each concept has content and scope. The content of a concept refers to the attributes which are particular to that concept and determines whether a concept is a scientific or an everyday concept. The scope of a concept refers to the narrowing or broadening of a concept’s attributes which defines the concept content in a specific manner.
3. Scientific concepts, also known as mature or authentic concepts, are units of scientific knowledge. The following features distinguish a scientific concept from an everyday concept:

   - a scientific concept contains the essential attributes integral to the concept
   - a scientific concept is positioned hierarchically within an ordered system of scientific knowledge
   - a scientific concept is mediated by other scientific concepts
   - a scientific concept can be transferred and applied to other contexts
   - a scientific concept employs specialised language terms.

4. Although everyday and scientific knowledge appear to be opposites, they are closely related and interdependent. Everyday knowledge is essential to the acquisition of scientific concepts, which once acquired, change existing everyday concepts and thinking.
5. The acquisition of a scientific concept involves generalisation and classification which requires mental tools i.e. language, logical memory, self-regulation, and higher order

thinking skills e.g. the ability to reflect, predict, imagine, and analyse. Schooling is essential to the acquisition of a scientific concept.

6. School knowledge refers to selected and officially sanctioned scientific concepts recontextualised for the purpose of teaching children about the world. School knowledge is differentiated into empirical and scientific concepts depending on the context of acquisition. The primary feature that distinguishes empirical concepts from scientific concepts is that the former is context-dependent whereas scientific concepts are universally applicable and transferable across contexts. School knowledge is taught to children in subjects such as school science (physics, biology, chemistry, natural science), school mathematics (calculus, algebra, geometry), and the social sciences (history and geography).

The final section of this chapter considers the first three ‘principles’ in relation to six-year-olds before creating the conceptual framework. The fourth, fifth, and sixth ‘principles’ which pertain primarily to the *acquisition* of school science are considered only in relation to understanding what constitutes school science *knowledge* for six-year-olds. This study’s focus is on knowledge (curriculum) rather than on acquisition (learning and teaching).

2.6. A NEO-VYGOTSKIAN APPROACH: SCHOOL SCIENCE FOR SIX-YEAR-OLDS

This second part of Chapter 2 narrows down the discussion on school science knowledge to forms of knowledge accessible to six-year-olds. The section begins by outlining the acquisition and development of knowledge in young children. The second section considers the notion of a scientific knowledge continuum that begins with simple scientific concepts. The third section explains the differentiation of school science for six-year-olds in relation to the context of acquisition. The final section conceptualises a neo-Vygotskian approach to school science for six-year-olds.

2.6.1. Understanding knowledge development in young children

3 Concept development is a three stage structure i.e. congeries, complexes and concepts according to Vygotsky (1962). Congeries pertain to heaps of unrelated information. Complexes establish relationships between individual elements. Concepts can be differentiated into three types: ‘true’ concepts which are units of context independent academic knowledge, pseudoconcepts which mimic scientific concepts, and potential concepts which have their roots in practical problem solving or in action.

In very young children concept development begins with congeries which are acquired firstly through trial and error. The organising of objects is done in an unrelated manner and is based solely on the child's visual perceptions using previously acquired information. The second stage is the development of complexes. The child's thinking is more organised and objective but her ideas are still based on the concrete and visible rather than on the abstract, essential and logical elements. The main function of complex thinking in young children is to establish bonds and relationships and to single out individual elements from their embedded totality in preparation for the third stage of development. Vygotsky identified five different types of complexes (Vygotsky, 1962).

The first four complexes pertain to early development. The fifth complex, pseudoconcepts, is relevant to understanding six-year-olds and science knowledge. Pseudoconcepts are 'the bridge' from everyday to scientific concept formation (Vygotsky, 1962). The attributes of a pseudoconcept resemble a scientific concept but the essential attributes are unstable because 'A complex does not rise above its elements as does a concept[41]; it merges with the concrete objects that compose it' (Vygotsky, 1962: 65). According to Vygotsky most six-year-olds think in pseudoconcepts:

> Pseudoconcepts predominate over all other complexes in the preschool[42] child's thinking for the simple reason that in real life *complexes corresponding to word meanings are not spontaneously developed by the child: The lines along which a complex develops are predetermined by the meaning a given word already has in the language of adults* (Vygotsky, 1962: 67).

Scholars in the 21st century now view children as more competent and capable than envisaged by Vygotsky (Winkler-Rhoades, Carey, & Spelke, 2013; Haynes & Murris, 2012; Egan, 2002). This does not mean that six-year-olds can think in terms of Vygotsky's 'true' concepts nor are they capable of formal operational thinking. Six-year-olds can however acquire scientific concepts as defined by Fleer and Hedegaard i.e. schooled concepts.

The third stage is concept development. According to Vygotsky, concept development begins when '… the grouping of maximum similarity is superseded by grouping on the basis of a single attribute: e.g. "only round objects or only flat ones"' (Vygotsky, 1962: 77). Vygotsky identified the first type of concepts as 'potential concepts'[43] which are formed '…

[41] Vygotsky is referring here to a scientific concept
[42] In Vygotsky's time of writing children in Russia started school when they were seven years old.

on the basis of similar impressions in the first case and of similar function in the second' (Vygotsky, 1962: 78). The lack of stability is one of the primary differences between a complex and a concept for 'In potential concepts proper, a trait once abstracted is not easily lost again among the other traits' (Vygotsky, 1962: 78). For example: when a six-year-old learns that she can identify a fruit from a vegetable by looking for a seed, or seeds, inside a juicy or fibrous skin[44], this idea remains stable for it is based on the 'abstracted traits' of the concept.

According to Vygotsky it is the process of acquisition that determines whether an idea is formed as a complex or a concept[45]. For example: a six-year-old may be able to count from one to a hundred, but this does not mean he/she has developed the concept of number for, when shown a handful of five counters, he/she is not able to tell you how many. Authentic concept development in young children is evident however when six-year-olds are playing an imaginary shopping game and the 'shopkeeper' recognises the label '5' on the box, tells the 'buyer' that the item costs 'five rand' and the child counts out five counters and hands it over to the 'shopkeeper'.

There is a clear relation between Vygotsky's ideas above and the neo-Vygotskians' understanding of knowledge development. Davydov's statement: 'The transition from perception through conception to concept is a transition from sensory, the concrete, and the individual to the mental, the abstract, and the general' (Davydov, 1990: 22), confirms Vygotsky's idea that every concept is represented in a certain way within a certain sequence. The neo-Vygotskians elaborated on Vygotsky's idea that concept formation does not operate in silos. Although mental development in babies and young children generally follows the path of perception, conception and concept formation, perception remains fundamental because sensorially perceived objects and phenomena are the basis of

[48] Vygotsky's 'potential concept' differs from this study's notion of a 'potential scientific concept' which pertains to pedagogical potential in terms of the likelihood that the educator will be prompted to translate an

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[43] Vygotsky's 'potential concept' differs from this study's notion of a 'potential scientific concept' which pertains to pedagogical potential in terms of the likelihood that the educator will be prompted to translate an everyday representation into a simple scientific concept

[44] Defined by the science dictionary as 'the fully matured ovary of a seed plant, including the seed or seeds, connecting tissues, and any covering' (Morris, 1992: 888).

[45] This idea precedes the neo-Vygotskian idea of procedural knowledge as integral to the notion of a scientific concept

everyday representation into a simple scientific concept.

generalisation in concept formation (Davydov, 1990). Perception, initially viewed as a simple process pertaining to young children, was redefined by Luria: '... perception is a complex process involving complex orientating behaviour, a probabilistic structure, an analysis and synthesis of perceived features, and a decision-making process' (1976: 20). Kozulin pointed out that conception also persists for the formation of complexes is not only related to immature concept development; adults use it in their everyday lives when they group together household items like cutlery and crockery, or calling a family by one name e.g. the Joneses (Kozulin, 1990). Davydov confirmed that most six-year-olds are at the conception stage of development (Davydov, 1990). In the next three sections this study extends Vygotsky's and the neo-Vygotskians' notions on knowledge and the development of young children to the idea of a simple scientific concept as school science knowledge for six-year-olds.

2.6.1. The notion of a simple scientific concept as an entry level concept on the scientific knowledge continuum

This notion is based on three ideas: 1) every concept has content and scope (Davydov, 2008, 1990), 2) Vygotsky's (1962) notion of a mature concept, and 3) 'Science aspires to pass from the description of phenomena to the disclosure of essence as their internal bond' (Davydov, 1990: 36). Firstly, the idea that a concept is defined in terms of its scope and content establishes that the position of a concept is always in relation to other concepts i.e. the notion of a knowledge continuum. Secondly, Vygotsky's notions on concept maturity and incompletion suggest that scientific knowledge can be differentiated into a range of concepts in terms of complexity. Thirdly, Davydov's understanding of 'science' points to the identification of the essential attributes of a concept.

The first two ideas together suggest the notion of a knowledge continuum which begins with simple[46] scientific concepts i.e. a basic scientific definition or 'germ cell' that is limited in scope, and 'ends'[47] in mature concepts i.e. scientific ideas involving complex content defining and delimitation of scope. The following table illustrates the notion of a scientific

[46] Egan (2002) points out the limitations in the use of metaphors as a device that humans use to explain difficult or unknown concepts. The term 'simple science' is used instead of 'emergent science' in order to put forward a fresh idea and escape the biological metaphor that is associated with child development.
[47] Because new scientific discoveries are constant, understanding the world never ends.

continuum as described in the statement above.

Table 2.1: The notion of a scientific knowledge continuum[48]

Simple scientific concepts = basic defining of content + limited scope	More complex scientific concepts →	Mature scientific concepts complex defining of content + delimitation of scope
Simple scientific definitions or 'germ cells' descriptions and relationships. Application of related mental processes and procedures in relation to the content of the simple definition or germ cell.	Understanding more complex scientific concepts and relationships e.g. weight and size inform mass. Application of more sophisticated mental processes and procedures in relation to content.	Understanding highly complex scientific concepts and relationships. Application of sophisticated mental processes and procedures to new contexts.
Examples of simple scientific concepts and germ cells: Weight Size Velocity Force Temperature The basic properties of materials Basic attributes of dead and living things The human body: simple functions and basic part Basic attributes of plants and animals Basic requirements of plants and animals	Examples of more complex scientific concepts: Gravity Mass Force Density Speed of light Photosynthesis Fossils Plant diversity Cellular structure	Examples of complex scientific concepts: $E = mc^2$ DNA String theory

Although each concept above is mediated in some way by a previous concept, the scientific knowledge continuum is not a linear structure; it is visualised as a spiralling web of scientific concepts. The term 'spiral' represents scientific knowledge as an expanding, increasingly complex, relational entity in relation to Vygotsky's idea that 'Development, as often happens, proceeds here not in a circle but in a spiral, passing through the same point at

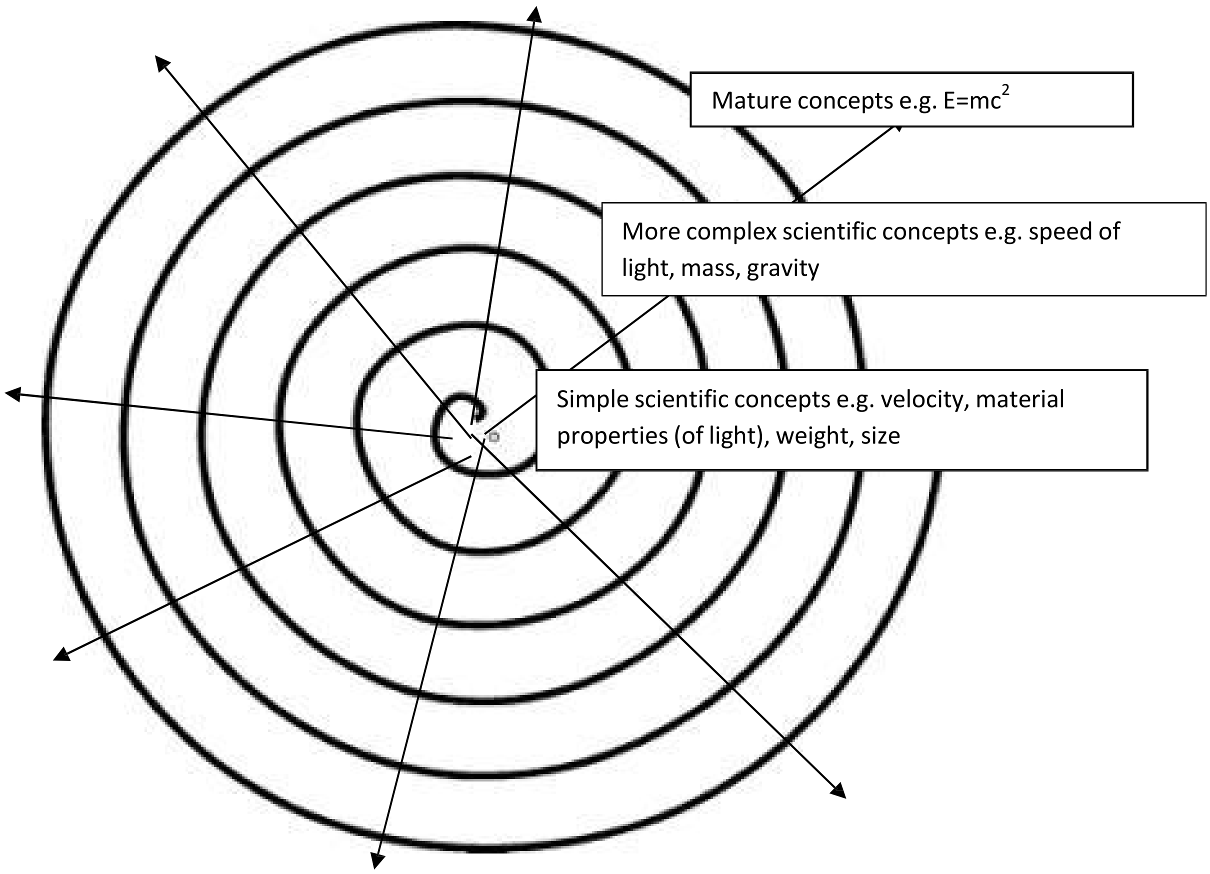
48 The table is simplistic in scientific terms; its purpose is to simply clarify the notion of an extended scientific continuum

each new revolution while advancing to a higher level' (Vygotsky, 1978: 56). The term 'web' represents the neo-Vygotskian idea that each scientific concept is mediated by other scientific concepts, and is hierarchically positioned in relation to one another. Like the strands of a silken web that vibrate in response to one strand being triggered providing the spider with relevant information, simple scientific concepts are related to and inform complex concepts[49].

Figure 1 illustrates the notion of a scientific continuum as a spiralling web of scientific knowledge. Simple scientific concepts are positioned at the beginning of the continuum. Simple scientific concepts, in turn, underpin more complex concepts e.g. 'speed of light', positioned further along the web. More complex concepts inform mature concepts such as '$E = mc^2$'.

[49] Bruner's statement '…that, unless certain basic skills are mastered, later, more elaborate ones become increasingly out of reach' (Bruner, 1968: 29) supports the idea that entry level concepts underpin more complex concepts.

Figure1: Visualising the notion of a scientific knowledge continuum



2.6.2. The differentiation of school science for six-year-olds

Although the notion of an expanded continuum of scientific knowledge establishes science for six-year-olds as simple scientific concepts, Hedegaard's (2002) idea that school knowledge is differentiated because it is dependent on the context of acquisition, raises the notion of more than one type of school science for six-year-olds. This notion[50], and Davydov's idea of a scientific concept being described in terms of its 'essence' (Davydov, 1990) like the previous example 'Autumn', is illustrated in the following example[51].

On Day 1 of teaching the Grade R workbook theme 'Day and Night' (DBE, 2012a) the Grade R educator discusses with six-year-olds what clothes they wear and what activities they do in the day and at night. The children dress up and

[50] The example also demonstrates Hedegaard's idea that everyday knowledge makes scientific meaningful (2002).
[51] Observed by the researcher in 2012 in a Grade R classroom.

dramatize daytime activities e.g. going to the beach, and night time activities e.g. having supper, bathing, watching TV and going to sleep. In this context of acquisition 'Day and Night' is an empirical concept for two reasons:

1) according to scientists a 'day' is 24 hours (Morris, 1992), and 2) the concept is context bound for in another place and time children may do different things. On Day 2 the educator changes the context of acquisition and discloses the 'essence' of the concept which results in simple scientific knowledge[52]. Firstly the educator provides a simple scientific definition of 'day' as a 24 hour period of time. Secondly, the educator darkens the classroom and fixes the position of a large torch (the sun) onto a rotating ball or globe (the earth) so that the six-year-olds can see and understand the relationship between the sun, the movement of the earth[53], and seasonal change. The description of the two days lifts out two ideas: The context of acquisition differentiates school science knowledge for six-year- olds into two types i.e. everyday (includes empirical) and scientific. A simple scientific concept cannot be understood in the absence of six-year-olds' everyday knowledge and experiences.

Although six-year-olds cannot understand what scientists understand about the solar system, this study has shown that six-year-olds can, in a particular context of acquisition, develop simple scientific concepts. This study's notion of simple scientific concepts differs from Vygotsky's idea of pseudoconcepts. Unlike pseudoconcept, simple scientific concepts will not change with the introduction of new concepts, simple scientific concepts are scientifically 'settled' and acceptable to most scientists even though they are couched in simple terms, and simple scientific concepts can be transferred across contexts and underpin more complex scientific concepts.

2.6.3. School science knowledge for six-year-olds: a neo-Vygotskian conceptual framework

This final section draws on the ideas generated by the literature review in order to create a conceptual framework that theorises the neo-Vygotskians' understanding of school science

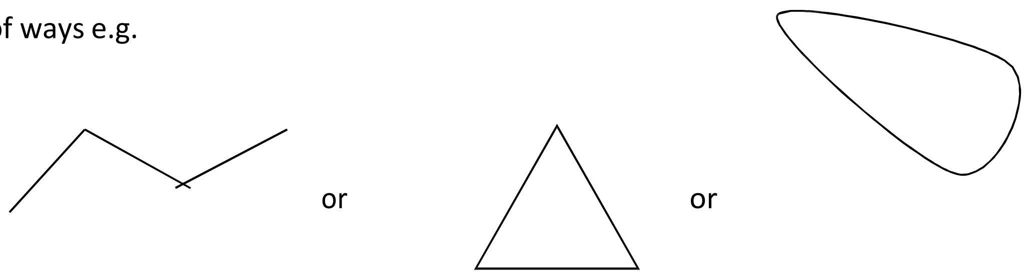
[52] In terms of the neo-Vygotskian approach the educator would switch Day 1 and Day 2 so that the abstract and theoretically (Day 2) could precede the concrete and empirical (Day 1).

[53] The ball or globe is stuck with small pictures of each child. The teacher slowly turns the globe so children can see the pattern of light and dark in relation to their photo.

knowledge for six-year-olds as simple scientific concepts[54]. Although this chapter established two types of school science concepts for six-year-olds, the conceptual framework reflects the neo-Vygotskian approach by focusing on the scientific. Like Hedegaard,'... I agree with Davydov that theoretical[55] knowledge should be the frame for empirical knowledge as well as other forms of knowledge' (Hedegaard, 2002: 42). The main ideas that inform the conceptual framework are summarised into the following three points:

1) No matter how simple, a scientific concept is defined by a particular set of criteria that scientists have generally agreed upon. This agreement usually takes the form of a scientific definition as for example in the *Academic Press Dictionary of Science and Technology* (Morris, 1992). A scientific definition makes visible the key content knowledge features i.e. two or more context-independent essential attributes and scientific terms that uniquely define it from all other concepts. Simple scientific definitions make scientific knowledge accessible to six-year-olds because they are a bridge between the everyday world of young children and the world of science.

2) Essential attributes are core to the idea of a scientific concept. In the absence of essential attributes content knowledge does not exist, and in the absence of content knowledge, procedural knowledge, i.e. the related internalising processes, does not exist. A simple scientific concept contains two or more essential attributes. One essential attribute does not sufficiently define a scientific concept because it offers ambiguity e.g. a *triangle* defined only by 'three sides' can be interpreted in a number of ways e.g.



Two or more essential attributes, on the other hand, define a scientific concept precisely e.g. 'A *triangle* has three straight sides and three angles' is a complete and scientifically

[54] The conceptual framework pertains only to knowledge and does not reflect the learning and teaching of school science to six-year-olds.
[55] Used by Davydov in place of 'scientific'

acceptable definition. Adding or delimiting non-essential attributes such as size, length, height, colour, and position in space, extend or limit the scope of a concept but do not change the 'essence' of the concept.

3) Procedural knowledge is a particular process of acquisition which 'operates' with the essential attributes of the concept by classifying, engaging the law of equivalence, and targeting the child's zone of proximal development (ZPD). Classifying is a basic learning process. Vygotsky's law of equivalence which governs all concepts posits that a concept is known by its relationship to other concepts (Vygotsky, 1962). The ZPD is the learning space between what a child already knows and what he/she can potentially learn with the support of a knowledgeable adult or older child (Vygotsky, 1962). If the internalising activities are simple and familiar, a child will not acquire new science knowledge because the law of equivalence does not engage and the child's ZPD is not targeted.

<u>Text summary 1</u>: A neo-Vygotskian conceptual framework: simple scientific concepts as school science knowledge for six-year-olds

1. A simple scientific concept is defined by the following criteria:

   - A simple scientific concept has two or more essential attributes
   - Although a simple scientific concept is couched in language that is likely to be understood by six-year-olds, simple scientific concepts also employ specialised terms that are universally understood to represent the same thing
   - A simple scientific concept is part of an ordered, hierarchical knowledge system
   - A simple scientific concept is transferable across contexts

2. Each simple scientific concept has two integral parts:

   - Content knowledge
   - Procedural knowledge i.e. the mental processes and activities related to the acquisition of the content knowledge.

3. A simple scientific concept underpins more complex scientific concepts.

2.7. CONCLUSION

This literature review on human knowledge spanned Vygotsky's early 20th century theories on everyday and scientific knowledge and the second generation neo-Vygotskians' understanding of school science in the 21st century. The review informed this study's idea of a simple scientific concept by marrying an understanding that young children can think abstractly (Fleer, 2010) with the idea that scientific knowledge and school science have distinct features (Vygotsky, 1962, 1978; Luria, 1976; Kozulin, 1990; Davydov, 1990, 2008; Morais et al, 2004; Hedegaard, 2002). Two novel contributions emerged. The first is the notion of a scientific knowledge continuum that begins with simple scientific concepts. The second is a conceptual framework (Text Summary 1) which makes the neo-Vygotskian idea of a simple scientific concept as a unit of school knowledge for six-year-olds explicit. The conceptual framework is taken forward to the next chapter where it is central to the analysis design

CHAPTER 3: Design

And what, Socrates, is the food of the soul? Surely, I said, knowledge is the food of the soul (Plato)[56]

3.1. INTRODUCTION

The purpose of this study is to analyse the current Grade R science curriculum in order to determine, from a neo-Vygotskian perspective, 'How does the South African Grade R curriculum represent school science knowledge for six–year-olds?' To this end, the task of this chapter is to describe the methodological approach adopted to generate an analytical description of the Grade R science curriculum. This chapter therefore:

- Identifies the data sources.
- Explains how data segments were selected, categorised and coded.
- Explains how the analytic framework was developed by translating the conceptual framework, created in the previous chapter, into analytic indicators
- Defines types of science concepts referred to in the analytic framework
- Presents a rating scale for measuring the Grade R science curriculum concepts
- Presents benchmark criteria for determining the type of knowledge concepts

I will also clarify the nature of the indicators used and provide two examples that illustrate the process of bringing the analytic indicators to bear on a data segment. A discussion of the study's concerns with regards to validity, reliability and ethics completes the chapter.

3.2. DATA

3.2.1. Data sources

The past twenty years has seen three significant changes to the South African curriculum. The National Curriculum Statement (NCS 2005[57]) was introduced in 1998 shortly after the democratic elections in 1994. A revision of the first national curriculum (NCS 2005) led to the introduction of the Revised National Curriculum Statement (RNCS, 2002) in 2004. The RNCS was replaced by the Curriculum Assessment Policy Statement (CAPS) in 2011[58]. As

[56] http://www.brainyquote.com/quotes/quotes/p/plato399001.html#u1AGUog36Hll2xEv.99
[57] Name of the curriculum not the date of publication
[58] Information available on www. westerncape.gov.za [2013, December 4]

each was developed in relation to the other and has its own pedagogical merit, three criteria determined the selection of texts as data sources for this study:

1) The text is sanctioned by the South African Department of Education and is part of the current public schools' curriculum.
2) The text pertains to the teaching and learning of Grade R school science.
3) The text is readily available and was likely to be used by Grade R educators in 2013 for the planning of science lessons.

The application of these criteria identified the following data sources for analysis:

- The *National Curriculum Statement (NCS), Curriculum and Assessment Policy Statement, Foundation Phase Grades R-3, English*[59] *Life Skills* was identified as the primary data source (DBE, 2011a). Commonly known as CAPS, this current officially sanctioned text contains four study areas of which one, *Beginning Knowledge* pertains to science[60] as 'The content and concepts of Beginning Knowledge have been drawn from Social Sciences (History and Geography); Natural Sciences and Technology' (DBE, 2011a: 8).
- Four Grade R learner workbooks (DBE, 2012a; DBE, 2012b; DBE, 2012c; DBE, 2012d) were issued nationally to Grade R children in 2013 by the Department of Basic Education. These workbooks are the only officially sanctioned Grade R resources that support the current CAPS (2011) curriculum.
- There were two reasons for including the current CAPS science curriculum for children between ten and twelve years old i.e. *The National Curriculum Statement (NCS), Curriculum and Assessment Policy Statement, Intermediate Phase Grades 4 – 6: Natural Sciences and Technology* (DBE, 2011b) as a data source. Firstly, in order to describe the Grade R science concepts in terms of their relations to other more complex concepts taught later (AI: 3) the study needed to look beyond the Foundation Phase. Secondly, the Grade R – 3 science study area 'Beginning Knowledge' (DBE, 2011a) is replaced in Grade 4 by the subject *Natural Sciences and Technology* (DBE, 2011b). As the

[59] Refers to the language in which the document is written.
[60] The other three study areas are Personal and Social Well-being, Creative Arts, and Physical Education.

Intermediate Phase Grade 4 – 6 science concepts are represented differently from the Foundation Phase Grade R - 3 science concepts, this document offered further insight into the curriculum's representation of science knowledge concepts across the grades.

The application of the three criteria excluded the CAPS (2011) language and mathematics curriculum texts, the *Grade R Laying Solid Foundations for Learning* (LSFL) resource kit, and the RNCS (2002) documents as data sources for this study. The Grade R CAPS (2011) language and mathematics texts are excluded because this study pertains to science. The RNCS (2002), NCS (2005) and the LFSL kit are not part of the current CAPS (2011) curriculum and therefore are not likely to be used in planning school science.

Scientists function at the 'unsettled' edge of knowledge production in which it is difficult to provide definitions of objects and phenomena[61]. School science is, however, concerned with the acquisition of 'settled' i.e. generally agreed upon, science knowledge. After much consideration I selected the *Academic Press Dictionary of Science and Technology* (Morris, 1992) as a source of scientific definitions that could verify scientific concepts and that would function as a bridge between the world of scientists and the world of young children. Although Morris (1992) is over 20 years old Morris proved to be a consistent and reliable source of simple scientific definitions for this study[62]. Dr Laugsch's approval as a scientist[63] and Vhurumuku's idea that 'Scientific knowledge may be changed or added to, but the body of knowledge is reliable in that most of it will not change much in the future' (Ramnarain, 2010: 29) were reassuring in terms of selecting Morris (1992) as a source of scientific definitions. Other more recent dictionaries were rejected for the following reasons. A more recently published Penguin *Dictionary of Science* (Clugston,2009) provided no definitions for eight of the 24 topic concepts i.e. 'Weather' (C14), 'Fruit' (C8), 'Vegetables' (C9), 'Colour' (C3), 'Spring' (C12), 'Summer' (C2), 'Autumn' (C5), and 'Winter' (C6), and two of the definitions were too technical for this study i.e. 'Water' (C7) and Aves[64] (C13). School science dictionaries, the Concise Oxford Dictionary (2010), on-line resources such as

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[61] Confirmed in conversation by Dr John Bolton, a University of Cape Town scientist (2012)

[62] In my search for a suitable science dictionary I phoned Van Schaik, Juta, My Supplier, Oxford University Press, Caxton, consulted the UCT librarian Ingrid Thomson, and looked online at Google Scholar, Amazon.com and Kalahari.com (June 2013)

[63] Dr Rudiger Laugksch confirmed by email on the 5th August 2013 that '...- the science appropriate / relevant for 6-year olds will not have changed in 20 years, and so the use of the 1992 I don't regard as an issue'.

[64] Scientific name for 'birds'

http://www.britannica.com.ezproxy.uct.ac.za and http://www.merriam-webster.com/dictionary were not as concise and consistent as Morris (1992). Wikipedia at http://en.wikipedia.org is an open source text and its scientific reliability depends on its contributors. A list of the simple scientific definitions (Morris, 1992) employed in this study is included in Appendix 1.

3.2.2. Data segments: selecting, categorising and coding

A reading of the data sources (DBE, 2012a; DBE, 2012b; DBE, 2012c; DBE, 2012d; DBE, 2011b) with the four criteria in mind refined the data selection to three types of data segments i.e. primary, supporting and related.

3.2.2.1. Primary data

Twenty two data segments were selected from the Grade R science study area *Beginning Knowledge* (DBE, 2011a: 15-21) as the primary data for analysis because they related to the data source criteria i.e. 1) 'part of the current public schools' curriculum', 2) 'pertains to the teaching and learning of the natural sciences to six-year-olds', and 3) 'readily available and most likely to be used by Grade R educators for the planning of science'. As *Beginning Knowledge* is integrated with *Personal and Social Well-being* (DBE, 2011a: 8), the remaining fourteen recommended Grade R knowledge topics (DBE, 2011a: 15–21) were ignored as their content did not relate to the natural sciences[65]. The following description of a science topic, which is reproduced exactly here as in the CAPS Grade R curriculum, is one example of the 22 primary data segments:

> Topic: Vegetables – 2 hours
>
> Different types of vegetables Tastes
> and textures of vegetables Where
> vegetables come from
> Colours and shapes of vegetables (DBE, 2011a: 20).

The 22 data segments were first categorised according to science disciplines (Morris, 1992) i.e. the fourteen topic concepts representing living things were grouped under Biology; the remaining seven topic concepts which represented matter, energy, motion and force were grouped under Physics. The topic concepts were then clustered together according to the

[65] The 14 topics that have been excluded from the analysis are:
Term 1: 'Me', 'At School', 'In the classroom', and ' Festivals and special days' Term 2: 'Home', 'Safety', My Family', and 'Festivals and special days'
Term 3: 'Jobs people do', 'Healthy Environment', and 'Festivals and special days'

science concept they represented and coded accordingly e.g. the topic concepts 'My Body' (C1), 'Sound' (C1.1), 'Sight' (C1.2), 'Touch' (C1.3), and 'Taste and smell' (C1.4) were clustered together and coded in relation to one another as the five topics together represent the science concept *human body*[66]. As C1.1, C1.2, C1.3 and C1.4 pertain to the human senses they are part of 'My Body' (C1). The topics 'Wool Farming' (C9) and 'Dairy Farming' (C10) were grouped together as representing *domesticated animal.* 'Dinosaurs' (C15) as once living but now extinct *reptiles* was grouped with 'Reptiles' (C14). Although 'Wild Animal', and 'Finding out about one wild animal' are listed in the Grade R curriculum as two separate topics (DBE 2011a: 21) they have been coded as one data segment (C16) as both topics are concerned with the same concept i.e. *wild animals*. Appendix 3 contains the 22 data segments reproduced exactly as in the curriculum texts.

Text summary 2 on page 62 summarises the clustering, categorisation and coding of the primary data for analysis. Column 1 lists the natural science discipline areas represented in the Grade R curriculum, Column 2 lists the selected Grade R science topics and groups them according to Column 1. Column 3 identifies the concept underpinning each science topic or topics. Thus the 22 curriculum topics are reduced to fourteen scientific concepts, as shown in the table. Table 3.1 also sets out the order in which the data segments were analysed in the next chapter.

[66] To avoid repetition in the analysis, the study uses italics to indicate that a word represents a concept e.g. *domesticated animal.* When a topic title represents the concept, e.g. 'Birds', the term' topic concept' precedes the title.

Table 3.1: Primary data for analysis: selection, categorisation and coding

DISCIPLINE AREA OF NATURAL SCIENCE	GRADE R SCIENCE TOPICS	RELATED SCIENTIFIC CONCEPT
The following concepts were identified in the Grade R science curriculum topics and workbook activities		
Life Sciences Biology (the study of living organisms)	My Body (C1) Sound(C1.1) Sight(C1.2) Touch(C1.3) Taste and smell(C1.4)	*Human body*
Zoology: 'the study of animals' (Morris, 1992: 2397).	Dairy farming (C10) Wool farming (C11)	*Domesticated animals* (*Animal*)
	Wild Animals& The study of one wild animal (C16)	*Wild animals* (*Animal*)
	Birds (C13)	*Birds* (*Animal*)
	Reptiles (C14) Dinosaurs (C15)	*Reptiles* (*Animal*)
Botany: 'the branch of biology that is concerned with the study of plants and plants life' (Morris, 1992: 295).	Fruit (C8)	*Fruit*
	Vegetables (C9)	*Vegetables*
Physical Sciences Physics: 'the scientific study of matter, energy, motion and force (Morris, 1992: 1643).	Shapes and colours around us (C3)	*Shape* *Colour*
	Water (C7)	*Water*
	Days of the week (C17)	*Time*
	Transport (18)	*Transport*
Earth Sciences Geology: 'the study of the earth in terms of its development as a planet since its origin, including the history of its life forms, the materials of which it is made, the processes that affect these materials, and the products that are formed of them' (Morris, 1992: 923).	Weather (C4)	*Weather*
	Summer(C2) Autumn (C5) Winter (C6) Spring(C12)	*Seasons: Summer, Autumn, Winter and Spring*

Appendices 1 and 3 contain a list of definitions from Morris (1990) and the primary data.

3.2.2.2. Supporting data

The four Grade R workbooks (DBE, 2012a; DBE, 2012b; DBE, 2012c; DBE, 2012d) function as supporting data sources because they 1) extrapolate the 22 primary data segments descriptions which are each limited to between two and six sentences, and 2) function as the internalising agents for the primary data segments. The Grade R workbooks are divided into themes which correlate to the topics e.g. Workbook 3 contains a section titled 'Things that go' (DBE, 2012c: 2-11) which extrapolates and internalises the topic concept 'Transport' (C18). Some of the topics are integrated into other themes e.g. there is no related workbook section for the topic concept 'Birds' (C13) but images of birds appear in 'Farm animals', 'Sea animal', 'Wild animals'(DBE, 2012c) and 'Creatures' (DBE, 2012d).

3.2.2.3. Related data

The third set of data relates to the criteria i.e. 'relate to the higher grades with regards to progression and the intended development of science concepts'. When science is taught at school progression is advisable according to the neo-Vygotskians. According to the scientific knowledge continuum more complex concepts precede simple concepts. An older child is therefore unlikely to acquire the concept *speed of light* without having first internalized simpler concepts such as *speed* and the *material properties of light*. I identified this type of data once the analytic framework was created. Bringing AI: 3 to bear required more complex science curriculum data that is underpinned by the primary data. This relational data was selected from the Grade 1- 3 *Beginning Knowledge* study areas in the CAPS *Foundation Phase Life Skills curriculum* (DBE, 2011a: 30-67) and the *Intermediate Phase Science and Technology curriculum* (DBE, 2011b).

The data selection, categorisation and coding of the supporting and relational data segments required a different approach. Unlike the primary data segments 'The workbooks integrate the teaching of literacy, numeracy and life skills across 20 themes ...' (front cover of DBE 2012a) and are mostly comprised of images. The relational data is extensive as it ranges between two school phases (DBE, 2011a; DBE, 2011b). In place of a data list describing each datum segment (as for the primary data) the data segments from the Grade 1- 6 curricula (DBE, 2011a; DBE, 2011b) are either quoted verbatim or referenced as a page number. The rest of the data is accessible in its original form. The electronic (CD) version of this study contains all the data sources, in full. As the data sources are all official documents they can be accessed from the official Department of Basic Education (DBE) websites, www.education.gov.za, or www.thutong.doe.gov.za,

3.3. DEVELOPING THE ANALYTIC INDICATORS

The conceptual framework, which was presented in the previous chapter, is central to the approach to analysis. The next three sections describes the tasks undertaken in preparation for the analysis of the 22 primary data segments in the next chapter i.e.1) creating analytic indicators that will be brought to bear on the data segments, 2) describing the knowledge types pertaining to the analysis, and 3) creating a rating scale and benchmark criteria.

3.3.1. Developing analytic indicators

The analytic indicators for this study were created by translating the conceptual framework into three questions i.e.:

Text summary 2: The analytic indicators (AI)

AI: 1.How does the Grade R curriculum represent the defining features of a science knowledge concept with regards to:

- *Its attributes*
- *The degree of specialisation of language*
- *Its relation to other concepts*
- *Its relation to context?*

AI: 2.How does the Grade R science curriculum represent the structure of a science knowledge concept with regards to the relation between content and procedural knowledge?

AI: 3.How does the Grade R curriculum represent the science knowledge concepts with regards to the relation between simple and complex concepts?

Table 3.3 below explains the relation between the analytic indicators and the conceptual framework so that the reader has a clear idea of how the analytic indicators will function in the analysis:

Table 3.3: Clarifying the function of the analytic indicators

Analytic indicator (Text summary 2 p. 62)	Relation to conceptual framework (Text summary 1 p. 53)
AI: 1.How does the Grade R curriculum represent the defining features of a science knowledge concept with regards to:	
• *Its attributes*	Does the Grade R science curriculum represent the concept in terms of two or more characteristics that describe the unique 'essence' of the concept? A simple scientific definition contains the 'essence' of a science concept.
• *The degree of specialisation of language*	Does the Grade R science curriculum represent the concept in two or more scientific terms that are acceptable to most scientists? A science dictionary (Morris, 1992) determines scientific acceptability in this analysis i.e. if a term is represented in Morris (1992) then the term is considered as scientifically acceptable unless it is referenced as 'common' or 'general'.
• *Its relation to context*	Is the concept represented as context-independent and therefore applicable to other contexts? A concept's capacity to be transferred is directly related to the provision of two or more essential attributes and scientific terms
• *Its relation to other concepts*	Does the Grade R science curriculum represent the concept in terms of the scientific knowledge continuum which hierarchically orders and arranges concepts in relation to one another? Are the Grade R science topics also positioned logically in relation to one another in terms of time and event? The following diagram explains the four types of relations to other concepts:

Topic concept in relation to:

sequence	co-location	grouping	logistics
Is the topic concept positioned in relation to other topics in terms of progression? Example: a topic on the basic structure of a plant as a whole (root,	Is the topic concept positioned in relation to complementary topics in terms of conceptual relatedness? Example: the topics	Is the topic concept positioned in relation to other topics representing the same concept? Example: the topics representing the	Is the topic concept logically positioned in relation to time and event Example: 'Summer', 'Autumn', 'Winter' and 'Spring' are not

stem, leaves, flower, fruit) logically precedes 'Fruit' a topic concept which only considers one part of a plant.	representing the basic concepts *wild* and *domesticated* are logically positioned next to each other in the curriculum.	human senses i.e. 'Sight', 'Touch', 'Sound', 'Taste and smell' are logically grouped together with 'My body' as they all pertain to the concept *human body.*	grouped together in the science curriculum even though they are conceptually related. Logically each season is positioned on the curriculum in relation to the time of the event.

AI: 1 describes the content of the concept. A conclusion is drawn at the end of the curriculum descriptions generated by AI: 1.

Analytic indicator (continued) (Text summary 2 on page 62)	Relation to conceptual framework (Text summary 1 on p. 53)
AI: 2.*How does the Grade R science curriculum represent the structure of a science knowledge concept with regards to the relation between content and procedural knowledge?*	Does the Grade R science curriculum represent the topic concept in terms of the neo-Vygotskian notion of simple scientific concept which comprises two integral parts i.e. content and procedural knowledge? This section depends on the conclusion to AI: 1 because, in the absence of content knowledge, procedural knowledge does not exist. Procedural knowledge is a particular kind of internalising process; it 'operates' with the concept's essential attributes, and employs classification and the law of equivalence as the basis of all learning.
AI: 3.*How does the Grade R curriculum represent the science knowledge concepts with regards to the relation between simple and complex concepts?*	Does the Grade R science topic underpin related science concepts in Grades 1 – 6? A concept's capacity to underpin more complex science concepts is directly related to the concept being represented as two or more essential attributes.

3.3.2. Defining types of science concepts

In bringing the three analytic indicators to bear, three descriptions of the Grade R science knowledge concepts will be generated i.e. a simple scientific concept, a potential scientific concept and an everyday concept. The following three sections explain each type of science concept:

- According to the neo-Vygotskians a *simple scientific concept* is distinguished from other types of concepts by 1) an explicit definition containing two or more essential attributes which uniquely define the concept from other concepts, 2) simple scientific terms, and 3) a description of the position of the concept in relation to other concepts on the scientific knowledge continuum. A simple scientific concept contains content and procedural knowledge, is transferable to other contexts, and underpins more complex scientific concepts. The imagined topic 'Birds 2' in Table 3.8is represented as a simple scientific concept.

- This study has created a new term i.e. a *potential scientific concept* to describe a concept which contains parts of, stands in place of, and/or infers the features of a simple scientific concept and is intended to lead towards the acquisition of new scientific knowledge. The term *potential scientific concept* does not pertain to Vygotsky's idea of a potential concept. Although it relates in part to Vygotsky's idea of pseudoconcept and to Hedegaard's description of an empirical[67] concept, the notion of 'potential' in this context pertains to the pedagogical and not to the developmental. Realising the scientific 'potential' of a science concept rests on the likelihood of the Grade R educator interpreting the partially described or implied into a simple scientific concept. Some educators will provide more scientific knowledge than others depending on the educator's own knowledge, or idea of what comprises science knowledge for six- year-olds and how much support the Grade R science curriculum provides in terms of simple scientific knowledge. My 37 years of ECD experience as a teacher, manager and trainer has informed, in part, in my view what determines pedagogic potential. The Grade R topic 'Birds 1', employed in Table 3.7 is represented as a potential scientific concept. Although partial and therefore erroneous in scientific terms, it nevertheless directs the Grade R educator towards thinking about *bird* in simple scientific terms.
- According to the neo-Vygotskians an *everyday concept* is a word or a description that defines an idea in terms of a person's everyday context-dependent sensory experiences and observations of the visible and obvious features of an object or phenomena. Everyday concepts are scientifically unacceptable because they are couched in everyday terms, are not transferable and do not portray the 'essence' of a concept. Everyday concepts can be erroneous e.g. 'a whale is a fish because it lives in water', or empirical i.e. factually correct within a particular context e.g.' it snows in winter'. In the curriculum the term 'tummy' (DBE, 2012a:19) pertains to the everyday because 'tummy' is not in the scientific dictionary (Morris, 1992). The topic 'Sight' (C1.2) is represented in the curriculum as an everyday concept because the

[67] Factual but within a specific context e.g. when the educator tells the class that 'In winter it snows and people wear warm coats'

topic statements 'Things around me; Light, dark, and shadows; How being able to see keeps us safe; Looking after my eyes' (DBE, 2011a: 18) do not describe the attributes unique to human sight.

A rating scale and benchmarks were developed in order to assess the degree of alignment between a concept description and the analytic indicators.

3.3.3. Creating a rating scale and benchmarks

Table 3.4 sets out the rating scale criteria. Table 3.5 provides an example that illustrates the application of the rating scale. Table 3.6 provides benchmarks for determining the knowledge type.

The rating scale and benchmarks are rooted in the conceptual framework. As comparing the Grade R topic concepts to the neo-Vygotskian notion of a simple scientific concept is at the heart of the analysis, six rating criteria were created from the six distinguishing features of a simple scientific concept. Each criterion was given a score of 2. A score of 2/2 indicated that the criterion was made explicit and is entire. A score of 1/2 indicated that the criterion was implied, partial and/or countered in some way in the text. A score of 0/2 indicated that there was no evidence of the criterion in the text or the evidence was erroneous.

The rating scale and the benchmarks scored the data in the following way. The description that was generated by bringing the analytical indicators to bear on the data was compared to each of the six rating criteria (Table 3.4) and rated as described in the preceding paragraph. The six ratings were tallied, compared to the benchmark scale and a conclusion on the nature of the data segment in terms of knowledge was drawn.

Table 3.4: The rating scale

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Contains two or more essential attributes that uniquely define the concept from other concepts Rating: 2	Employs two or more scientific terms Rating: 2	Described in relation to other concepts on the scientific knowledge continuum Rating: 2	Is transferable across contexts Rating: 2	Structured as two integral parts i.e. content knowledge and procedural knowledge Rating: 2	Underpins more complex scientific concepts Rating: 2

Table 3.5: Example: applying the rating criteria to knowledge types

Knowledge Type	EXAMPLES	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Total rating
Simple scientific concept:	A triangle is a geometric shape that has three straight sides and three angles. Sort a variety of shapes according to the definition above.	2/2	2/2	2/2	2/2	2/2	2/2	12/12
Potential scientific concept:	A triangle has three sides and three corners.	2/2	1/2	0/2	2/2	0/2	2/2	7/12
Everyday concept	Look around and point out the triangles in the classroom. Colour in the picture of a triangle	0/2	0/2	0/2	0/2	0/2	0/2	0/12

Table 3.6: Benchmark scale

Knowledge type	Benchmark	Criteria
Simple scientific concept	=12/12	All six criteria are evident i.e. all the features of a simple scientific concept are made explicit.
Potential scientific concept	≥ 5/12 ≥11/12	A minimum of 2.5 criteria and a maximum of 5.5.criteria are evident either explicitly or by implication
Everyday concept	≥ 4/12	Two or less criteria are evident.

3.4. GENERATING A LANGUAGE OF DESCRIPTION FOR THE GRADE R SCIENCE CURRICULUM CONCEPTS

This section provides two examples, Table 3.7 and Table 3.8, with four purposes in mind: 1) to illustrate how the analytic indicators function in the analysis of the Grade R science curriculum concepts, 2) to demonstrate that the curriculum description generated by the analytic indicators is dependent on the data segment, 3) to foreground the differences in knowledge types, and 4) to remind the reader that the analysis is normative in so far as it describes the Grade R science curriculum concepts in terms of the neo-Vygotskian notion of an ideal school science concept for six-year-olds. This normative stance is based on the premise that certain kinds of representations of knowledge align more appropriately with the practice of science as a discipline and so are more likely to give learners access to that practice and knowledge.

Table 3.7 and Table 3.8 each demonstrate how the three analytic indicators are brought to bear on a data segment in order to generate a description of a Grade R science knowledge concept. Both tables employ the topic concept ‘Birds’ as the data segment for analysis but each represents ‘Birds’ in a particular way. The topic ‘Birds 1’ in Table 3.7 is one of the Grade R science curriculum topics selected for analysis (C13) and is reproduced exactly as in the Grade R science curriculum (DBE 2011a: 21). The topic ‘Birds 2’ in Table 3.8 is not a curriculum data segment; it is an imaginary topic that was specifically created to illustrate how a concept might be represented in the curriculum if all the features of a simple scientific concept were present.

Table 3.7: ‘Birds 1’ (C13): a Grade R science curriculum concept

AI: 1. How does the Grade R curriculum describe ...with regards to:

- The degree of specialisation of language

Description: ‘Birds 1’ is couched in simple but appropriate academic language i.e. ‘beak’ (instead of mouth), ‘feathers’, ‘nests’, ‘lays eggs’, ‘penguin’ and ‘ostrich’.

AI: 1. How does the Grade R curriculum describe ...with regards to:

- Its attributes

Description: ‘Birds 1’ lists four essential attributes that pertain to all birds i.e. ‘feathers, two legs, beak, lays eggs’ but omits wings. The concept underpins this error by identifying an uncommon attribute i.e. the ostrich and penguin which have wings but cannot fly. There are however sufficient attributes for an object to be classified in terms of a bird.

AI: 1. How does the Grade R curriculum describe ...with regards to:

- Its relation to other concepts

Description: ‘Birds 1’ does not describe the hierarchical position of birds in terms of other living things e.g. a bird is a vertebrate and belongs to the animal kingdom

Topic: Birds – 2 hours

- Different types of birds
- General characteristics of a bird – feathers, two legs, beak, lays eggs
- Bird that cannot fly – ostrich, penguin
- Nests

(DBE, 2011a: 21)

AI: 3. How does the Grade R curriculum describe the science knowledge concepts with regards to the relation between simple and complex concepts?

Description: N/A in terms of describing ‘Birds 1’ in relation to other concepts. *(However, when AI: 3 was brought to bear on the Grades 1 – 6 science curriculum (DBE, 2011a; DBE, 2011b), ‘Birds 1’ underpins, in part, more complex science concepts)*

AI: 1. How does the Grade R curriculum describe ...with regards to:

- Its relation to context

Description: Although ‘Birds 1’ omits the essential attribute *wings* the concept is transferable and applicable in part to other contexts i.e. a child will be able to identify an object as a bird by generalising the four essential attributes described in ‘Birds 1’.

AI: 2.How does the Grade R science curriculum describe the structure of a science knowledge concept with regards to the relation between content and procedural knowledge?

Description: ‘Birds 1’ is described, in part, in terms of knowledge content but there are no explicit descriptions of procedural knowledge i.e. classification according to the essential attributes of birds.*(However, when AI: 2 was brought to bear on Workbook 4 (DBE, 2012d), then ‘Birds’ is described, in part, in terms of content and procedural knowledge as two parts of a simple scientific concept)*

In Table 3.7 the analytic indicators generated a description of the topic 'Birds' (13) as a potential scientific concept. 'Birds' (C13) pertains, in part, to a simple scientific concept by containing two or more transferable essential attributes couched in scientific terms, and partial content and procedural knowledge. 'Birds' also 4) underpins more complex concepts in Grades 1 – 6, and relates to the following scientific definition:

> bird: *Vertebrate Zoology*. any of the many vertebrates in the class Aves; all are warm- blooded, lay eggs, and have wings and feathers, and most can fly (Morris 1992: 264).

However, 'Birds' (C13) also counters the notion of a simple scientific by omitting an essential concept i.e. 'wings' and foregrounding an uncommon attribute 'cannot fly'. The analysis of 'Birds' (C13) in the following chapter provides further descriptions with regards to AI: 2 and AI: 3.

In contrast, Table 3. 8, below, demonstrates how the same three analytic indicators generated different description when brought to bear on 'Birds 2' which is structured as a neo-Vygotskian simple scientific concept. The primary difference is the provision of a simple scientific definition of *bird.*

Table 3.8: 'Birds 2': described in terms of the neo-Vygotskian notion of a simple scientific concept

AI: 1. How does the Grade R curriculum describe ...with regards to:

- Its attributes

Description: According to Davydov (1990:) the definition of *bird* (in bold text) contains the essential attribute i.e. 'feathers' that pertains only to *birds* as well as the general characteristics of all *birds* i.e. '...wings, a beak ', '...lay eggs and have two feet'.

AI: 1. How does the Grade R curriculum describe ...with regards to:

- The degree of specialisation of language

Description: The definition of *bird* employs simple i.e. 'wings', 'beak', 'feathers', 'lay eggs', 'nests', and more specialised academic terms i.e. 'vertebrates', and 'animal kingdom'

Topic : Birds

Definition of a bird:

We know an animal is a bird if it has feathers all over its body. All birds have wings, a beak and two feet. Most birds can fly and make nests. Female birds lay eggs. Birds are vertebrates who, like reptiles, fish and mammals, belong to the animal kingdom.

- Use the definition to classify different animals into groups i.e. birds and not birds (fish, reptiles, insects, mammals). Document findings.
- Observe birds (visit a bird sanctuary or garden) and model findings (drama, visual arts)
- Home project: choose a bird and with the help of an adult or older child, plan and carry out an investigation into the bird's habitat
- Present findings to class. Feedback and evaluation.

AI: 1. How does the Grade R curriculum describe ...with regards to:

- The degree of specialisation of language

Description: The definition of *bird* employs simple i.e. 'wings', 'beak', 'feathers', 'lay eggs', 'nests', and more specialised academic terms i.e. 'vertebrates', and 'animal kingdom'

AI: 1.How does the Grade R curriculum describe ...with regards to: • Its relation to context (generalisation)

~~Description~~: the definition of the essential and general attributes is transferrable because it can be used in other contexts (generalised) to determine if an object is a bird.

AI: 3.How does the Grade R curriculum describe the science knowledge concepts with regards to the relation between simple and complex concepts? ~~Description~~: N/A. *(This description will be generated when AI: 3 is brought to bear on the Grades 1 – 6 science curriculum concept descriptions (DBE, 2011a; DBE, 2011b).*

AI: 2.How does the Grade R science curriculum describe the structure of a science knowledge concept with regards to the relation between content and procedural knowledge? D~~escription:~~ The topic describes the concept in terms of knowledge content (the definition) and a related procedure (i.e.' use the definition to classify different animals into groups: birds and not birds').

The description generated by the three analytic indicators in Table 3.8 contains all the elements that comprise the neo-Vygotskians' idea of a simple scientific concept i.e.:

- A simple scientific concept has two or more essential attributes
- A simple scientific concept is part of an ordered, hierarchical knowledge system
- Although a simple scientific concept is couched in language that is understood by six-year-olds, simple scientific concepts also employ specialised terms that are universally understood to represent the same thing
- A simple scientific concept is transferable across contexts (because it contains two or more essential attributes, is part of the knowledge continuum and is represented in simple academic terms).
- Each simple scientific concept has two integral parts: content knowledge and procedural knowledge i.e. the mental processes and the procedures related to the acquisition of the content knowledge. The content knowledge cannot be separated from the related procedural knowledge.
- A simple scientific concept is a unit on the scientific knowledge continuum. Basic and simple scientific concepts underpin more complex scientific concepts.

According to the rating scale and benchmarks the topic concept above is a simple scientific concept because all six criteria are evident i.e. a rating of 12/12 because all the features of a simple scientific concept have been made explicit. If one or more of the features had been omitted then the topic concept would have been rated as a potential scientific concept or an everyday concept.

After the analytic indicators have been brought to bear on all the Grade R science curriculum concepts in Chapter 4, a conclusion will be drawn in relation to the research question 'How does the South African Grade R curriculum represent school science knowledge for six–year-olds: a neo-Vygotskian perspective?' Before proceeding to Chapter 4, the issue of validity, reliability and ethical concerns are discussed.

3.5. VALIDITY

Establishing a study's credibility is a key concern even though the subject of validity in qualitative studies has long been the subject of debate (Maxwell, 1992). This study, which is based solely on analysing stable and non-reactive documents, is likely to encounter different threats to validity than one that involves human participants (Maxwell, 2010). In the matter of establishing validity and reliability I have been guided by Maxwell (2010), Dowling & Brown (2010) and Bowen's (2009) recommendations that a researcher provides:

- Detailed information on the research design
- A 'rich' i.e. detailed, description of the analysis
- A selection of texts that draws from more than one datum source
- Data that is authentic, credible, accurate, relevant and representative
- An approach that demonstrates objectivity (a fair and accurate representation) and sensitivity (responding to subtleties and omissions)

The primary threat to this study was researcher subjectivity. In the 1970's teacher training in state colleges in South Africa drew loosely on the views of Piaget in a simplified and particular way that suited the apartheid government. Vygotsky's historical materialist approach, which ran counter to the apartheid government, did not surface in my training or in the subsequent in-service teacher development courses I attended. Although my pedagogical experiences have contributed to this study they initially undermined the descriptive[68] and interpretative[69] validity of the study because I was immersed in the 'truths' and biological metaphors imparted by a training steeped in a particular ideology. As it is difficult to be aware of one's own bias and as bias cannot be eliminated completely (Maxwell, 2010), I minimised the threat in the following ways:

- I raised my awareness by reading texts that critique traditional pedagogical approaches. Egan's (2002). *Getting it wrong from the beginning: our progressive inheritance from Herbert Spencer, John Dewey, and Jean Piaget,* was an eye-opener. This allowed me to have a more balanced approach and understanding of the contributions made by Piaget and Vygotsky in the field of early education
- Ongoing thorough reading i.e. an initial scan in order to gain an overview, a second more thoughtful reading with the analytic indicators in mind, and a deeper 'combing' of the data texts, ensured that the selected datum was'...

[68] Factual accuracy i.e. not distorting or making things up (Maxwell, 1992).
[69] The meaning the researcher gives to the objects, events and behaviours in the study (Maxwell 1992).

detailed and varied enough that they provide a full and revealing picture of what is going on' (Maxwell, 2010: 110).

- I applied Maxwell's idea that 'Identifying and analysing discrepant and negative cases is a key part of the logic of validity testing in qualitative research' (Maxwell, 2010: 112) by providing numerous examples, explanations and footnotes that point to omissions, errors and discrepancies.

The threat to theoretical[70] validity was further minimised by constructing an explicit analytic framework that was rooted in a conceptual framework drawn from seminal and peer- reviewed texts. Furthermore, the conceptual framework is principle based and can be generalised to other phenomena. This explicit principle-based design minimised the threat to '... the validity of the concepts themselves as they are applied to the phenomena, and the validity of the postulated relationships among the concepts' (Maxwell, 1992: 291). In addition, the data for analysis is based on the phenomenon itself i.e. the Grade R science curriculum which is the subject of the analysis is not a record or description of something else, it is the phenomenon itself and therefore free of interpretations. In all this, my intention was to ensure that the ideas drawn from the literature review and analysis were authentic, credible, accurate, relevant, representative, objective and sensitive to omissions by implementing the recommendations above.

3.6. RELIABILITY

With regards to reliability I aimed to produce a study that could be replicated by another researcher. A replicated study is likely to achieve similar results because of the following:

- The conceptual framework, that is central to the analysis, is derived from seminal works e.g. Vygotsky (1978, 1962) and Davydov (2008, 1990).
- The data for analysis is contained in official school curriculum documents (DBE, 2011a; DBE, 2011b; DBE, 2012a; DBE, 2012b; DBE, 2012c; DBE, 2012d) and is therefore stable and accessible. Appendix 3 contains the selected datum segments reproduced exactly as in the data sources. The data is also sufficient and clear. Reasons have been given for excluding particular documents.

[70] Refers to the theory of some phenomena (Maxwell, 1992)

- The research design is explicit and provides clear categorisation, rating and benchmarking criteria.
- The analysis descriptions are 'rich' and 'detailed'.

3.7. ETHICS

In terms of ethics, this study, which pertains to a stand-alone document analysis, has abided by i) the University of Cape Town's code of ethics for students, and ii) the memorandum of understanding between myself, as a student, and my supervisors.

3.8. GENERATING AN ANALYSIS

The analysis proceeded in the order set out in Table 3.1. The next chapter describes the findings of the analysis which were wrought as follows:

The three analytic indicators were each brought to bear, in turn, on each of the primary data segments C1 – C18 (DBE, 2011a) and the supporting data in the four Grade R workbooks (DBE, 2012a; DBE, 2012b; DBE, 2012c; DBE, 2012d). AI: 3 was also brought to bear on the related science topics in the Grade 1 – 3 Foundation Phase Life Skills and the Intermediate Phase science curricula (DBE, 2011a; DBE, 2011b). A description of each of the twelve Grade R science knowledge concepts was generated in relation to Text Summary 1 (page 53): *A neo-Vygotskian conceptual framework: simple scientific concepts as school science knowledge for six-year-olds*. Each description was then rated according to the science concept type rating scale and benchmark criteria as set out in Table 3.3 and Table 3.5 respectively. At the end of the analysis a conclusion was drawn on the twelve analytic descriptions and ratings in terms of the research question: *How does the South African Grade R curriculum represent school science knowledge for six–year-olds: a neo-Vygotskian perspective?*

3.9. CONCLUSION

This chapter presented an analytic framework that structured the analysis of the Grade R science knowledge concepts in a valid and reliable manner and generated the findings that will be presented in the next chapter. This framework was informed by a principle-based conceptual framework which was described in Chapter 2. By translating the conceptual framework into analytic indicators, science concept descriptions, a rating scale and benchmark criteria, the study connects the theoretical (the neo-Vygotskian idea of a simple scientific concept) to the empirical (an analysis of the Grade R science curriculum concepts). Two examples clarified for the reader how the analytic indicators will function in the next chapter's analysis of the Grade R science curriculum concepts. The chapter concluded by considering the issues of validity, reliability and ethics particular to this study and outlining the analytic process.

CHAPTER 4: Findings

Education is the most powerful weapon you can use to change the world

(Nelson Mandela)[71]

4.1. INTRODUCTION

This chapter sets out the findings i.e. descriptions of the Grade R science curriculum concepts wrought by bringing the three analytic indicators to bear on the primary, supporting and related data. The sequence of the analytic descriptions is set out in the table below. Each Grade R curriculum concept is represented by one or more primary data segments.

Table 4.1: Sequence of analytic descriptions

1. Human body (C1, C1.1, C1.2, C1.3, C1.4)
2. Domesticated animals (C10, C11)
3. Wild animals (C16)
4. Birds (C13)
5. Reptiles (C14)
6. Fruit and vegetables (C8, C9)
7. Shape and colour (C3)
8. Water (C7)
9. Time (C17)
10. Transport (C18)
11. Weather (C4)
12. Summer, Autumn, Winter and Spring (C2, C5, C6, C12).

Each of the twelve analytic descriptions below begins with a reproduction of the data segment followed by a related scientific definition (Morris, 1992). As this study pertains to six-year-olds, a simple scientific definition is created from each scientific definition. The findings wrought by bringing each analytic indicator to bear on the Grade R science curriculum concepts are then described in turn. A summary and rating concludes each

[71] Quoted by South African Broadcasting Corporation (SABC), 2013, December 11)

analysis. A final conclusion draws the twelve findings together in preparation for Chapter 5's discussion.

4.2. ANALYSIS DESCRIPTIONS

4.2.1. Knowledge concept: human body

The primary topic (C1) representing the Grade R science curriculum concept *human body* is:

Topic: My Body – 2 hours[72]

- Identify and name body parts – include how many of each
- Functions of different body parts
- Who may or may not touch my body
- What my body needs to keep healthy (DBE, 2011a: 16).

'My body' is supported by the following four topics (C1.1, 1.2, C1.3, C1.4) which represent the human senses:

Topic: Sound – 2 hours

- Sounds we hear
- What makes the sounds we hear
- Music I like
- How hearing keeps us safe
- Looking after my ears (DBE, 2011a: 18).

Topic: Sight – 2 hours

- Things around me
- Light, dark and shadows
- How being able to see keeps us safe
- Looking after my eyes

Note: Adapt curriculum as necessary for learners who are blind or partially sighted. (DBE, 2011a: 18).

[72] Each topic in the analysis is reproduced exactly as in the Grade R curriculum (DBE, 2011a).

Topic: Touch – 2 hours

- Different things feel different
- Introduce new words: hard, soft, smooth, rough, cold, hot warm, cool
- Experiencing different temperatures and textures (DBE, 2011a: 18).

Topic: Taste and smell – 2 hours

- Tastes and smells I like
- Tastes that are new to me
- Safety when tasting
- Different smells around us
- Where smells come from (DBE, 2011a: 18).

As a scientific definition contains the essential attributes, describes the concept in specialised terms, and indicates the concept's relationship to other concepts, this study turned to the *Academic Press Dictionary of Science and Technology* (Morris, 1992) for a definition of *human body*[73]. As the term *human body* was not in the dictionary, the concept was separated into two:

> human: *Vertebrate Zoology*. 1. a[74] member of the species *Homo sapiens*, especially the modern subspecies *Homo sapiens sapiens*, the group of mammals characterized by an erect stance, a large, highly developed brain, and the use of tools and language (Morris, 1992: 1051).
>
> body: '*Biology*. the complete physical substance and structure of an organism, living or dead' (Morris, 1992: 285).

From these definitions a simple scientific definition appropriate for six-year-old was compiled for the purposes of analysing the Grade R science curriculum's representation of *human body*:

> human body: the whole person i.e. all the inside and outside parts that make up a human being. Humans are called homo sapiens sapiens. 'Homo' means being human; 'sapiens sapiens' means that we have a large intelligent brain. Human also stand upright, make things and use language. Humans are mammals a type of animal that provides milk for its babies (based on and adapted from Morris, 1992:

[73] The idea of the concept as *human body* emerged in relation to the pronoun 'My (body)'.
[74] Morris (1992) begins each definition in lower case.

285, 1051).

As the analysis of the Grade R concept *human body* involves two aspects the discussions below generally begin with *body* followed by *human.* Conclusions were, however, drawn on *human body* as a single concept as defined above.

AI: 1. How does the Grade R curriculum describe the defining features of *human body* as represented by the topics 'My Body' (C1), 'Sound' (C1.1), 'Sight' (C1.2),' Touch' (C1.3), and 'Taste and smell' (C1.4) with regards to:

- Its attributes

The primary topic 'My Body' (C1) contains four statements of which the first two i.e. 'Identify and name body parts – include how many of each' and 'Functions of different body part' (DBE, 2011a: 16), have the potential to be sharpened into two or more essential attributes for *human body*. Although these scientifically framed statements direct the Grade R educator towards providing children with content knowledge, the nature of this knowledge rests on the educator. One educator may be prompted by the two statements to source simple but scientifically acceptable information from an encyclopaedia; another educator may rely on his/her own (potentially erroneous) everyday understanding of the human body. The third and fourth topic statements, e.g. 'Who may or may not touch my body', are unlikely to generate scientific knowledge for they pertain to the study area *Personal and Social Well-being*[75].

The topics 'Sound' (C1.1), 'Sight' (C1.2), 'Touch' (C1.3) and 'Taste and smell' (C1.4) underpin the topic concept 'My body' (C1) by defining the human body in terms of its sensory faculties (DBE, 2011a: 18). While the first two[76] 'My body' statements have the potential to be translated into simple scientific information, the nineteen supporting statements are unlikely to prompt the Grade R educator into providing six-year-olds with the essential attributes of the human senses. The reasons are as follows:

- Three statements direct the educator's attention to material properties perceived by the senses i.e. 'Light, dark and shadows', 'Introduce new words: hard, soft, smooth rough, cold, hot, warm, cool', and 'Experiencing different

[75] An example of how the Foundation Phase curriculum (DBE, 2011a) has integrated the two study areas *Beginning Knowledge* (science) and *Personal and Social Well-being*

[76] 'Identify and name body parts – include how many of each' and 'Functions of different body part' (DBE, 2011a: 16)

temperatures and textures' (DBE, 2011a: 18). The material properties do not relate to the attributes of *human body* as defined by Morris (1992).

- Nine statements suggest the identification of familiar phenomena and objects associated with the five senses e.g. 'Music I like', 'Things around me' and 'Tastes and smells I like' (DBE, 2011a: 18).
- Seven statements do not pertain to science: five are related to *Personal and Social Well-being* e.g. 'How hearing keeps us safe' and 'Safety when tasting', and two are pedagogical references e.g. 'Note: Adapt curriculum as necessary for learners who are hearing impaired' (DBE, 2011a: 18).

Although the supporting topics contain little scientific information, Workbook 1 provides thirteen pages[77] of activities that support the internalising of the concept *human body* (DBE 2012a: 2, 3, 5-7, 8, 9, 12-15, 19, 47). The open-ended statement, 'Look at the picture and talk about what you see', that accompanies the introductions to 'About me' (DBE, 2012a: 2-11) and 'My body' (DBE, 2012a: 12-13) provides the Grade R educator with two potential opportunities for introducing the essential attributes of *human body*. The remaining descriptions pertain, however, to the visually obvious physical attributes of the human body e.g. 'foot', 'head', 'toes' , 'see', 'walk' and 'run'[78] and not to the 'essence' as in the simple scientific definition of *human body* (created from Morris, 1992: 285, 1051).

Although the curriculum omits the two unique attributes that distinguish the human from other animals i.e. a well-developed brain and the ability to make abstract representations[79], the curriculum nevertheless signals *human* by describing the body in terms of 'my', 'I', 'us', 'me' and 'we' (DBE, 2011a: 16, 18). This idea is not, however, carried through to the internalising activities. None of the body parts named in Workbook 1 are unique to the human animal; all apply in some way to other animals e.g. primates also possess 'hands', 'knees' and 'shoulders', birds 'feet', mice 'ears'. In conclusion: the Grade R science curriculum's partially represents the concept *human body* in terms of the neo-Vygotskian notion of two or more essential attributes.

[77] Four of the pages are integrated with mathematics

[78] The relationship is not a one to one correspondence between body part and function e.g. there is no function for 'head' whereas two terms are used to describe the ears in terms of function.

[79] By drawing, painting, writing, using symbols as in mathematics.

• Degree of specialisation of language

Of the 24 Grade R science topic statements pertaining to the concept *body,* five are couched in simple scientific terms:

- 'Identify and name body parts ...'
- 'Functions of different body part'
- 'Light, dark, and shadows'
- 'Introduce new words: hard, soft, smooth, rough, cold, hot warm, cool'
- 'Experiencing different temperatures and textures' (DBE, 2011a: 16, 18).

Of the five statements above, the first two have the potential to prompt educators into introducing scientific terms in terms of *human body.* Although the term 'body part' is an everyday term, its juxtaposition to 'Identify and name' and 'Functions' signals the introduction of specialised body terms. The third statement pertains to the properties of *light*. The fourth statement is contestable in terms of 'new words' as most six-year-olds are, in my experience, familiar with these basic ideas. Although the fifth statement directs educators to 'experiencing' which pertains to the acquisition of everyday concepts (Karpov, 2005; Hedegaard, 2002), there is scope for the extrapolation of 'temperature' into scientific terms and ideas e.g. 'tepid', 'thermometer' and 'water boils at 100^{0}C. However, none of these scientific terms are related to the essential attributes of *human body.*

The remaining nineteen topic statements are couched in everyday terms e.g. 'Looking after my eyes' and 'Tastes that are new to me' (DBE, 2011a: 18). These brief everyday references potentially offer opportunities for language specialisation if, for example, the Grade R educator includes specialised terms such as 'iris' and 'tear duct' when discussing the topic statement 'Looking after my eyes' (DBE, 2011a: 18).

As most six-year-olds cannot read, the four Grade R workbooks are dominated by illustrations[80]. Twenty-two nouns and nineteen verbs accompany the images and describe in simple terms the basic anatomy and functions of the human body e.g. 'head', 'knees', 'walk', 'run' (DBE, 2012a). The descriptions are all (except 'tummy') scientifically acceptable (Morris,

[80] Available http://www.thutong.doe.gov.za. Click onto 'Foundation Phase' and go to 2013 Grade R Workbooks. All the pages reflect the highly illustrated nature of the supporting materials.

1992) but, in relation to the learning of new knowledge, most six-year-olds are likely to be already familiar with these terms[81]. However, while one educator may adhere to the terms provided by the Grade R workbooks, another educator may be prompted by the simplicity of the terms to provide more complex scientific terms e.g. 'skeleton', 'skull', 'vertebrae' and 'abdomen'.

There are no scientific terms in the Grade R science curriculum that define *human*. In my experience most six-year-olds enjoy learning academic terms such as *homo sapiens sapiens* if they are explained in terms young children understand e.g. '*homo* is a science word for us as a special kind of animal. Sapiens is a word for wise or clever. Because humans have a large and very clever brain scientists use the word s*apiens* twice as we are very, very clever.' In conclusion: with regards to *human body,* the Grade R science curriculum's specialisation language relates, in part, to the neo-Vygotskian notion of a simple scientific concept by containing two or more specialised terms.

- Relation of topic concept to other concepts

This section describes the Grade R science curriculum's representation of the concept *human body* in terms of the neo-Vygotskians' notion of sequence, grouping, co-location and positioning[82]. On the matter of relations to other concepts the Grade R curriculum states:

> Sequencing and Progression
> A suggested order for the topics is provided as one of the most important principles of early childhood education is to begin with what is familiar to the learner and introduce less familiar topics and skills later. Therefore sequencing and progression have been built into the design of the topics. The sequence of the topics can be changed, but teachers should pay attention to the progression and level at which the topic is addressed (DBE, 2011a: 14).

The topic 'My Body' introduces the concept *human body* in Term 1 (DBE, 2011a: 16). The curriculum groups together the supporting topic concepts, 'Sound', 'Sight',' Touch', and 'Taste and smell' (DBE, 2011a: 18), but dislocates these human senses from 'My Body' by 1) introducing the five sense at the end of Term 2, and 2) positioning seven unrelated topics, e.g. 'Summer', 'Shapes and colours' and 'Autumn' (DBE, 2011a: 16-17), in between 'My

[81] Pertains to learners who are being taught in his/her home language
[82] Refer to Table 3.3.

body' and the senses. Although *human* pertains to the animal kingdom (Morris, 1992: 117, 285, 1051), the Grade R science curriculum isolates the one from the other by positioning the *human body* topics (C.1, C1.1, C1.2, C1.3 and C1.4) in Term 1 and 'Birds' (C13), 'Reptiles' (C14) and 'Wild Animals' & 'Finding out about one wild animal' (C16) together in Term 4 (DBE, 2011a: 21).

There are no references in the Grade R science curriculum to a human as part of the animal kingdom[83]. This notion of sequencing in terms of animals pertains to the curriculum idea of introducing the familiar before the unknown but it is counter to the scientific view.

In addition, while the Grade R curriculum sequences from the general 'My Body' (DBE, 2011a: 16) to the particular 'Sound', 'Sight',' Touch', and 'Taste and smell' (DBE, 2011a: 18), Workbook 1 subverts this logic by introducing 'My Senses' (DBE, 2012a: 3, 8-9) before 'My Body' (DBE, 2012a: 12-15, 19, 47). In conclusion: the Grade R science curriculum's dislocation of the concept *human body* into two separate parts and delocation from other related concepts does not relate to the neo-Vygotskian idea of a simple scientific concept relations to other concepts on the scientific knowledge continuum.

• Relation of topic concept representation to context

The Grade R science curriculum concept *human body* is, in part, potentially transferable to other contexts. The open-ended terms, 'Identify and name body parts ...' and 'Functions of different body part' (DBE, 2011a: 16), are content independent. Workbook 1 (DBE, 2012a) supports this stance by providing simple but scientifically acceptable[84] terms such as 'leg', 'arm', 'shoulder', that can be used in other scientific contexts. Workbook 1, however, undermines this potential transferability to other contexts in the following way:

- In relation to the scientific statement 'the complete physical substance and structure of an organism ...' (Morris, 1992: 285), the human body attributes represented in Workbook 1 are limited and random e.g. 'knee' and 'hip' are described but not the ankle or elbow joints (DBE, 2011a: 13, 19).
- The essential physical differences in gender are ignored. Girls and boys are differentiated by dress and hair style i.e. cultural artefacts.
- 'Tummy' is an everyday term that cannot be applied to phenomena or objects

[83] This idea is made explicit in Grade 6 (DBE, 2011b).
[84] These terms are in a science dictionary (Morris, 1992)

outside a particular cultural context.

- Describing the concept 'touch' only in terms of an image of a hand is misleading. In a random experiment[85] in which five educators were asked to name the sense organs illustrated in Workbook 1 (DBE, 2011a: 3, 8), all five named the images of the hand representing 'Touch' as 'hand' rather than the scientifically correct 'skin'.

In conclusion: the Grade R science curriculum representation of the concept *human body* relates, in part, to the neo-Vygotskians' notion of content knowledge in terms of essential attributes, specialised terms and context.

AI: 2.How does the Grade R science curriculum describe the structure of the science knowledge concept *human body* with regards to the relation between content and procedural knowledge?

The section above (AI: 1) has already established that the Grade R curriculum representation of the concept *human body* pertains, in part, to content knowledge. This section therefore focuses on comparing the related Grade R internalising activities with the neo-Vygotskian notion of procedural knowledge.

The 'My body' statements 'Identify and name body parts ...' and 'Functions of different body part' (DBE, 2011a: 16), and the Workbooks 1 and 4 activities (DBE, 2012a: 3, 5- 8, 13-15, 19, 47; DBE, 2012d: 46, 47), represent the related internalising processes in the Grade R curriculum. These processes relate, in part, to procedural knowledge by 'operating' with the concept *human body* in simple ways e.g. 'Show your right hand', 'Draw yourself. Point to your head, arms, legs and body' and 'Do what these children are doing'[93] (DBE, 2011a: 5, 14, 19). Although the workbook activities pertain, in a simple[86] manner, to knowing what to do with the tool i.e. the concept (Karpov, 2005), these activities diverge from the neo-Vygotskian notion of procedural reasons in the following ways:

- Generalisation underpins procedural knowledge because it is the primary cognitive process in young children acquiring new knowledge (Davydov, 1990, 2008). There is, however, little evidence of classification in the related workbook

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[85] 28 July 2013: at the Early Learning Resource Unit (ELRU) with two ECD teacher trainers and three ECD practitioners.

[86] 'hands on hips' 'touch your knees' ...'cross your arms' ...'touch your nose ...(DBE, 2011a: 19).

activities e.g. 'Sort and mark which parts belong to the human leg – knee, wing, elbow, thigh, wrist, neck, ankle, shoulder, tail'

- The knowledge in the Grade R workbook activities is too simple in relation to what most six-year-olds know and can do[87] and therefore does not adhere to the law of equivalence or target the child's zone of proximal development (ZDP). E.g. the law of equivalence is engaged and the ZPD[88] targeted when the educator tells six-year-olds that 'The *calf muscle* (unknown potential new concept) is at the back of the *leg* (known i.e. previously acquired concept), above the *foot* (known) but below the *knee* (known)', or when they get six-year-olds to apply their learning of *human body* to an unfamiliar context by drawing 'What would happen to my body if I had no bones?'

In conclusion: the Grade R science curriculum's representation of the concept *human body* relates in part to the neo-Vygotskian notion of content and procedural knowledge as two integral parts of a simple scientific concept.

AI: 3.How does the Grade R curriculum describe the science knowledge concept *human body* with regards to the relation between simple and complex concepts?

The Grade R curriculum's representation of *human body* (DBE, 2011a: 16, 18; DBE, 2012), underpins, in part, the following more complex school science concepts:

- The Grade R Workbook 1 descriptions of the visible parts of the body e.g. 'head', 'leg' (DBE, 2012a) underpin the Grade 1 topic 'My Body' as in 'Parts of my body that I cannot see - lungs, heart, stomach, brain, skeleton' (DBE, 2011a: 31).
- The Grade 6 topic 'Animals with Skeletons'[89] (DBE, 2011b: 58) describes the human skeleton in more specialised terms while referring back to the simpler Grade R Workbook 1 terms 'arms', 'shoulders', 'hip', 'legs'[90] (DBE, 2012a).
- Although couched mostly in everyday terms the Grade R topics 'Sound', 'Sight', 'Touch', and 'Taste and smell' (DBE, 2011a: 18) have, depending on the educator,

[87] According to the notion of a generic six-year-old (WCED, 2011).

[88] The space between what children already know and can acquire by themselves and what they can potentially learn with the help of a more competent person.

[89] This Grade 6 topic also redresses the dislocation between human and animals in Grade R by positioning the human skeleton in relation to other animals.

[90] Demonstrating Vygotsky's law of equivalence (1962)

the potential to support the Grade 5 *Natural Sciences and Technology*[91] topic 'Senses in animals and humans' (DBE, 2011b: 44).

However, by locating the Grade 1 topic 'My body', as in the single statement 'The five senses and their uses – touch, smell, sound, sight and taste' (DBE, 2011a: 31), after the introduction of the four Grade R topics 'Sound' (C1.1), 'Sight' (C1.2), 'Touch' (C1.3), and 'Taste and smell' (C1.4), the curriculum counters the notion of progression in terms of simple to complex. In conclusion: the Grade R science curriculum's representation of *human body* pertains, in part, to the neo-Vygotskian notion of a simple scientific concept underpinning more complex concepts on the scientific knowledge continuum.

Summary

After bringing the three analytic indicators to bear on the Grade R topic concepts 'My body' (C1), 'Sound' (C1.1), 'Sight' (C1.2),' Touch' (C1.3), and 'Taste and smell' (C1.4), and related workbook activities (DBE, 2012a; DBE, 2012d), the conclusion was that the Grade R science curriculum represents the concept *human body* as a potential simple scientific concept. The reasons are as follows:

- The Grade R science curriculum sufficiently represents (≥ 5/12 ≤11/12) *human body* in terms of the six key features of a simple scientific concept i.e. two or more transferable essential attributes, scientific terms, relations to other science concepts, content and procedural knowledge, and underpins more complex science concepts.
- The Grade R representation of *human body* has the potential to prompt the Grade R educator into translating the curriculum representations in terms of a simple scientific concept.

[91] The Foundation Phase science study area 'Beginning Knowledge' is replaced in Grade 4 by the Intermediate Phase subject *Natural Sciences and Technology*

<u>Table 4.2</u>: Rating for the Grade R science curriculum representation of *human body*.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	1/2	0/2	1/2	1/2	1/2
RATING: 5/12 = Potential scientific concept					

4.2.2. Knowledge concepts: domesticated animals

The following two Grade R curriculum topics, 'Dairy farming' (C10) and 'Wool farming' (C11) represent the concept *domesticated animals*:

Topic: Dairy farming – 2 hours

- Dairy products and the animals they come from
- How we get butter (DBE, 2011a: 20).

Topic: Wool farming – 2 hours

- A sheep farm
- Where wool comes from
- Uses of wool (DBE, 2011a: 20).

These topics and the related supporting activities (DBE, 2012c) were analysed according to the following scientific definitions. The first definition is how scientists think about *domesticated animals* and is represented in a science dictionary (Morris, 1992); the second is a simple scientific definition for six-year-olds created from the dictionary definition for the purpose of analysing the Grade R science curriculum's representation of *domesticated animals*:

> Domesticated: *Biology*. to control or adapt an animal or plant for human use or life with humans (Morris, 1992: 671).
>
> Domesticated: Animals that humans keep and live with because they are helpful to us in some way (based on and adapted from Morris, 1992: 671).

The essence of *domesticated* (and, its counterpart, *wild)* is that it pertains to the human perspective e.g. we consider crocodiles who roam freely in the Kruger Park as *wild* but, when crocodiles are farmed for their hide, the crocodile has become *domesticated* in terms of human use. *Domesticated animals*, as in the topics above, pertain to a particular context i.e. the agricultural. Pets are also *domesticated animals* but the context differs.

AI: 1. How does the Grade R curriculum describe the defining features of the concept *domestic animals* as represented by the curriculum topics 'Dairy farming' (C10) and 'Wool farming' (C11) with regards to:

- Its attributes

The concept, *domesticated animals*, which is inferred in the topics 'Dairy farming' and 'Wool farming', is made more explicit in Workbook 3's 'Farm animals' (DBE, 2012c: 22-25). The two page introduction depicts images of humans engaging with farm animals for their own use e.g. milking a cow, collecting eggs and honey from hens and bees, and shearing a sheep for its wool (DBE, 2012c: 22-23). The open-ended question, ‘Look at the picture and talk about what you see’ (DBE, 2012c: 23), in conjunction with these explicit images, is likely to prompt discussions on *animal domestication* in the farming context. The matching activity that follows refers to one of the essential attributes of domestication i.e. ‘Draw a line to show *what we get from these animals’* (my italics, DBE, 2012c: 24). Teaching six-year-olds the song ‘Old MacDonald’ (DBE, 2012c: 25), supports, in part, the concept of *domesticated animals* by naming the animals.

Two factors counter the Grade R science curriculum’s representation of the concept *domesticated animals*. Firstly, in the absence of a simple scientific definition of *domesticated animals* in the curriculum, it rests on the Grade R educator to: 1) identify the underlying concept underpinning the topics ‘Dairy farming’ and ‘Wool farming’ and 2) determine the essential features unique to the concept. Secondly, the Grade R science curriculum confines *domesticated animals* to one particular context i.e. farming. These two factors are likely to result in conceptual differentiation. In other words: one Grade R educator may represent *domesticated animals* as an everyday concept by taking the topics and related workbook activities at face value e.g. matching the image of a hen to an image of an egg, but another Grade R educator may be prompted to 1) provide a simple scientific definition containing the attributes that unique to *domesticated animals,* and 2) ask questions that lift out the essential attributes contained in the definition and apply them to another context e.g. ‘Why do we keep dogs?’ and ‘Are the crocodiles at a crocodile farm domesticated or wild? Why?’ In conclusion: the Grade R science curriculum’s partially represents the concept *domesticated animals* in terms of essential attributes.

- The degree of specialisation of language

The Grade R curriculum employs the context specific terms ‘Dairy farming’, ‘Wool farming’ (DBE, 2011a: 20) and ‘Farm animals’ (DBE, 2012c: 22-31) in place of the more scientifically appropriate ‘domesticated animals’. If the curriculum introduces the topic concept ‘Wild animals’ (DBE, 2011a: 21), the notion of opposites indicates the logical inclusion of its conceptual counterpart i.e. ‘Domesticated animals’. In conclusion: the Grade R science curriculum represents *domesticated animals* in everyday terms.

• Relation of topic concept to other concepts

In terms of grouping the Grade R science curriculum introduces the topics 'Wool Farming' and 'Dairy farming' (DBE, 2011a: 20) in relation to one another in Term 3. In terms of co-location *domesticated animals* is isolated from its conceptual counterpart 'Wild animals' & 'Find out about one wild animal' (DBE, 2011a: 21) which is positioned at the end of Term 4 In terms of sequence the two related topic concepts *domestic* and *wild* are illogically separated by the topic concepts 'Healthy Environment', Spring', 'Birds', 'Reptiles' and 'Dinosaurs' (DBE, 2011a: 20, 21). In Workbook 3 'Sea animals' (DBE, 2012c: 32-41), which features *wild* and *domesticated animals,* is logically positioned after 'On the farm' (DBE, 2012c: 22-31) but, counter to the notion of sequence in terms of progression, precedes the introduction of 'Wild animals' (DBE, 2012c: 42-53). In conclusion: the concept *domesticated animals* is a stand-alone concept in terms of its relations to other concepts.

• Relation of topic concept representation to context

In the absence of the term 'domesticated animal' or its equivalent the Grade R science curriculum's representation of the concept *domesticated animals* is not transferable.

In conclusion: The Grade R science curriculum's representation of farmed animals pertains, in part, to the neo-Vygotskian notion of content knowledge[92] because the workbook images and text have the potential to prompt the educator into defining *domesticated animals, in part,* in terms of essential attributes.

AI: 2.How does the Grade R science curriculum describe the structure of the science knowledge concept *domesticated animals* with regards to the relation between content and procedural knowledge?

Having established above that the curriculum relates, in part, to content knowledge, this section considers the related curriculum activities in terms of procedural knowledge. The Grade R science curriculum provides one internalising activity i.e. a simple one-to-one matching activity (DBE, 2012c: 24) which places farm animals in relation to their produce. This activity pertains to the internalisation of *domesticated animals* by 'operating' with the concept but is unlikely to operate according to the law of equivalence i.e. the activity is too simple and therefore familiar to most six-year-olds. In conclusion: the Grade R science curriculum represents, in part, the concept *domesticated animals* as procedural and content knowledge.

[92] Content knowledge has four components: essential attributes, specialised terms, relations to other scientific concepts, and context

AI: 3.How does the Grade R curriculum describe the science knowledge concept *domesticated animals* with regards to the relation between simple and complex concepts?

The Grade R representation of *domesticated animals* potentially underpins one other more complex school science concept. *Domesticated animals* in the farming context in Grade R, is extended to another context i.e. 'Pets' in Grade 1 as in 'How to look after pets at home – include shelters, food water, animal cleanliness ... giving exercise ...' (DBE, 2011a: 32). 'Pets' is, however, positioned in isolation without any references to *domesticated animals* in the farming context.

The following topic concepts counter the notion of *domesticated animals* in Grade R underpinning more complex concepts in later grades:

- The Grade 2 topic 'Animals' (DBE, 2011a: 43), which describes the simple division of 'Animals' into 'Farm animals' and 'Wild animals', precedes the more complex Grade R topic concepts 'Wool Farming' and 'Dairy farming' (DBE, 2011a: 21) and 'Wild animals' & 'find out about one wild animal' (DBE, 2011a: 21).
- The Grade 3 topic 'Animals and creatures that help us' is underpinned, in part, by Grade R understanding of animal domestication but it also reiterates Grade R content (DBE, 2012c: 22-24) by stating 'Animals that give us food and/or clothes –bees – chickens - cows - sheep' (DBE, 2011a: 57).
- The simple scientific concept that 'All animals depend on green plants for food: energy' (DBE, 2011b: 39) is introduced in Grade 4 whereas the more complex idea of mankind's dependency on and use of farm animals as a source of energy is positioned in Grade R (DBE, 2011a: 20; DBE, 2012a: 22- 24).
- The concept *domesticated animals* does not feature in the Intermediate science curriculum (DBE, 2011b).

In conclusion: the Grade R's representation of *domesticated animals* does not underpin more complex science concepts.

Summary

After bringing the three analytic indicators to bear on the Grade R topics 'Dairy farming' (C10) and 'Wool farming' (C11) related internalising activities (DBE 2012c), the conclusion was that the Grade R science curriculum represents the topic concept *domesticated animals* as an empirical concept i.e. a type of everyday concept that is factually correct within a particular context. The reasons are as follows:

- The Grade R science curriculum insufficiently represents (≤ 4/12) *domesticated animal* in terms of the six key features of a simple scientific concept
- The Grade R representation of *domesticated animal* is unlikely to prompt the Grade R educator into translating the curriculum representations in terms of a simple scientific concept.

Table 4.3: Rating for the Grade R science curriculum representation of *domesticated animals*.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	0/2	0/2	0/2	1/2	0/2
RATING: 2/12 = Everyday concept					

4.2.3. Knowledge concept: Wild animals

The notion of *wild animals* is represented in the Grade R science curriculum by the following two topics:

Topic: Wild Animals – 2 hours

- What is a wild animal?
- Types of wild animals
- Where we find wild animals
- How wild animals live (DBE, 2011a: 21).

Topic: Finding out about one wild animal – 2 hours

- Choose one animal to study
- What the animal looks like
- Where it lives
- What it eats
- Babies and where they are born

  An additional interesting fact (DBE, 2011a: 21).

As 'Finding out about one wild animal' is an extension of 'Wild animals' the two topics were categorised as one (C16). An ampersand is used to indicate that the two topics represent one concept i.e. *wild animals.* The topics are supported by the workbook section 'Wild animals' (DBE, 2012c: 42-53). Images of 'wild animals' are also integrated into 'Creatures' (DBE, 2012d: 33-41) and 'Sea animals' (DBE, 2012c: 32-41).

As pointed out in the analysis of *domesticated animals*, the essence of *wild* is that it pertains to the human perspective e.g. a crocodile or ostrich can be *wild* or *domesticated* depending on the context. As the term *wild* is not represented in the scientific dictionary (Morris, 1992), this study understands *wild animals* in terms of the following scientific definitions:

> *Animal: Zoology*. any member of the kingdom that is generally characterized by the power of voluntary movement, specialized sense organs that provide rapid motor response to stimuli, limited capacity for regenerative growth, the lack of rigid cell walls, and the inability to manufacture nutrients from inorganic

substances. These qualities and others distinguish the animal kingdom from the plant kingdom (Morris, 1992: 117).

wildlife: *Zoology*. 1. a general term for all undomesticated[93] animals that live free in nature... (Morris, 1992: 2370).

As this analysis pertains to science knowledge for six-year-olds, a simple scientific definition was created for the purposes of analysing the Grade R science curriculum's representation of *wild animals*:

Wild animals: animals that roam around freely and feed, reproduce (have babies), and take care of themselves without the help of humans (based on and adapted from Morris, 1992: 671, 2370).

AI: 1. How does the Grade R curriculum describe the defining features of the concept *wild animals* as represented by the topic 'Wild Animals & Finding out about one wild animal' (C16), with regards to:

- Its attributes

The topics 'Wild animals' & 'Finding out about one wild animal' (DBE, 2011a: 21) clearly intend the teaching and learning of the attributes, habitat and behaviour of *wild animals.* The first topic statement, 'What is a wild animal?', signals the defining of *wild animals* but, in the absence of a simple scientific definition provided by the curriculum, the identification of the essential attributes of *wild animals* is left to the Grade R educator. While one educator may rely on her own empirical experiences and ideas to translate the statement into 'lions, tigers, elephants, snakes ...', another educator may consult a dictionary or encyclopaedic and provide six-year-olds with a simple scientific definition like the one above.

The representations in Workbooks 3 and 4 offer limited support for the internalising of *wild animal* in terms of essential attributes. The images of *wild animals* pertain mostly to one context i.e. animals in an African game reserve (DBE, 2012a: 42-43) and do not always portray the 'essence' of *wild animals*. The curriculum does not point out that *wild animals* can be *domesticated* in another context e.g. antelope farmed for venison, and crocodiles farmed for their hide on commercial game farms. The two page introduction to 'Wild animals' depicts thirteen unnamed wild animals e.g. elephant, monkey, rabbit, bird, and

[93] I.e. in contrast to domesticated: *Biology*. to control or adapt an animal or plant for human use or life with humans (Morris, 1992: 671).

crocodile, accompanied by three sentences (DBE 2012a: 42-43). The open-endedness of the first sentence, ‘Look at the picture and talk about the animals you see’, provides an opportunity for the Grade R educator to name and describe *wild animals* in terms of their unique features but the remaining sentences ‘Make the sounds that these animals make’ and ‘Which animals make loud noises?’ detract from the pedagogical potential of the first sentence. The image of a rabbit confuses because 1) many six-year-olds know rabbits as pets, and 2) the rabbit is also grouped with domesticated animals (DBE, 2012c: 46-47). The two activities that follow the introduction 1) a story of a baby elephant asking other animals for help, and a song that represents baby elephants as blue, dressed, and balancing as in a circus performance (DBE, 2011a: 44, 45) both undermine the ‘essence’ of *wild*. The depiction of *wild* and *domesticated animals* together (in a train) without differentiating between the two (DBE, 2012a: 45-46) confuses further. The introductory pages to ‘Creatures’ (DBE, 2012d: 32-33) and ’Sea animals’ (DBE, 2012c: 32-33) offer further opportunities for lifting out the essential attributes of *wild animals* but this depends on the Grade R educator making the difference between *wild* and *domesticated* explicit. In conclusion: the open-ended topic and workbook statements may prompt an educator into translating the Grade R science curriculum’s representation of *wild animals* into two or more essential attributes.

- The degree of specialisation of language

Although there are no specialised terms in ‘Wild animals & Finding out about one wild animal’ (DBE, 2011a: 21), the open-ended topic statements invite the introduction of scientific terms. The related workbook section ‘Wild animals’ (DBE, 2012c: 42-53), however, undermines language specialisation by not identifying the images on the introductory pages, omitting an explicit description of the attributes, and by using the colloquial terms ‘mama’ and ‘elephant folk’ (DBE, 2011a: 44-45) in place of the scientific ‘elephant cow’ and ‘herd of elephants’. Although ‘Creatures’ is an everyday term for ‘an animal, as distinct from a human being’ (Oxford, 2010: 274) and therefore does not relate directly to *wild animals*, it nevertheless contains related scientific terms such as ‘feathers’, ‘scales’, ‘’eagle’, ‘penguin’, ‘lizard’, ‘snake’ and ‘ostrich’ (DBE, 2012d: 32, 33, 35, 37). In conclusion: the Grade R science curriculum’s representation of *wild animals* may prompt the Grade R educator into representing *wild animals* in specialised terms.

• Relation of topic concept to other concepts

The Grade R science curriculum sequences, groups, co-locates and logically arranges the topic representing *wild animals* in terms of other concepts as follows:

- The topic concept 'Wild animals' & 'Finding out about wild animals' (C16) is positioned in the curriculum in relation to other *animal* topics i.e. 'Dinosaur' (C15), 'Birds' (C13) and 'Reptiles' (C14). However, *wild animals* is isolated from its conceptual counterpart *domesticated animals* as represented by 'Dairy farming' (C10) and 'Wool farming' (C11).
- 'Sea animals' (DBE, 2012c: 32-41) illogically introduces six-year-olds to the notion of *wild animals* before the introduction of 'Wild animals' (DBE, 2012c: 42-53).
- 'Sea animals' is confusing because it represents *wild* and *domesticated animals* in various contexts i.e. animals whose habitat is in or near the sea (e.g. octopus, whale, fish, seagull), freshwater animals (dragonfly, dove, frog), insects (butterfly, bee), humans and their pets engaged in activities at the seaside, and wild animals not common to the sea (bat, elephant). It rests on the educator to lift out and make the attributes of each explicit in relation to *wild animals*.
- 'Wild animals' (DBE, 2012c: 42-53) depicts *wild animals* such as a lion, zebra, tortoise, birds, octopus, insects, spiders and snails, in relation to *domesticated animals* such as pets and farm animals.
- One activity on 'count the insects ...' erroneously includes spiders (DBE, 2012c: 50).
- 'Creatures' (DBE, 2012d: 32-41) positions the concept *creature* in relation to *wild animals* because the images of reptiles, insects, worms, spiders, the penguin and ostrich are also represented in 'Wild animals' (DBE, 2012c).

In conclusion: the Grade R science curriculum represents the concept *wild animals* as an everyday concept in relation to other concepts because the representations are loosely arranged in terms of the systematic and logical ordering of the scientific knowledge continuum.

• Relation of topic concept representation to context

The Grade R's representation of *wild animals* is potentially transferable to other contexts if the educator 1) translates the questions in the topic 'Wild animals' (DBE, 2011a: 21) into essential attributes and scientific terms, and 2) clarifies the various representations of *domesticated* and *wild animal* in the Grade R workbooks (DBE, 2012c; DBE, 2012d).

In conclusion: The Grade R science curriculum's representation of *wild animals* pertains in part to the neo-Vygotskian notion of content knowledge because the open-ended topic questions and statements of C16 may prompt the educator into providing a simple scientific definition of *wild animals*.

AI: 2.How does the Grade R science curriculum describe the structure of the science knowledge concept *wild animals* with regards to the relation between content and procedural knowledge?

Having established the potential scientific content of the topic 'Wild animals' & 'Finding out about one wild animal', this section considers whether the related internalising activities function as procedural knowledge. Workbook 4 provides a single internalising activity (DBE, 2012d: 37) that pertains to the neo-Vygotskian idea that procedural knowledge involves classification and the law of equivalence. The activity, however, 'operates' with the essential attributes of 'Birds' (feather, lays eggs, two legs, beak) and 'Reptiles' (scaly skin, lays eggs, cold-blooded) and not the essential attributes of *wild animals* contained in the simple scientific definition i.e. 'roams freely, can feed, reproduce and care for itself'. In conclusion: the Grade R science curriculum does not, however, represent *wild animals* in terms of procedural knowledge.

AI: 3.How does the Grade R curriculum describe the science knowledge concept *wild animals* with regards to the relation between simple and complex concepts?

Depending on how the educator translates C16, the Grade R science curriculum representation of *wild animals* underpins, in principle, the following more complex school science concepts:

- In Grade 2 the concepts 'Animals and creatures that live in water' and 'Animal homes' (DBE, 2011a: 43) are potentially underpinned by the content derived from the Grade R topic question 'Where do we find wild animals?' (DBE, 2011a: 21). The idea of a general understanding being narrowed down to specific habitats appears contradictory but it relates to Davydov's notion of delimitation of a concept by the addition of attributes[94] (190: 20). The Grade 2 topic 'Life at night' is underpinned by the content potentially derived from Grade R statement 'Where do we find wild animals?' (DBE, 2011a: 21).

- In Grade 3 the Grade R topic concept *wild animals* potentially underpins the more complex science topics, 'Insects' and 'Life cycles' (DBE, 2011a: 55).

However, the simpler Grade 2 topic concept 'Animals' (DBE, 2011a: 43) reverses the notion of a simple concept underpinning a more complex one by preceding the more complex Grade R topics 'Wool farming', Dairy farming', 'Wild animals' and 'Finding out about one wild animal' (DBE 2011a: 20-21). The introduction of the Intermediate Phase[95] subject *Natural Sciences and Technology* (DBE, 2011b) further counters the notion of the simple underpinning the complex. Grade 4 introduces the concept *living* and *non-living things* (DBE, 2011b: 21) which precedes understanding *animal* in Grade R. The scientific notion of *human* as part of the animal kingdom is only made explicit in Grade 6 (DBE, 2011b: 58). In conclusion: the Grade R concept *wild animals* underpins more complex concepts, in part, in Grades 1-3.

Summary

The concept *wild animals* is represented in the Grade R science curriculum as a potential simple scientific concept. The reasons are as follows:

- The Grade R science curriculum sufficiently represents (≥ 5/12 ≤11/12) *wild animal* in terms of the six key features of a simple scientific concept.
- The open-ended topic questions and statements (C16) have the potential to prompt the Grade R educator into translating the curriculum representations in terms of a simple scientific concept.

[94] Discussed in the literature review

[95] Grades 4 -6

Table 4.4: Rating for the Grade R science curriculum representation of *wild animals*.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	1/2	0/2	1/2	0/2	1/2
RATING: 4/12 = Everyday concept					

4.2.4. Knowledge concept: Birds[96]

The concept, *birds,* is represented in the Grade R science curriculum by the following topic:

Topic: Birds – 2 hours

- Different types of birds
- General characteristics of a bird – feathers, two legs, beak, lays eggs
- Bird that cannot fly – ostrich, penguin
- Nests (DBE, 2011a: 21).

This topic (C13) and the related supporting activities (DBE, 2012c; DBE, 2012d) were analysed in terms of the following scientific definition:

> bird: *Vertebrate Zoology*. any of the many vertebrates in the class Aves; all are warm- blooded, lay eggs, and have wings and feathers, and most can fly (Morris, 1992: 264).

The following simple scientific definition for six-year-olds was compiled for the purpose of analysing the Grade R science curriculum's representation of *birds*:

> bird: Birds are a type of animal. Birds have feathers, a beak, and two wings. Most birds can fly. The female bird lays eggs. A bird is also a vertebrate – it has a skeleton made of bones inside its body just like reptiles, mammals and fish. Birds are warm-blooded; like mammals they have the ability to keep their blood at the same temperature regardless of the weather (based on and adapted from Morris, 1992: 264).

AI: 1. How does the Grade R curriculum describe the defining features of the concept *birds,* as represented by the topic 'Birds' (C13) with regards to:

- Its attributes

The Grade R science topic 'Birds' (DBE, 2011a: 21, is explicit in terms of the essential attributes of *birds*. The topic lists four attributes that *together* distinguish an animal as a bird i.e. 'feathers, two legs, beak, lays eggs'[97]. Three of these attributes are contained in the scientific definition of *bird* (Morris, 1992) but the curriculum 1) omits one defining attribute i.e. 'wings' and 2) emphasises an attribute that is not common to most birds by stating 'Birds that cannot fly – ostrich, penguin' (DBE, 2011a: 21).

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[96] This section extrapolates the example in Table 3.7 in Chapter 3

[97] Other animals lay eggs and have beaks (reptiles) and fly (insects) but not feathers. However, neither Morris (1992) nor Clugston (2009) identify feathers as unique to birds.

Although there is no related workbook section titled ‘Birds’ in the Grade R workbooks, the concept *birds* is well represented in Workbooks 3 and 4 in ‘Farm animals’ (DBE, 2012c: 22-31), ‘Sea animals’ (DBE, 2012c: 32-41), ‘Wild animals’ (DBE, 2012c: 42-53) and ‘Creatures’ (DBE, 2012d: 32-41). There are images of hens, a rooster, geese, ducks, eagles, doves, a seagull, parrots, penguins, small unidentifiable birds, ostriches, penguins, an owl, vulture, flamingo and stork. One workbook activity i.e. ‘Cut out these cards. Sort them into two groups, one group for birds and one group for reptiles’ (DBE, 2012d: 37) potentially lifts out the essential attributes of *birds* <u>if</u> the educator directs the sorting according to the topic statement ‘General characteristics of birds – feathers, two legs, beak, lays eggs’ (DBE, 2011a: 21). In conclusion: the Grade R science curriculum partially represents the concept *birds* in terms of two or more essential attributes.

- The degree of specialisation of language

According to a science dictionary (Morris, 1992) ‘Birds’ provides simple but scientifically acceptable terms such as ‘beak’ and ‘feathers’ (DBE, 2011a: 21). The topic statement ‘Types of birds’ (DBE, 2011a: 21) is likely to prompt the naming of birds but ,as the workbooks provide only five names i.e. ‘penguin’, ‘ostrich’, ‘duck’, ‘eagle’ and ‘dove’ (DBE, 2012d: 37), it rests on the educator to name the unidentified images. While one educator may employ an encyclopaedia or reputable field guide[98], another educator may name the images according to his or her own experiences or take the curriculum at face value and remain with the curriculum’s limited terms of description. In conclusion: the Grade R science curriculum represents the concept *birds,* in part, in terms of two or more specialised terms.

- Relation to other concepts

The Grade R science curriculum infers a relationship between *birds, animal and reptiles* by:

- Positioning the topic concept, ‘Birds’, adjacent to another related *animal* topic concept i.e. ‘Reptiles’ (DBE, 2011a: 21).
- Providing a classification activity that positions *reptiles* and *birds* in relation to one another as two types of *animals* (DBE, 2012d: 37).

However, the Grade R science curriculum partially isolates ‘Birds’ (and ‘Reptiles) by omitting the related *animal* topic concepts e.g. ‘Insects’, ‘Mammals’ and ‘Fish’. In conclusion: the

[98] E.g. the Roberts or Newman birding books, and/or the e-SASOL bird app for cell phones

Grade R science curriculum positions the concept *birds*, in part, in relation to other scientific concepts.

- Relation to context

The Grade R's representation of *birds* is transferable to other contexts. Although one attribute is omitted a child can identify a bird from other animals regardless of context by employing the attributes described in 'Birds' i.e. 'feathers ...beak, lays eggs' (DBE, 2011a: 21).

In conclusion: the Grade R science curriculum's representation of *birds* pertains, in part, to the neo-Vygotskian idea of scientific content knowledge by providing two or more transferable essential attributes couched in simple scientific terms.

AI: 2.How does the Grade R science curriculum describe the structure of the science knowledge concept *birds* with regards to the relation between content and procedural knowledge?

As the section above has established 'Birds' in terms of simple scientific content knowledge, this section considered whether the Grade R internalising activities function as procedural knowledge. The topic statements 'Types of birds', 'General characteristics of a bird – feathers, two legs, beak, lays eggs' and 'Nests' (DBE, 2011a: 21) are likely to prompt a Grade R educator into 1) naming different birds, 2) discussing the attributes of birds, and 3) describing the habitat and reproduction of certain birds. Procedural knowledge, on the other hand, is *the knowing what to do with the mental tool* i.e. 'operating' with the concept *birds* by classifying according to the essential attributes of *birds.* Workbook 4 provides a single activity, i.e. the sorting of nine pictures into *birds* and *reptiles* (DBE, 2012d: 37), that relates to procedural knowledge if the educator makes the classification criteria in 'Birds' (C13) explicit. In conclusion: the Grade R science curriculum represents the topic concept, 'Birds', in part, as content and procedural knowledge.

AI: 3.How does the Grade R curriculum describe the science knowledge concept *birds* with regards to the relation between simple and complex concepts?

The partial representation of essential attributes in 'Birds' (C13) is limiting but there is sufficient to underpin the following more complex science concepts:

- The concept of *bird habitat,* as in the Grade 2 topic 'Animal homes' (DBE, 2011a: 43).
- The Grade 3 topic concept 'Life cycles' and *bird* domestication as in the topic concept 'Animals and creatures that help us' (DBE, 2011a: 55, 57).
- The Grade 4 topic 'Living things and non-living things that share the world with us' as in 'Features of ...animals', 'Habitats of animals' and 'Animal shelters' (DBE, 2011b: 21-22). If the related technology project problem scenario, i.e. 'need for an animal shelter' (DBE, 2011b: 23), pertains to *birds*, then the design specifications will be underpinned by 'Birds' (C13) in Grade R.
- In part, the Grade 5 topic 'Biodiversity of living things' (DBE, 2011b: 40).
- The Grade 6 topic 'Animals with skeletons' (DBE, 2011b: 58).

In conclusion: In the absence of one essential attribute, the Grade R science curriculum's representation of *birds* underpins, in part, more complex science concepts in the Foundation and Intermediate Phase grades.

Summary

After bringing the three analytic indicators to bear on the Grade R topic 'Birds' (C13) and related internalising activities (DBE, 2012c; DBE, 2012d), the conclusion is that the Grade R science curriculum represents the concept *birds* in terms of a potential scientific concept. The reasons are as follows:

- The Grade R science curriculum sufficiently represents (≥ 5/12 ≤11/12) *birds* in terms of the six key features of a simple scientific concept.
- The Grade R representation of *birds* has the potential to prompt the Grade R educator into translating the curriculum representations in terms of a simple scientific concept.

Table 4.5: Rating for the Grade R science curriculum representation of *birds*

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	1/2	1/2	1/2	1/2	1/2
RATING: 6/12 = Potential scientific concept					

4.2.5. Knowledge concept: Reptiles

The concept *reptiles* is represented in the Grade R science curriculum by the following two topics (C14, C15):

Topic: Reptiles – 2 hours

- Different reptiles – e.g. crocodile, snake, lizard
- Characteristics of reptiles – cold-blooded, scaly body, lays egg
- Find out more about at least one reptile (DBE, 2011a: 21).

Topic: Dinosaurs[99] – 2 hours

- Different dinosaurs
- How dinosaurs lived
- How we know about dinosaurs today

Note: use picture books from the library (DBE, 2011a: 21).

These topic statements (C14, C15) and the related supporting activities were analysed in terms of the following two scientific definitions[100]:

> Reptile: *Vertebrate Zoology*. any cold-blooded vertebrate animal belong to the class Reptilia including extinct dinosaurs as well as crocodilians, turtles, lizards, snakes, amphisbaenids[101] and tuatara (Morris, 1992: 1836).
>
> Reptila: *Vertebrate Zoology.* the reptiles, a class of aquatic or terrestrial, cold-blooded vertebrates having bodies covered with horny scale or plates, breathing by means of lungs, and usually laying eggs outside the body (Morris, 1992: 1836).

The following simple scientific definition for six-year-old was created for the purpose of analysing the Grade R science curriculum's representation of *reptiles*:

> Reptile: A reptile is an animal. Reptiles live on land and in water. All reptiles have scaly bodies, breathe air and lay eggs. A reptile is also a vertebrate – it has a skeleton made of bones inside its body just like birds, mammals and fish. Reptiles are cold-blooded like fish; their body temperature depends on the conditions around them. Dinosaurs are extinct reptiles. Today's reptiles include crocodiles, tortoises, turtles, lizards, and snakes (based on and adapted from Morris, 1992: 1836).

AI: 1. How does the Grade R curriculum describe the defining features of the concept *reptiles* as represented by the topics 'Reptile' (C14) and 'Dinosaurs' (C15), with regards to:

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99 'Dinosaurs: *Palaeontology*. a general name for two orders of extinct reptiles ...' (Morris 1992: 646).

100 Both definitions were used as each contributed in different ways to the simple scientific definition of *reptile.*

101 'A suborder of reptiles that comprises the worm lizards' (Oxford, 2010: 36).

• Its attributes

The Grade R science topic ‘Reptiles’ describes three essential attributes that together distinguish an animal as a *reptile* i.e. ‘cold-blooded, scaly body, lays eggs’ (DBE, 2011a: 21). All of these attributes are represented in the scientific definition ‘Reptilia’ (Morris, 1992: 1836). ‘Dinosaurs’ (DBE, 2011a: 21) is not described in terms of essential attributes but the juxtaposition of the two curriculum topics suggests that ‘Dinosaurs’ is an extension of ‘Reptiles’ and therefore the ‘characteristics’ described in ‘Reptiles’ pertain to ‘Dinosaurs’. This suggestion relies, however, on the Grade R educator understanding *dinosaur* in terms of an *extinct reptile*. In conclusion: the Grade R science curriculum represents the topic concept ‘Reptiles’ in terms of two or more essential attributes.

• The degree of specialisation of language

The topic ‘Reptile’ (C14) is represented in terms of a simple scientific description and terms that are scientifically acceptable (Morris, 1992) i.e. ‘Characteristics of reptiles – cold- blooded, scaly body, lays egg’ (DBE, 2011a: 21).

This scientific stance is, however, countered in Workbooks 3 and 4 (DBE, 2012c; DBE, 2012d) as follows. A single new term is added i.e. ‘chameleon’ because the workbooks omit to name most of *reptile* images. In lieu of the scientific terms ‘extinct’, ‘reptile’ and ‘dinosaur’, Workbook 4 describes the images of a dinosaur as ‘... an animal that we do not have on earth any more’ (DBE, 2012d: 39). In conclusion: the Grade R science curriculum represents *reptiles,* in part, in specialised terms.

• Relation to other concepts

The Grade R science curriculum implies a relationship between *reptiles* and other simple science concepts in three ways:

- The topics concepts, ‘Reptiles’ and ‘Dinosaurs’, are located between ‘Birds’ and ‘Wild animals’ & ‘Finding out about one wild animal’ (DBE 2011a: 21) which indicates there is a relationship in terms of *animal.*
- A single classification activity in Workbook 4 establishes *reptiles* and *birds* as two related groups in terms of *animals* (DBE, 2012d: 37).
- The illustrated introduction to ‘Creatures’ in Workbook 4 relates *reptiles* to *animal, birds* and *fish* by grouping the following statements together:

> Look at the picture and talk about the different kinds of animals
> you can see.
> Which animals have feathers?
> How do they feel?
> Which animals have scales? How
> do they feel?
> Which animals can fly? Which
> animals can swim?
> How many eggs can you see? (DBE, 2012d: 33).

However, this introduction confuses in two ways. Depicting images of 'eggs' only in relation to *bird*[102] contradicts the statement 'Characteristics of reptiles – cold-blooded, scaly body, lays egg' (DBE, 2011a: 21). Mixing the non-essential attributes 'swim' and 'fly' with the essential attributes 'feather' and 'scales' undermines understanding a concept's relations to other science concepts in terms of essential attributes.

Although Workbook 3's 'Wild animals' (DBE, 2012c: 42-53) and Workbook 4's 'Creatures' (DBE, 2012: 32-41) both represent *reptiles* they are dislocated from one another in the following ways. Three unrelated topics, i.e. 'About time', 'About town' and 'Sport' (DBE 2012d: 2- 31) are positioned between 'Wild animals' and 'Reptiles'. *Reptiles* in 'Wild animals' are introduced in Term 3 while r*eptiles* in 'Creatures' are introduced in Term 4. Moreover, the curriculum illogically introduces the topic 'Reptiles' in the middle of Term 4 after the children have completed the workbook section on 'Wild animals' in Term 3. 'Reptiles' relations to other concepts are weakened by the absence of explicit explanations and cross referencing to related concepts, and by structuring 'Dinosaurs' (C15) and 'Reptiles'(C14) as two topic concepts. It rests on the educator to make the relation between 'Reptiles' and other science concepts explicit. In conclusion: the Grade R science curriculum positions the concept *reptiles,* in part, in relation to other science concepts.

- Relation to context

The Grade R topic concept *reptiles* is transferable to other contexts because the topic 'Reptiles' (C14) contains two or more essential attributes and scientific terms that 1) are

[102] There are no images of a reptile with eggs

acceptable to most scientists and 2) can be used to identify a *reptile* from other objects regardless of context.

In conclusion: the Grade R representation of *reptile* relates closely to the neo-Vygotskian notion of content knowledge by providing two or more transferable essential attributes and representing *reptiles* in specialised terms.

AI: 2.How does the Grade R science curriculum describe the structure of the science knowledge concept *reptiles* with regards to the relation between content and procedural knowledge?
The topic 'Reptiles' (C14) signals a scientific stance to internalising the concept *reptile* as a simple scientific concept by describing all the essential attributes in scientific terms and stating 'Find out more about at least one reptile' (DBE, 2011a: 21).

The related Grade R workbooks are, however, less rigorous in their approach to the internalisation of *reptiles*. There is no section dedicated to 'Reptiles'. The activities related to the acquisition of *reptiles* are integrated into Workbook 3's 'Wild animals' (DBE, 2012c: 42-53) and Workbook 4's 'Creatures' (DBE, 2012d: 32-41). The workbook representations are discussed below:

- Of the sixteen unidentified animals depicted in the two-page illustrated introduction to 'Wild animals', three are reptiles[103] (DBE, 2012c: 42-43). These images, in relation to the accompanying text 'Look at the picture and talk about the animals you see', have the potential to prompt the Grade R educator into describing the images in terms of the essential attributes listed in 'Reptiles' (C14). However, the remainder of the section 'Wild animals' pertains to mathematics and literacy activities (DBE 2012c: 44-53) which portray *reptiles* in everyday terms e.g. the image of a tortoise in a train embraced by a hippopotamus (DBE, 2012c: 46) counters the introduction's image of a solitary tortoise in its characteristic habitat (DBE, 2012c: 42).
- The two-page introduction to 'Creatures' is more representative of *reptiles* (DBE, 2012d: 32-33). The directive 'Look at the picture and talk about the different kinds of animals you can see' in relation to the images of chameleons, lizards, tortoises, crocodiles and snakes is likely to prompt a discussion on *reptiles*. The introduction,

[103] The other animals are either mammals or birds

however, lacks conceptual clarity because 1) the reptiles are integrated with a mammal (aardvark), an amphibian (frog), and eleven kinds of birds in the absence of naming or grouping according to type, and 2) there is a single question that relates to *reptile* and it pertains to only one of the three essential attributes i.e. ‘Which animals have scales?’ A single activity (DBE, 2012d: 37) pertains, in part, to the neo-Vygotskian notion of ‘operating’ with the concept by asking children to sort picture cards into *reptiles* and *birds*. As the activity omits the classification criteria, it rests on the Grade R educator to make the essential attributes in ‘Reptiles’ (C14) explicit. A single activity page represents *dinosaur* (DBE, 2012d: 39). Realising this activity’s scientific potential depends on the Grade R educator 1) providing the term ‘dinosaur’, 2) replacing the activity description of a dinosaur as ‘an animal we do not have on earth any more’ with the term ‘extinct reptile’, and 3) making the essential attributes of *reptiles* explicit*.* Furthermore, the activity’s scientific potential is watered down by employing the images of *dinosaur* for the development of number and colour recognition, fine motor and visual perceptual skills as in ‘Join the dots to draw an animal...then colour (by numbers) in your picture ... Cut out the puzzle and then try to build it again’ (my insert in brackets, DBE, 2012d: 39).

In conclusion: the Grade R science curriculum’s represents *reptiles*, in part, in terms of the neo-Vygotskian notion of procedural knowledge.

AI: 3.How does the Grade R curriculum describe the science knowledge concept *reptiles* with regards to the relation between simple and complex concepts?

The Grade R topic ‘Reptiles’ (DBE, 2011a: 21) underpins the following more complex scientific concepts:

- Knowing that reptiles are cold-blooded, have scaly bodies, and lay eggs (DBE, 2011a: 21) underpins understanding the habitat of the crocodile, snake and tortoise in the Grade 2 topics ‘Animals and creatures that live in water’ and ‘Animal homes’ (DBE, 2011a: 43).
- ’Reptiles’ in Grade R underpins, in part, the Grade 4 topic content ‘Features of ...animals’, ‘Habitats of animals’, and ‘Animal shelters’ (DBE, 2011b: 21-22), the Grade 5 topic ‘Biodiversity of living things’ (DBE, 2011b: 40), and the Grade 6 topic

‘Animals with skeletons’ (DBE, 2011b: 58).

- The Grade R knowledge acquired in Grade R from ‘Find out more about at least one reptile’ (DBE, 2011a: 21) potentially underpins ‘Habitat for... animals’ in the Grade 6 topic ‘Environment and water resources’ (DBE, 2011b: 56).
- If represented by the educator in terms of *extinct reptile,* ‘Dinosaurs’ and ‘Reptiles’ (DBE, 2011a: 21), underpin, in principle, the Grade 5 topic ‘Fossils’ as in ‘Remains of living organisms that lived long ago’ (DBE, 2011b: 43).

In conclusion: the Grade R science curriculum’s representation of the concept *reptiles* underpins more complex school science concepts.

Summary

After bringing the three analytic indicators to bear on the Grade R topics, ‘Reptiles’ (C14) and ‘Dinosaurs’ (C15), and related internalising activities (DBE, 2012c; DBE, 2012d)*,* the conclusion is that the Grade R science curriculum concept *reptiles* is represented as a potential simple scientific concept. The reasons are as follows:

- The Grade R science curriculum sufficiently represents (≥ 5/12 ≤11/12) *reptiles* in terms of the six key features of a simple scientific concept.
- The Grade R representation of *reptiles* has the potential to prompt the Grade R educator into translating the curriculum representations in terms of a simple scientific concept.

Table 4.6: Rating for the Grade R science curriculum representation of r*eptiles*

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
2/2	1/2	1/2	2/2	1/2	2/2
RATING: 9/12 = Potential scientific concept					

4.2.6. Knowledge concepts: Fruit and vegetables

The Grade R topic concepts, 'Fruit' (C8) and 'Vegetables' (C9), below were analysed together to avoid repetition as the curriculum represents the concepts *fruit* and *vegetables* in similar ways and in relation to one another:

Topic: Fruit – 2 hours

- Different types of fruit
- Tastes and textures of fruit
- Where fruit comes from

Colours and shapes of fruit (DBE, 2011a: 19).

Topic: Vegetables – 2 hours

- Different types of vegetables
- Tastes and textures of vegetables
- Where vegetables come from

Colours and shapes of vegetables (DBE, 2011a: 20).

The topics (C8, C9) and related supporting activities were analysed in relation to the following scientific definitions:

> Fruit: *Botany*. the fully matured ovary of a seed plant, including the seed or seeds, connecting tissues, and any covering (Morris, 1992: 888).
>
> Vegetable: *Botany*. of or relating to plants (Morris, 1992: 2321).

These scientific definitions were translated into simple scientific definitions appropriate for six-year-olds for the purpose of analysing the Grade R science curriculum's representation of *fruit* and *vegetables*:

> Fruit: In some plants the ovary of the plant grows into a fruit after the flower has died. Fruit usually contains the seeds of the plant. Examples of fruit are tomatoes, apples, avocado pears, beans, oranges (based on and adapted from Morris, 1992: 888).
>
> Vegetable: when botanists talk about plants they use the word 'vegetable' e.g. 'A compost heap contains *vegetable* matter' (based on and adapted from Morris, 1992: 2321).

AI: 1. How does the Grade R curriculum describe the defining features of the concepts *fruit* and *vegetables* as represented by the topics 'Fruit' (C8) and 'Vegetables' (C9), with regards to:

- Its attributes

The topic title 'Fruit' (C8) may prompt a simple scientific definition *fruit* in terms of two or more attributes but the Grade R's representation of *vegetables* pertains to an everyday concept because it does not relate to the scientific definition (Morris, 1992: 2321). Realising

fruit in terms of simple scientific definition and understanding that 'Vegetables' (C9) pertains an everyday concept depends on the Grade R educator's own knowledge and understanding of science for six-year-olds. In the absence of a simple scientific definition it is likely that everyday experience and observation will inform the topic statements 'Different types of fruit' (DBE, 2011a: 19) and 'Different types of vegetables' (DBE, 2011a: 20). In other words, the educator and children are likely to name the familiar sweet and edible apple, banana, orange, and pear as 'fruit', and the familiar edible onion, carrot, bean
and peas as 'vegetables'[104]. This everyday identification of *fruit* and *vegetables* is supported by the empirical topic statements i.e. 'Tastes and textures of fruit' and 'Colours and shapes of fruit' (DBE, 2011a: 19), and 'Tastes and textures of vegetables' and 'Colours and shapes of vegetables' (DBE, 2011a: 20).

Although there are no workbook sections dedicated to 'Fruit' and 'Vegetables', the two topic concepts are made more explicit in Workbook 3's 'On the farm' (DBE, 2012c). The images of plant cultivation depicted in the introduction, the open-ended directive 'Look at the picture and talk about what you see', and the question 'What fruit can you see in the picture?' (DBE, 2012c: 12-13) may prompt the Grade R educator into defining *fruit* in simple scientific terms. 'Vegetables' is similarly represented but the representation of *vegetable* is unlikely to prompt a scientific definition as in Morris (1992). Workbook 3 provides a single classification activity (DBE, 2012c: 15) but in the absence of a simple scientific definition the children are likely to sort the sixteen images in terms of their everyday understanding of *fruit* and *vegetables.* The activity is also erroneous in scientific terms because according to Morris (1992) some *fruits* e.g. pumpkin and peas are represented as *vegetables*.

With the exception of the three pages in Workbook 3 (DBE, 2012c: 12, 13, 15) the images of fruit and 'vegetables' in the four Grade R workbooks are employed for facilitating:

- mathematics (DBE, 2012a: 10, 29, 41; DBE, 2012b: 20, 50-53; DBE, 2012c: 13, 19-21; DBE, 2012d: 20-21, 38, 51, 53),

[104] During a sorting activity, all 25 ECD practitioners identified the tomato, bean, avocado pear, and pumpkin as 'vegetables'. When provided with a definition of *fruit* the students quickly relocated the items to 'Fruit' (observed by the researcher in 2012 whilst facilitating a Level 4 ECD training session at the Early Learning Resource Unit).

- language (DBE, 2011b: 8, 25, 48; DBE, 2012c: 9, 14, 15; DBE, 2012d: 17, 35), and
- perceptual and fine motor skills (DBE, 2012a: 35, 36, 46; DBE, 2012b: 47; DBE, 2012c: 12-13).

In conclusion: the Grade R science curriculum representation of *fruit* has the potential to prompt an educator into proving a simple scientific definition. According to the science dictionary (Morris, 1992), the curriculum represents *vegetables* as an everyday concept.

• The degree of specialisation of language

The Grade R science curriculum's represents *fruit* and *vegetables* in everyday terms that relate to most young children's observations and experiences e.g. 'Tastes and textures of fruit' (DBE, 2011a: 19) and 'Colours and shapes of vegetables' (DBE, 2011a: 20).

• Relation of topic concept to other concepts

The Grade R science curriculum clearly positions Fruit' (C8) and 'Vegetables' (C9) in relation to one another by co-locating the topics in the curriculum and describing each in similar terms. If 'Fruit' is represented in terms of a simple scientific definition, 'Fruit' has the potential to relate to *domesticated animals. '*Vegetable*s'* on the other hand is represented as an everyday construct and cannot be positioned in relation to other scientific concepts.

• Relation of topic concept representation to context

If defined in terms of its essential attributes, 'Fruit' is transferable to other scientific contexts. As an everyday concept 'Vegetables' is context-dependent and cannot be transferred to other scientific contexts.

In conclusion: the Grade R science curriculum's representation of the concept *fruit* has the potential to prompt an educator into representing 'Fruit' (C8) in terms of the neo-Vygotskian idea of content knowledge as represented by AI: 1. The Grade R curriculum represents *vegetables* as an everyday concept.

AI: 2.How does the Grade R science curriculum describe the structure of the science knowledge concept *fruit* with regards to the relation between content and procedural knowledge?

As the concept *fruit* is potentially represented in terms of content knowledge, this section considers the related internalising activities in terms of the neo-Vygotskians' idea of procedural knowledge. Workbook 3 contains a single activity that potentially relates to the neo-Vygotskian idea of 'operating' with the concept because it directs children towards classifying according to *fruit* i.e. 'Paste the fruit and vegetables in the correct column ...'

(DBE 2012c: 15). However, realising this potential depends on the Grade R educator 1) changing the term ‘Vegetables’ at the top of the column to ‘Not fruit’ because *vegetable* does not exist as a scientific concept, and 2) providing the essential attributes of *fruit* so that the children can use them as a tool for classifying the pictures into ‘Fruit’ and ‘Not fruit’. This potential is however undermined by the topic statements ‘Tastes and textures of fruit’ and ‘Colours and shapes of fruit’ (DBE 2011a: 19) which direct the children towards sorting according to the non-essential attributes of fruit. In conclusion: the Grade R science curriculum represents *fruit,* in part, in terms of content knowledge but not procedural knowledge. In terms of ‘Vegetables’; in the absence of content knowledge procedural knowledge does not exist.

AI: 3.How does the Grade R curriculum describe the science knowledge concept *fruit* with regards to the relation between simple and complex concepts?

The Grade R topic concept ‘Fruit’ (C8) underpins the following empirical concepts[105] in the Foundation Phase: the Grade 1 topic ‘Healthy habits’ (DBE, 2011a: 30), the Grade 2 topics ‘What we need to live’ and ‘Healthy Living’ (DBE, 2011: 42), and the Grade 3 topic ‘Healthy living’ (DBE, 2011a: 55).

The introduction of simple scientific concepts in the Intermediate Phase science curriculum (DBE, 2011b) counters the idea of ‘Fruit’ (C8) underpinning more complex science concepts. As *plant* subsumes the notion of *fruit,* it is illogical to position the following topic concepts after the Grade R topic concept ‘Fruit’:

- The Grade 4 topic ‘Living and non-living things that share the world with us’ as in the statement ‘Basic structure of plants: roots, stems, leaves, flowers, fruits, seeds’ (DBE, 2011b: 21).
- The Grade 5 topic, ‘Biodiversity of living things’, as in the topic content ‘Plant lifecycle’ statements ‘- flowering, pollination, fruiting and seed dispersal’ (DBE, 2011b: 40).

In conclusion: the Grade R topic concept ‘Fruit’ underpins other everyday concepts but not more complex school science concepts.

[105] Factually correct within a particular context e.g. ‘Healthy habits’ - eating lots of fat may be considered as ‘Eating healthy food’ (DBE, 2011a: 30) by the Inuit people but it is generally recognised in South Africa as an unhealthy habit.

Summary

After bringing the three analytic indicators to bear on the Grade R topics and activities representing the concepts *fruit* and *vegetables* the following was concluded. The Grade R science curriculum represents both as everyday concepts. The reasons are as follows:

- The Grade R science curriculum insufficiently represents (≤ 4/12) *fruit* and *vegetables* in terms of the six key features of a simple scientific concept
- According to the scientific definition of *vegetable* (Morris, 1992), the Grade R science curriculum representation of *vegetables* pertains to a common term that is in everyday use.

Table 4.7: Rating for the Grade R science curriculum representation of *vegetables*.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
0/2	0/2	0/2	0/2	0/2	0/2
RATING: 0/12 = Everyday concept					

Table 4.8: Rating for the Grade R science curriculum representation of *fruit*.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	0/2	1/2	1/2	0/2	0/2
RATING: 3/12 = Everyday concept					

The analysis, which has, until now, pertained to the Life sciences topic concepts, moves to the Grade R's representation of the following physics[106] concepts i.e. *shape, colour, water, time, transport* and *summer, autumn, winter and spring.*

[106] Physics: 'the scientific study of matter, energy, motion and force (Morris, 1992: 1643).

4.2.7. Knowledge concept: *Shape* and *colour*

To avoid repetition the topic concepts, *shape* and *colour,* were analysed in relation to one another. Both concepts are represented by one topic (C3), and *colour* and *shape* are mostly represented in relation to one another in the Grade R workbooks e.g. colouring in the triangles, circles and squares.

The concepts *shape* and *colour* are represented in the Grade R science curriculum by the following topic (C3):

Topic: Shapes and colours around us – 2 hours

- Look at and name different shapes
- The shapes that make up different objects
- Look at and name the different colours
- Shades of colours – e.g. light, dark (DBE, 2011a: 16).

As the first two statements pertain to *shape* and the third and fourth to *colour,* discussions on the Grade R science curriculum's representations generally begin with *shape* followed by *colour*.

The Grade R science curriculum's representation of *shape* was translated for this analysis into the concepts *triangle, square,* and *circle.* The reasons are as follows:

- There was no scientific definition available for *shape* or *form,* a concept that potentially could stand in place of *shape* (Morris, 1992). Although this points to *shape* as an everyday concept, the Grade R curriculum clearly intends the learning of two dimensional 'shapes' as the *triangle, circle* and *square* are well represented in the four Grade R workbooks.
- The topic statement 'shapes that make up different objects' (DBE, 2011a: 16) implies s*phere, pyramid* and *cube* but these are not represented in the Grade R science curriculum.
- The Grade R curriculum clearly intends the learning of *triangle, square,* and *circle* as 'shapes' in the subject *Mathematics* (DBE, 2011c).

Shape and *colour* are understood by most scientists as:

> Triangle: *Mathematics.* a plane polygon with three sides; equivalently, a plane polygon with exactly three (noncollinear) vertices (Morris, 1992: 2259).
>
> Square: *Mathematics.* 1. a quadrilateral having all four sides and all four angles equal; ... (Morris, 1992: 2070).
>
> Circle: *Mathematics.* 1. a plane curve consisting of all points a fixed distance from a given point... (Morris, 1992: 433).
>
> Colour: *Optics*. 1. The sensation, determined by wavelength, that is generated by light in the visible spectrum. 2. The characteristic of light that produces specific degrees of hue, saturation and brightness... (Morris, 1992: 469).

For this analysis the above scientific definitions were translated into simple scientific definitions that six-year-olds can understand:

Triangle: a flat (two dimensional) geometric shape that has three straight sides and three angles (based on and adapted from Morris, 1992: 2259).

Square: a flat (two dimensional) geometric shape that has four equal straight sides and four equal angles (based on and adapted from Morris, 1992: 2070).

Circle: a flat (two dimensional) geometric shape made up of a continuous line that is the same distance away from the point in the middle of the circle (based on and adapted from Morris, 1992: 433).

Colour: the different kinds of reflected light that the human eye can see are found in the colours of a rainbow. There are three primary colours, red, blue and yellow; all the other colours are made by mixing these three colours. We can also see black and white but they are not considered to be colours (based on and adapted from Morris, 1992: 469).

AI: 1. How does the Grade R curriculum describe the defining features of the concepts *shape* and *colour* as represented by the topic 'Shapes and colours around us' (C3), with regards to:

- Its attributes

The Grade R topic 'Shapes and colours around us' (C3) is likely to prompt educators into describing *triangle, square* and *circle* and *colour* in everyday terms. The reasons are as follows. The first statement 'Look at and name shapes' directs the educator to focus on the visible features instead of the essential attributes that uniquely define *triangle, square* and *circle*. In place of the scientific, 'We know a shape is a triangle because it has three straight sides and three angles', the topic statement is likely to prompt educators into pointing to an image of a triangle and asking the children 'What shape is this?' The second statement, 'The shapes that make up different objects', is not explicit in terms of *sphere, pyramid* and *cube.* The Grade R workbooks also do not support the acquisition of *triangle, sphere* and *cube* in terms of their essential attributes. The images of three dimensional objects are used to facilitate mathematical concepts e.g. matching objects in a one to one correspondence activity (DBE, 2012b: 46).

In terms of *colour*, the third and fourth topic statements, 'Look at and name the different colours' and 'Shades of colours – e.g. light, dark' (DBE 2011a: 16), pertain, in part, to the simple scientific definition statement 'the different kinds of reflected light that the human eye can see are found in a rainbow'. There are eight workbook activities that refer to or imply the attributes of *colour* by either naming some of the colours on the spectrum or representing the colour spectrum as a rainbow (DBE, 2012a: 28, 36, 44, 50; DBE, 2012b: 16, 43, 44; DBE, 2012d: 39).

In conclusion: the Grade R science curriculum topic concept, ' 'Shapes and colours around us' (C3), is not likely to prompt the Grade R educator into translating the term 'shape' into simple scientific definitions of *triangle, square* and *circle*. The Grade R science curriculum represents, in part, the essential attributes of *colour.*

• The degree of specialisation of language

In terms of 'shape' the Grade R science curriculum provides the scientific term 'object' (DBE, 2011a: 16) and two workbooks employ the terms *triangle, square,* and *circle* (DBE, 2012b: 16; DBE, 2012c: 28). In terms of 'colour' the Grade R science curriculum topic 'Shapes and colours around us' (C3) employs the terms 'Shades', 'light', and 'dark' (DBE, 2011a: 16). The Grade R workbooks refer to individual *colours* e.g. 'red', 'green' (DBE, 2012a: 44) and use the term 'rainbow' (DBE, 2012d: 49). However, in terms of learning new knowledge the terms are likely to be familiar to many six-year-olds. In conclusion: the Grade R science curriculum describes *colour* and *triangle, square,* and *circle,* in part, in specialised terms.

• Relation of topic concept to other concepts

Empirically 'shape' and 'colour' relate to one another in terms of a visible material property. However, in scientific terms, co-locating *colour* and 'shape' as *triangle, square and circle* is confusing because the two do not relate. *Colour* pertains to physics whereas *triangle, square and circle* pertain to mathematics. In terms of co-location, ‘Shapes and colours around us’ is isolated between ‘Summer’ (C2) and the *Personal and Social Well-being* topic ‘Home’ (DBE, 2011a: 17). The early introduction of ‘Shapes and colours around us’ (C3) in Term 1,is logical in empirical terms to the topic concepts ‘Sight’ and ‘Touch’ (C1.2; C1.3), and ‘Fruit’ (C8) which narrows down to ‘Colours and shapes of fruit’ (DBE, 2011a: 19). In conclusion: the Grade R science representations of *colour* and *triangle, square, circle* relate empirically to each other and other concepts.

- Relation of topic concept representation to context

The Grade R curriculum’s representation of ‘shape’ as *triangle*, *square* and *circle* is not, in the absence of essential attributes, transferable to other science contexts. The Grade R partial representation of the essential attributes of *colour* i.e. ‘rainbow’, ‘red’, ‘blue’, ‘green’, ‘yellow’ and ‘orange’, is transferable, in part, to other scientific contexts.

In conclusion: the Grade R science curriculum’s representation of the concept *colour* relates, in part, to the neo-Vygotskian’s notion of content knowledge in terms of specialised terms and transferable attributes. In the absence of essential attributes the Grade R science curriculum’s representation of ‘shape’ as *triangle, square,* and *circle* pertains to everyday knowledge.

AI: 2. How does the Grade R science curriculum describe the structure of the science knowledge concept *colour* with regards to the relation between content and procedural knowledge?

In the absence of content knowledge the internalising activities for *triangle, square,* and *circle* cannot function as procedural knowledge. As the Grade R curriculum represents *colour,* in part, as content knowledge, this section focuses on describing the internalising activities for *colour.* There are 62 *colour* internalising activities in the workbooks but only nine relate to the neo-Vygotskian notion of procedural knowledge as ‘operating’ with the concept (DBE, 2012a: 36, 44. 50; DBE, 2012b: 7, 36, 43, 44, 47; DBE, 2012d: 39). Table 4.7.2 provides three examples that illustrate how the workbook *colour* activities relate, in part, to procedural knowledge by being too simple for most six-year-old and not employing classification.

Table 4.9: Colour activities that function, in part, as procedural knowledge

Essential attributes of colour	Examples of workbook activities that potentially function as procedural knowledge
Colour: the different kinds of reflected light that the human eye can see are found in the colours of a rainbow.	1. 'Draw a red apple ... Draw an orange orange ...Draw a green balloon... Draw a blue pencil' (DBE, 2012a: 36). 2. 'Colour in this picture. Copy the colours from the small picture' (DBE, 2012a: 44). (each picture includes a rainbow of which one is coloured) 3. Trace the dots to complete the picture and then colour it in' (DBE, 2012a: 50). (The picture includes a rainbow that is partially coloured in as a guide)

The analysis also established that 1) the workbook activities integrate *colour* with t*riangle, square,* or *circle* 'shape'*,* and 2) the primary function of *colour* and *shape* is the internalising of other concepts and skills. Table 4.7.2 points out the extent[107]:

[107] The term 'shape' is used in the Table 4.7.2. as a 'shortcut' to stand in place of *triangle, square, circle*

Table 4.10: The internalising role of *colour*

Workbook pages related to *colour*	Concepts and skills	Examples of workbook activities
DBE, 2012a: 2, 3, 13, 23, 43. DBE, 2012b: 2-6, 13, 16, 26, 43. DBE, 2012c: 3, 7, 12, 13, 22, 23, 35, 43. DBE, 2012d: 12, 13, 22, 23, 32, 33, 39.	Visual discrimination One to one correspondence in terms of 'shape' Fine motor control	Matching 'shape' and colour: Stickers are matched to an identical coloured and shaped picture to foreground science content knowledge. For example: in the introduction to 'Wild animals' (DBE, 2012c: 43) the directive 'Paste the sticker in the correct spaces' requires a sticker of an elephant to be matched to a faded identical picture. Colouring in after joining the dots to make an outline of a dinosaur (DBE, 2012d: 39)
DBE, 2012a: 11, 21, 34, 37, 39, 40, 45, 48. DBE, 2012b: 11, 21, 31-35, 37, 41, 53. DBE, 2012c: 13, 15, 28, 47. DBE, 2012d: 8, 25, 52.	Number One to one correspondence Symmetry Pattern Classification Spatial relations Basic mathematical concepts	Matching and colouring in circles, squares or triangles to the numbers 1, 2 and 3 (DBE, 2012a: 40). Matching a coloured 'shape' to another similar colour and 'shape' Copying coloured 'shapes' so that they match 'shapes' on the other half of an object e.g. wing of a butterfly (DBE, 2012b: 21) Extending the pattern of coloured 'shapes' (DBE, 2012a: 39) Sorting and matching coloured freeform stickers (DBE, 2012b: 34-35). Matching stickers in terms of positions 'on top', 'inside', next to, 'in front' (DBE, 2012b: 41) Matching a sticker to a faded picture in 'big and small' and in 'front and back' (DBE, 2012b: 32-33).

In conclusion: the Grade R science internalising activities for *colour* pertain, in part to the neo-Vygotskian notion of content and procedural knowledge as two integral parts of a simple scientific concept. The curriculum's representation of 'shape' as t*riangle, square,* or *circle* is insufficient in terms of content knowledge and procedural knowledge.

AI: 3. How does the Grade R curriculum describe the science knowledge concept *colour* with regards to the relation between simple and complex concepts?

This section, like the one above, pertains to *colour* in the absence of content knowledge for 'shape' i.e. t*riangle, square,* or *circle*. The Grade R topic concept *colour* underpins two types of more complex concepts:

1) Empirical concepts i.e. everyday concepts that are factually correct within a particular context i.e.:

- The Grade 1 topic: 'Picture maps' as in interpreting the meaning that humans give to different colours in the statement 'Finding places and things on a picture map' (DBE, 2011a: 32).
- The Grade 2 topics: 'Road safety' as in interpreting *colour* with regards to 'Road signs for pedestrians and cyclists', and 'Our country' as in the topic statements 'A map of South Africa' and 'South African flag – include recognising the flag ... (DBE, 2011a: 44-45).

2) School science concepts i.e. 'settled' concepts that are acceptable to most scientists:

- The Grade 4 topics: 1) 'Living and non-living things that share the world around us' as in the topic content statement 'Features of plants and animals' which states 'Visible differences between plants ...' and 'Visible differences between animals ...' (DBE, 2011b: 21), and 2) 'Materials' as in the topic content 'Properties of materials' which states 'Descriptions of materials' (DBE, 2011b: 24).
- The Grade 5 topics: 'Energy we can see, hear and feel' as in the content statements 'Light: Energy we can see' (DBE, 2011b: 36), and 'Senses in animals and humans' as in the content statement 'Stimulation of the sense organs: - eyes: light' (DBE, 2011b: 44).
- The Grade 6 topics: 'Solar system' as in the content statements '- The Sun is a source of ...light energy', '- The Earth get ...light from the Sun', and '- The Moon reflects light from the Sun' (DBE, 2011b: 50-51), and 'Life on planet Earth' as in the content statement 'Features of the Sun, Earth and Moon in relation to ...radiation of light' (DBE, 2011b: 52).

A basic understanding of *colour* in Grade R also underpins scientific processes as in 'Possible activities: investigations, practical work and demonstrations' which require older children to 'identify', 'observe', 'tabulate the differences', 'compare', 'distinguish between objects'. 'Explore properties that can be seen ...', 'record changes', 'write a simple description', 'illustrate', 'Investigate the stimulation of the different sense ... seeing (kaleidoscope, colours, lights, etc.)', and 'describe the appearance of ...' (DBE, 2011b: 21-59). In conclusion: the Grade R science curriculum's representation of the concept *colour* underpins, in part, more complex science concepts and processes.

Summary

After bringing the three analytic indicators to bear on the Grade R topic (C3) and related internalising activities representing the topic concepts *colour* and 'shape' (*triangle, square* and *circle),* the following was concluded:

- The Grade R science curriculum's representation of 'shape' as *triangle, square* and *circle* pertains to the everyday in the absence of the key features of a simple scientific concept.
- The Grade R science curriculum sufficiently represents (≥ 5/12 ≤11/12) *colour* in terms of the six key features of a simple scientific concept

Table 4.11: Rating for the Grade R science curriculum representation of *colour*

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	1/2	0/2	1/2	1/2	1/2
RATING: 5/12 = Potential scientific concept					

<u>Table 4.12</u>: Rating for the Grade R science curriculum representation of *shape*.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
0/2	1/2	0/2	0/2	0/2	0/2
RATING: 1/12 = Everyday concept					

4.2.8. Knowledge concept: Water

The concept *water* is represented in the Grade R science curriculum by the following topic (C7):

Topic: Water – 2 hours

- Objects that float and sink
- Things that live in the water
- Mixing different things in water to change what it looks like
- Pouring and measuring water
- Saving water (DBE, 2011a: 19).

This topic concept (C7) and the related supporting activities (DBE, 2012a; DBE, 2012b; DBE, 2012c; DBE, 2012d) were analysed in terms of the following scientific definitions:

> Water: *Chemistry.* H_2O, a colourless, odourless, tasteless liquid having a melting point of 0^oC and a boiling point of 100^oC at standard atmospheric pressure, and having the allotropic forms of ice (solid) and steam (vapour) (Morris, 1992: 2352).

From this definition a simple scientific definition for six-year-olds was compiled for the purpose of analysing the Grade R science curriculum's representation of *water*:

> Water is called H_2O because it is made up of two chemicals i.e. two parts of hydrogen (H_2) and one part of oxygen (O)[108]. Water is a clear liquid that has no colour, smell or taste[109]. When you make water very cold (0^o or less) it turns into ice; when you make water very hot (100^o or more) it turns into vapour (steam) (based on and adapted from Morris, 1992: 2352).

AI: 1. How does the Grade R curriculum describe the defining features of *water* as represented by the topic 'Water' (C7), with regards to:

- Its attributes

The topic concept 'Water' (C7) is represented in scientific terms but none pertain to the simple scientific definition of *water* as defined by Morris (1992: 2352) i.e.

[108] Grade R educators explain this notion by drawing a comparison with something familiar e.g. water is made up of parts - like a fruit salad. A fruit salad is one thing made up of different parts such as one apple, two oranges, one banana, one pear and one pawpaw. Water is made up of two parts, one part oxygen and two parts hydrogen. Although you can see and take out the separate parts in a fruit salad, it is hard to do the same with water.

[109] i.e. distilled water. Our tap water is not pure water as it contains other chemicals such as chlorine.

- ‘Objects that float and sink’ pertains to a material property of a concrete object such as a wooden stick, a plastic lid or a mental ring.
- ‘Things that live in the water’ pertains to the biological study of living things whose habitat is watery e.g. seals, fish, crocodile and crab.
- ‘Mixing different things in water to change what it looks like’ pertains to chemistry as in chemical reactions.
- ‘Pouring and measuring water’ pertains to the mathematics as in measuring volume.
- ‘Saving water’ related to the subject ‘Personal and Social well-being’ as it pertains to the use of water in the everyday context.

None of the above statements describe the essential attributes of *water.* Some Grade R educators may take the curriculum statements at face value but other teachers may be prompted by the title ‘Water’ and the topic’s scientific stance into providing a simple scientific definition of *water*. Translating ‘Water’ into simple scientific terms depends on the educator’s science knowledge, expectations of what six-year-olds can understand and do, and approach to early science.

The Grade R workbooks do not contain a section dedicated to ‘Water’*. Water* is depicted in the form of images in relation to other concepts as follows:

- ‘The weather’ portrays images of *water* as a solid (snow), a liquid (rain), and vapour (cloud) (DBE, 2012b: 2-6). ‘Being safe’ includes an image of a steaming kettle (DBE, 2012b: 12). Although these illustrations represent the three phases of substance, it rests on the Grade R educator to lift out this essential characteristic of *water* across themes.
- Images of *water* also appear in relation to farming (watering plants), drinking (tea time), hygienic practices (cleaning), seasons (rain, snow, clouds), safety (fire engine), animal habitats (river, pond) and human activities (swimming) (DBE, 2012a: 22-26, 32-33, 43, 45; DBE, 2012b: 3-4; DBE, 2012c: 12, 23, 42-43; DBE, 2012d: 9, 10, 15, 32, 33, 40). Most of these images pertain to the how water is used.

- The theme ‘Sea animals’ (DBE 2012c: 32-36) offers an opportunity to define *water* in terms of taste and smell.

In conclusion: although the Grade R science curriculum’s does not represent *water* in terms of two or more essential attributes, the topic title ‘Water’ and the scientific perspective adopted by the topic may prompt the educator into defining *water* in terms of its essential attributes.

• The degree of specialisation of language

The Grade R topic concept ‘Water’ contains simple scientific terms but, as pointed out above, these terms refer to other science concepts in relation to the medium water e.g. ‘Objects that float and sink’ pertains to understanding the material properties of objects in terms of buoyancy, and ‘Pouring and measuring’ pertains to understanding the concept of volume using water as the medium of measurement. The Grade R workbooks also do not refer to *water* in specialised terms. However, as pointed out in the section above, the title ‘Water’ in relation to the topic’s scientific stance has the potential to prompt Grade R educators into providing scientific terms such as ‘H_20’, ‘solid’, ‘liquid’, ‘tasteless’ and ‘colourless’. In conclusion: the Grade R science curriculum’s representation of *water* has the potential to prompt an educator into describing *water* in specialised terms.

• Relation of topic concept to other concepts

In terms of sequence, grouping, co-location and logistics the Grade R science topic ‘Water’ is positioned as a stand-alone concept in the Grade R curriculum. The reasons are as follows:

- The topic concept ‘Water’ is isolated between the unrelated topic concepts ‘Jobs people do’ and ‘Fruit’ (DBE, 2011a: 19).
- The ‘Weather’ (DBE, 2011a: 17) which is a conceptually more complex concept in that it pertains to *water* as *rain* (liquid water), *snow* (solid water), *cloud* (water as vapour) precedes, by eight topic concepts, the topic concept ‘Water’ (DBE 2011a: 19). This is illogical in terms of progression.
- In terms of grouping, the Grade R science curriculum introduces ‘Water’ in isolation from the other related elements necessary for life on earth. ‘Soil’ is located in Grade 2 (DBE, 2011a: 44) and ‘Air (Gas) in Grade 4 (DBE, 2011b: 26).

In conclusion: the Grade R science curriculum does not represent the concept *water* in relation to other simple science concepts.

• Relation of topic concept representation to context

The Grade R topic concept 'Water' is transferable, in principle, to other scientific contexts if the Grade R curriculum representation of *water* prompts the educator into providing a simple scientific definition of *water*.

In conclusion: the Grade R science curriculum represents the topic concept 'Water' as a potential concept in terms of content knowledge. The topic's terms signal a scientific approach which may prompt educators into providing a transferable simple scientific definition of *water* that relates to other simple scientific concepts.

AI: 2. How does the Grade R science curriculum describe the structure of the science knowledge concept *water* with regards to the relation between content and procedural knowledge?

'Water' (C7) has the potential to be translated by the educator into content knowledge. However, in terms of procedural knowledge the topic 'Water' (C7) statements pertain only to the internalisation of other science concepts. Furthermore, there are no activities in the Grade R workbooks (DBE, 2012a; DBE, 2012b; DBE, 2012c; DBE, 2012d) that pertain to the neo-Vygotskians' idea of 'operating with the concept'. In conclusion: the Grade R science curriculum represents *water*, in part, in terms of content knowledge but not procedural knowledge.

AI: 3. How does the Grade R curriculum describe the science knowledge concept *water* with regards to the relation between simple and complex concepts?

The curriculum's representation of *water* in terms of potential content knowledge underpins, in principle, the following more complex school science concepts:

- The Grade 1 topic 'The weather', as in 'misty, rainy' (DBE, 2011a: 30), is underpinned by understanding in Grade R that *water* has three states i.e. solid, liquid and vapour.
- The Grade 2 topics: 'Healthy living', as in understanding the science behind 'purifying water' (DBE, 2011a: 42), and 'Animals and creatures that live in water', as in differentiating between 'Fresh water' and 'Salt water' (DBE, 2011a: 43), are

both underpinned by the Grade R definition of *water* as odourless, tasteless and colourless.

- The Grade 4 topic ‘Phases of Substances’ (DBE, 2011b: 25) extends the Grade R concept of *water* as a solid or liquid to other substances such as wax, butter and chocolate. ‘Properties of Material’ (DBE, 2011b: 32) compares *water* and other materials in terms of phases of a substance.
- The Grade 5 topic ‘Energy’ considers *water* in terms of ‘renewable and non-renewable sources of energy’ (DBE, 2011b: 35). The topic ‘Energy systems’ considers ‘Parts of systems that can fall: water’ in relation to the liquid phase of *water* (DBE, 2011b: 37). ‘Biodiversity of living things’ considers the relationship between *water* and *living things* (DBE, 2011b: 40).
- The Grade 6 topic ‘Life on planet Earth’ refers to the ‘presence of water’ (DBE, 2011b: 52). The topic ‘Mixtures, Solutions and Melting’ employs water as a medium for dissolving (DBE, 2011b: 54). ‘Environment and water resource’ considers *water* in terms of a solvent, habitat, disperser and supporter of all life (DBE, 2011b: 56). ‘Health of the planet’ pertains to the role of water in a healthy environment (DBE, 2011b: 57).

However, the following point counters the notion of ‘Water’ (C7) as a potential scientific concept underpinning more complex science concepts. The Intermediate Phase science curriculum introduces the basic scientific concept ‘Phases of substances’ as ‘solid: shape does not change, liquid – flows but stays in a container, gas: will not stay in a container but will spread upwards and sideways’ (DBE, 2011b: 25) in Grade 4 after the Grade R educators have represented *water* in terms of the above because ice, water and steam are familiar to most six-year-olds.

In conclusion: the potential content knowledge as represented by the Grade R topic concept ‘Water’ underpins, in part, more complex science concepts.

Summary

After bringing the three analytic indicators to bear on the Grade R topic, ‘Water’ (C7), and related internalising activities*,* the conclusion is that the Grade R science curriculum represents *water* as an everyday concept. The reason is that the Grade R science curriculum insufficiently represents (≤ 4/12) *water* in terms of the six key features of a simple scientific concept

Table 4.13: Rating for the Grade R science curriculum representation of *water*

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	1/2	0/2	1/2	0/2	1/2
RATING: 4/12 = Everyday concept					

4.2.9. Knowledge concept: Time

The following topic (C17) represents the concept *time* in the Grade R science curriculum:

Topic: Days of the week – 2 hours

- Days of the week
- What we do on different days
- Yesterday, today and tomorrow (DBE, 2011a: 15).

The Grade R science curriculum topics concepts, 'Summer', 'Autumn', 'Winter' and 'Spring' (DBE, 2011a: 16, 17, 19, 21) and 'Dinosaurs' (DBE, 211a: 21), also potentially represent *time* in terms of 'a fundamental dimensional quantity by which physical events can be place in an ordered sequence ' (Morris, 1992: 2223). The curriculum supports this idea by locating the single internalising activity (DBE, 2012d: 10) for 'Summer', 'Autumn', 'Winter' and 'Spring' under the section 'About time' (DBE, 2012d: 2-11). However, these five topic concepts were not included in the analysis of *time* because 1) the topics pertain to and have already been analysed in terms of other concepts,[110] and 2) the concept *time* is well represented in the Grade R science curriculum. The topic 'Days of the week' is supported by two workbook sections: 'About time' in Workbook 4 (DBE, 2012d: 2-11) and 'Day and Night' (DBE, 2012b: 22-31) in Workbook 2. References to *time* are also included in 'Birthdays' (DBE, 2012b: 42-53) and 'Celebrations' (DBE, 2012d: 42-53).

Time, as represented in the Grade R science curriculum was analysed in relation to the following scientific definitions:

> Time: *Physics.* 1. a fundamental dimensional quantity by which physical events can be placed in an ordered sequence. 2. A given instant within this sequence that may refer to a specific event 3. A continuous process made up of the complete range of such instants, regarded as constantly advancing and irreversible in nature (Morris, 1992: 2223).
>
> Day: *Science.* 1. *Astronomy*. 1. A period of time that is based on the spinning of the earth on its axis as it moves around the sum, varying slightly from 24 hours and measured, for example, from noon to noon (Morris, 1992: 589).

[110] 'Dinosaurs' has been analysed in terms of *reptile*'. The four seasons have been analysed in terms of the *seasons: summer, autumn, winter,* and *spring*.

From this definition a simple scientific definition appropriate for six-year-olds was created for the purpose of analysing the Grade R science curriculum's representation of *time*:

> Time: time is something you cannot see or feel but everything that happens in the world is ordered according to time. Time always moves forward and never comes back. We measure time in seconds, minutes, hours, days, weeks, months and years. A day is 24 hours long and is measured from 12 o'clock daylight time (based on and adapted from Morris, 1992: 2223, 589).

AI: 1. How does the Grade R curriculum describe the defining features of the concept *time* as represented by the workbook topic, 'Days of the week' (C17), with regards to:

• Its attributes

There are three essential attributes pertaining to *time* embedded in the Grade R topic 'Days of the week' (DBE, 2011a: 15). Although couched in everyday terms that six-year-olds understand, the topic statements relate to the scientific definition of *time* as follows*:*

- 'Days of the week' pertains to *time* as 'A continuous process made up of the complete range of such instants...' (Morris, 1992: 2223).
- 'What we do on different days' pertains to *time* as '...physical events [that] can be placed in an ordered sequence' (my insert in brackets, Morris, 1992: 2223).
- The terms 'yesterday' and 'tomorrow' pertain to *time* as '...constantly advancing and irreversible in nature' (Morris, 1992: 2223).

These notions of *time* are supported by the Grade R workbooks in the following ways:

- The section dedicated to *time*, 'About time' (DBE, 2012d: 2-11), links *time* to familiar events and routines e.g. birthdays and going to school on Monday. 'About time' also provides questions likely to prompt discussions on time as irreversible and continuous e.g. 'What did you do yesterday?' and 'What will you do tomorrow?' (DBE, 2012d: 3).
- The section 'Celebrations' (DBE, 2012d: 42-44) depicts events that recur regularly at a particular time of the year e.g. Christmas, Eid, Diwali, a birthday These events are likely to prompt discussion in terms of *time.*
- 'Birthdays' (DBE, 2012b: 42-43) relate to *time* in terms of aging as irreversible and continuous.

- There are two activity pages in the workbook activities (DBE, 2012c: 5; DBE, 2012d: 38) that pertain to *time* as the chronological sequencing of events e.g. ordering the following images: 1) getting ingredients and utensils ready for baking a cake, 2) mixing the ingredients, 3) putting the mixture in the oven, and 4) eating the baked cake.

However, these scientific representations of time are countered by the curriculum's introduction of *night* (DBE, 2011b: 22-24, 26, 27; DBE, 2012d: 4, 9) which is an everyday concept according to the science dictionary's definition of *day* (Morris, 1992).

In conclusion: the Grade R science curriculum represents the concept *time,* in part, in terms of two or more essential attributes.

• The degree of specialisation of language

The science dictionary (Morris, 1992) definition of 'day' in relation to the Grade R science curriculum's notion of 'night' determined that the Grade R science curriculum represents basic notions of *time* in everyday terms.

• Relation of topic concept to other concepts

In terms of location, grouping and sequence the Grade R science curriculum represent *time* logically as follows:

- The single internalising activity pertaining to *summer, autumn, winter* and *spring* is located in the workbook section 'About time' (DBE, 2012d: 10). The depiction of the four seasons in terms of cyclic change confirms the relationship to *time* in terms of 'physical events [which] can be placed in an ordered sequence (my insert in brackets, Morris, 1992: 2223).
- *Time* in terms of a series of chronologically ordered events is related to the Workbook 4 activity on the concept *life cycle of a plant* (DBE, 2012d: 38), and to the logical positioning of the topic concepts 'Summer', 'Autumn', 'Winter' and 'Spring' in the curriculum (DBE, 2011a: 16, 17, 19, 21).
- *Time* is related to the *human body* in terms of aging as a continuous and irreversible process (DBE, 2012d: 47).

The Grade R science curriculum isolates *time* from related concepts as follows:

- Although the workbook positions the *seasons* in terms of *time*, the topic descriptions of ‘Summer’, ‘Autumn’, ‘Winter’ and ‘Spring’ pertain to *weather* (DBE, 2011a: 17).
- The workbook section ‘About time’ (DBE, 2012d: 2-11) is located between two unrelated sections, ‘Wild animals’ (DBE, 2012c: 42-53) and ‘About town’ (DBE, 2012d: 12-21). Three unrelated sections, ‘About town’, ‘Sport’, and Creatures’ (DBE, 2012d: 12-41), separate ‘About time’ from the related ‘Celebrations’ (DBE, 2012d: 42-53)
- The Grade R curriculum locates the *time* topic ‘Days of the Week’ in Term 1 but the related workbook activities are illogically located in Terms 2 and 4.
- The relationship between *time* and the topic concept ‘Dinosaurs’ (C15) is undermined by the ‘out-of-time’ image of two children riding on the back of an extinct animal (DBE, 2012d: 39).
- The Grade R curriculum provides for chronological differences by locating ‘Festivals and special days’ at the end of each term (DBE, 2011a: 16, 18, 20, 21) but this sequencing of events is undermined by the workbooks which group special events at the end of Term 4 in Workbook 4’s ‘Celebrations’ (DBE, 2012d: 42-53).

In conclusion: the Grade R science curriculum relates *time,* in part, to other science concepts.

• Relation of topic concept representation to context

According to the analysis of time in terms of its essential attributes, *time* is transferable, in principle, to other scientific contexts if the Grade R educator makes the essential attributes explicit and corrects the everyday notion of *night*.

In conclusion: the Grade R science curriculum’s representation of *time* pertains, in part, to the neo-Vygotskian idea of content knowledge in terms of essential attributes, relations to other concepts, and being transferable to other science contexts.

AI: 2. How does the Grade R science curriculum describe the structure of the science knowledge concept *time* with regards to the relation between content and procedural knowledge?

There are 21 activity pages representing the concept *time* in the Grade R workbooks (DBE, 2012b: 22-24, 26, 27, 43; DBE, 2012c: 5, 34, 44; DBE, 2012d: 2-5, 9-11, 38, 39, 42, 43, 47) of which the following twelve pertain, in part, to the neo-Vygotskian idea of 'operating' with the concept:

- Three workbook activities (DBE, 2012c: 5, 34; DBE, 2012d: 38) 'operate' with *time* as 'physical events in an ordered sequence' (Morris, 1992: 2223) by directing children to sequence pictures according to *time* e.g. 1) a seedling grows, 2) the plant flowers, 3) the fruit is picked, and 4) the fruit is eaten (DBE, 2012d: 38).
- The workbooks employ the themes 'Celebrations' and 'Birthdays' (DBE, 2012b: 42, 43; DBE, 2012d: 11, 42, 43, 47) as 'A given instant within this sequence that may refer to a specific event' (Morris, 1992: 2223). For example: the birthday chart charts and celebrations sequence the designated day of the event in terms of 'day', 'month' and 'year'.
- Three of the workbook activities in 'About time' (DBE, 2012d: 2, 3, 5) operate with *time* as 'A continuous process made up of the complete range of such instants, regarded as constantly advancing and irreversible in nature' (Morris, 1992: 2223) by ordering days into a week and asking 'What will you do today?, 'What did you do yesterday?, and 'What will you do tomorrow?' (DBE, 2012d: 2-3).
- The workbooks provide an activity that classifies according to *time* by sorting birthdays into months on a year's calendar (DBE, 2012d: 11).

Translating the above curriculum representations of *time* into content and procedural knowledge depends on the Grade R educator: 1) making the essential attributes of *time* and *day* explicit 2) correcting the erroneous representation of *day* and *night,* and 3) expanding the basic descriptions of *time* into the 'instants' i.e. the seconds, minutes and hours that make up *day*. In conclusion: the Grade R science representation of the concept *time* relates, in part, to the neo-Vygotskians' notion of content and procedural knowledge as two integral parts of a simple scientific concept.

AI: 3.How does the Grade R curriculum describe the science knowledge concept *time* with regards to the relation between simple and complex concepts?

If the three essential attributes embedded in the topic 'Days of the week' (C17) are made explicit, then the Grade R science curriculum's representation of *time* underpins the following more complex school science concepts:

- The Grade R's concept of *time* as 'events that happen in the world physical events can be placed in an ordered sequence... constantly advancing and irreversible in nature' (Morris, 1992: 2223) underpins: 1) the Grade 3 topic concept 'Life cycle' (DBE, 2011a: 55), 2) The Grade 5 topic 'Biodiversity of living things' as in the life cycles of plants and animals (DBE, 2011b: 40), and 3) The Grade R topics 'Rocks' and 'Fossils' (DBE, 2011b: 43).
- The Grade R concept of *time* as 'A continuous process made up of the complete range of such instants regarded as constantly advancing and irreversible in nature' (Morris, 1992: 2223) underpins: 1) The Grade 4 topic 'Our place in space: Objects in the sky' as in distance (light years), and the rotation of planets and moons (DBE, 2011b: 29-30), 2) The Grade 6 topic 'Solar system' (DBE, 2011b: 50-51), and 3) The Grade 6 topic 'Rate of dissolving' (DBE, 2011b: 55).

This potential in terms of scientific underpinning is, however, countered by the Grade R's representation of *night* as an everyday concept which is carried forward to Grade 1 topic concept 'The sky at night' (DBE, 2011a: 33) and the Grade 2 topic concept 'Life at night' (DBE, 2011a: 45). In conclusion: the Grade R's simple representations of *time* underpin, in part, more complex science concepts.

Summary

After bringing the three analytic indicators to bear on the Grade R's representation of the concept *time* (C17) and related activities (DBE, 2012b; DBE, 2012c; DBE, 2012d), the conclusion is that the Grade R science curriculum represents the concept *time* as a potential simple scientific concept. The reasons are as follows:

- The Grade R science curriculum sufficiently represents (≥ 5/12 ≤11/12) *time* in terms of the six key features of a simple scientific concept.

- The Grade R representation of *time* has the potential to prompt the Grade R educator into translating the curriculum representations in terms of a simple scientific concept.

Table 4.14: Rating for the Grade R science curriculum representation of time.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	0/2	1/2	1/2	1/2	1/2
RATING: 5/12 = Potential scientific concept					

4.2.10. Knowledge concept: Transport

The following topic (C18) represents the concept *transport* in the Grade R science curriculum:

Topic: Transport – 2 hours

- Getting to school
- Different kinds of transport
- Transport long ago (DBE, 2011a: 19).

The topic (C18) and the related workbook section 'Things that go' (DBE, 2012c: 2-11) were analysed in terms of the following scientific definitions:

> Transport*: Engineering.* equipment used for transporting or conveying something from one place to another (Morris, 1992: 2252).

From this definition a simple scientific definition for six-year-olds was created for the purpose of analysing the Grade R science curriculum's representation of *transport*:

> Transport*:* equipment i.e. useful things made by humans for the purpose of carrying humans, other animals and things from one place to another (based on and adapted from Morris, 1992: 2252).

AI: 1. How does the Grade R curriculum describe the defining features of the concept *transport* as represented by the topic 'Transport' (C18), with regards to:

- Its attributes

According to the simple scientific definition above *transport* is defined by two essential attributes: 1) 'equipment' i.e. something that is engineered and made to be useful to humans e.g. car, pram, truck, boat, aeroplane, cart, shoes and the supermarket trolley, and 2) the capacity to carry. In terms of these attributes animals commonly associated with transport e.g. donkey, horse and camel, are excluded. The topic title, 'Transport' (DBE, 2011a: 10), has the potential to prompt a simple scientific definition but the topic statements steer the educator towards describing *transport* in empirical terms e.g. getting to school.

In Workbook 3 the section 'Things that go' (DBE, 2012c: 2-11) supports, in part, the describing of the essential attributes of *transport* as defined by Morris (1992: 2252). Firstly, the title 'Things that go' relates, in part, to the simple scientific definition above. 'Things' relates to 'equipment' as in non-living objects that have a use, and '…that go' implies the capacity to move as in '...from one place to another'. However, in the absence of the essential attribute 'the capacity to carry' as in 'transporting or conveying something' (Morris, 1992), the title 'Things that go' becomes meaningless in terms of *transport*.

Secondly, Workbook 3 provides two opportunities that may prompt the Grade R educator into defining *transport* in terms of its essential attributes:

1. The two –page workbook introduction (DBE, 2012c: 2-3) is likely to prompt a discussion on *transport* by depicting sixteen different types of modern day transport in relation to the question 'Look at the picture and talk about what you see'. Making the essential attributes explicit depends, however, on the Grade R educator understanding *transport* in terms of the simple scientific definition above.
2. The mathematics activity (DBE, 2012c: 10), which requires six-year-olds to classify nineteen images into six categories (cars, planes, buses, trucks, bicycles, motorbikes) may prompt the educator into making the classification criteria explicit. Explaining the criteria to six-year-olds may prompt talking about *transport* in terms of essential and non-essential attributes[111]. The essential attributes are 'equipment as useful things made by humans' and having 'the capacity to carry'; the non-essential attributes are 'many people', 'wheels', 'an engine', and 'can fly'. In the absence of one of the essential criteria *transport* no longer exists but in the absence of a non- essential attribute the scope of the concept may change but not its 'essence' e.g. without the non-essential attribute 'can fly' an aeroplane becomes more like a bus with wings but it is remains *transport* because it is 'equipment' and it has the capacity to carry.

The remaining 'Things that go' activities relate to *transport* in everyday ways e.g. drawing ways of getting to school, singing a song about a bus, discussing road safety, and colouring in pictures of transport (DBE, 2012c: 4-7, 11)[112]. There are no workbook images or activities related to the topic statement 'Transport long ago' (DBE, 2011a: 19). In conclusion: the Grade R science curriculum representation of *transport* pertains in part to two or more

[111] The idea of differentiating attributes relates to Davydov's idea of broadening and narrowing the scope of a concept by adding or taking away attributes (Davydov, 1990: 20) and is explained in the literature review in terms of *transport*.

[112] Two literacy activities are unrelated to transport (DBE, 2012c: 8-9).

essential attributes because it has the potential to prompt the educator into describing *transport* in simple scientific terms.

- The degree of specialisation of *language*

The Grade R curriculum and scientific definitions are both limited in terms of scientific terms. However, the title ‘Transport’ (DBE, 2011a: 19) is a specialised term and is differentiated in Workbook 3 into type using the scientifically acceptable ‘land’, ‘sea’ and ‘air’ (DBE, 2012c: 3). In conclusion: the Grade R science curriculum represents *transport*, in part, in specialised terms.

- Relation of topic concept to other concepts

The topic ‘Transport’ is located between, and in relation to, ‘Winter’ and ‘Jobs people do’ (DBE, 2011a: 19). The relationship between the science concepts *winter* and *transport* is likely to emerge in relation to the prevailing winter weather and a discussion on ‘Getting to school’ (DBE, 2011a: 19). The relationship between *transport* and the empirical ‘Jobs people do’ is made explicit in the topic statement ‘Transport e.g. train, truck and taxi drivers, traffic officer; pilot and crew’ (DBE 2011a: 19) and in the related workbook introduction to ‘About town’ (DBE, 2012d: 12 – 13) which is ‘thick’ with images of different kinds of *transport* in relation to ‘Jobs people do’. In Workbook 3 *transport* as in ‘Things that go‘ is carried through to the following section ‘On the farm’ (DBE, 2012c: 12-21) in the form of images of a tractor and trailer transporting children and wheelbarrows carrying soil and vegetables.

The remaining images of *transport* in the Grade R workbooks are employed to teach mathematics, literacy and perceptual skills (DBE, 2012a: 9, 12, 23, 35, 46; DBE, 2012b: 15, 16, 25, 32, 36, 37, 40; DBE, 2012c; 46, 47, 52; DBE, 2012d: 11, 15, 44, 48, 51)[113]. In the absence of a simple scientific definition provided to educators at the beginning of the year, it is unlikely that these images will be identified in relation to *transport*. ‘Transport’ is also a stand-alone topic concept because there are no related topic concepts in the Grade R curriculum e.g. ‘Machines in the home[114]’. In conclusion: the Grade R science curriculum represents the topic concept *transport*, in part, in relation to other simple science concepts.

- Relation of topic concept representation to context

[113] Images of that are obviously toys were not included in this reference

[114] Machines in the home pertain to ‘equipment’ as in things invented by humans for their usefulness, e.g. scissors, toaster, kettle, radio, phone, computer, washing machine, stove, fridge.

The analysis of the essential attributes established that the Grade R curriculum's representation of *transport* (DBE, 2011a: 19; DBE, 2012c: 2- 11) is transferable, in principle, to other contexts if the Grade R educator is prompted into translating 'Transport', into a simple scientific definition.

In conclusion: the Grade R science curriculum's representation of the concept *transport* has the potential to be translated by the Grade R educator into a simple scientific definition. 'Transport' relates, in part, to the neo-Vygotskian idea of content knowledge in terms of transferable essential attributes, specialised terms, and relations to other science concepts.

AI: 2. How does the Grade R science curriculum describe the structure of the science knowledge concept *transport* with regards to the relation between content and procedural knowledge?

Having established the Grade R topic concept *transport* in terms of potential content knowledge, this section considers whether the related internalising processes pertain to procedural knowledge. The Grade R science curriculum topic descriptions and workbook activities pertain, in part, to idea of 'operating' with the concept by engaging the law of equivalence and classifying according to the essential attributes of *transport*:

- The topic concept 'Transport' (C18) is introduced to six-year-olds in terms of the familiar i.e. 'Getting to school', before the acquisition of the unfamiliar i.e. 'Transport long ago' (DBE, 2011a: 19). The latter rests on the Grade R educator as there are no further representation of 'Transport long ago'.
- The related workbook section 'Things that go' provides three activities that potentially 'operate' with *transport.* The statement, 'Look at the pictures and talk about what you see', in relation to 30 images of *transport* (DBE, 2012c: 2-3) may prompt a discussion on *transport* in terms of its essential attributes. If the educator introduces new ideas then the activity also engages with the law of equivalence. The second activity requires six-year-olds to classify *transport* according to 'land', 'water' and 'air' (DBE, 2012c: 3) but the classifying pertains to the non-essential rather than the essential attributes of *transport*. The third activity also relates to classifying according to the non-essential features of *transport* (DBE, 2012c: 10) but there is potential to 'operate with the concept' if

  the Grade R educator differentiates between the essential and non-essential criteria.

The remaining internalising activities relate in everyday ways to *transport* e.g. 'How many children in your class walk to school?', 'Draw a picture to show how you go to school?' and 'Colour the picture while you sing the song[115]' (DBE, 2012c: 3- 4, 6). In conclusion: the Grade R science representations of the concept *transport* relate, in part, to the neo-Vygotskians' idea of content and procedural knowledge.

AI: 3.How does the Grade R curriculum describe the science knowledge concept *transport* with regards to the relation between simple and complex concepts?

The Grade R science curriculum's representation of *transport* in terms of potential content knowledge indicates that, in principle, the curriculum's representation of *transport* underpins the following more complex school science concepts:

- The Grade 3 topic 'Space' as in 'Space travel' and 'Satellites and information we get' (DBE, 2011a: 56)
- The Grade 4 topic 'Finding out about space' as in:
  - Visits to Moon and Mars
  - Machines/craft needed for space travel (simple examples)
  - Type of structures, materials and energy used for space craft
  - Machines and energy (fuel) essential for space exploration:
  - Types of structures used for space craft: pictures
  - Possible materials for building space craft specifications regarding temperature and pressure (DBE, 2011b: 29)
- The Grade 4 topic, 'Movement', as in:

  Moving on land: Mechanical systems
  - Vehicles used for transport of people and goods on Earth.
  - Simple mechanism used in vehicles to enable rotary motion: wheels and axles ... (DBE, 2011b: 31).
- The Grade 5 topic, Machines and mechanisms as in 'Wheels and axles, gears and axles ...' (DBE, 2011b: 38).
- The Grade 5 topic 'Moving an object' as in 'Technology process ...' (DBE,

115 'The wheels of the bus go round and round'

2011b: 39).

- The Grade 6 topic 'Types of movement/motion' (DBE, 2011b: 59).

In conclusion: if defined in simple scientific terms the Grade R topic concept *transport* potentially underpins more complex science concepts.

Summary

After bringing the three analytic indicators to bear on the Grade R topic 'Transport' (C18) and related internalising activities (DBE 2012c), the conclusion is that the Grade R science curriculum represents the concept *transport* as a potential simple scientific concept. The reasons are as follows:

- The Grade R science curriculum sufficiently represents (≥ 5/12 ≤11/12) *transport* in terms of the six key features of a simple scientific concept.
- The Grade R representation of *transport* has the potential to prompt the Grade R educator into translating the curriculum representations in terms of a simple scientific concept.

Table 4.15: Rating for the Grade R science curriculum representation of transport

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	1/2	1/2	1/2	1/2	1/2
RATING: 6/12 = Potential scientific concept					

4.2.11. Knowledge concept: Weather

The concept *weather* is represented in the Grade R science curriculum by the following topic (C4):

> Topic: Weather – 2 hours
>
> - What the sky looks like – include colour and clouds
> - Hot days, cold days, sunny days, rainy days, windy days – include what we wear on these days
>
> Note: ensure learners never look at the sun (DBE, 2011a: 17).

This topic (C4) and the related supporting activities (DBE, 2012b) were analysed in terms of the following scientific definitions:

> Weather*: Meteorology*. 1. The short-term state of the atmosphere, as distinguished from the long-term condition of climate; this includes temperature, humidity, precipitation, wind, visibility, and other factors, chiefly considered in terms of their effects on life and human activity. 2. In a surface weather observation, a category of atmospheric phenomena that are used to identify a localized atmospheric state at the time the observation is taken; this includes conditions such as rain, sleet, snow, tornado, and thunderstorm (Morris, 1992: 2358).

From the above definition a simple scientific definition for six-year-old was created for the purposes of analysing the Grade R science curriculum's representation of *weather*:

> Weather*: t*he day to day conditions and changes in the air around us (the earth's atmosphere). The weather can be rainy, sunny, hot, warm, cool or cold, stormy, windy, calm, cloudy, foggy, snowing or humid. Weather affects what animals, plants and humans do (created from Morris, 1992: 2358).

AI: 1. How does the Grade R curriculum describe the defining features of the concept *weather* as represented by the topic 'Weather' (C4), with regards to:

- Its attributes

The Grade R topic 'Weather' (C4) relates, in part, to the scientific definition Morris, 1992) above because each simple topic term can be matched to a term from the scientific definition above i.e.

Scientific definition terms (Morris, 1992: 2358)	Grade R topic ‘Weather’ (C4) terms (DBE, 2011a: 17)
‘atmosphere’	‘sky’
’temperature’	‘hot days, cold days’
‘precipitation’	‘rainy days’
‘wind’	‘windy days’
‘visibility’	‘sunny days’
‘their effects on human activity’	‘ what we wear on these days’

As the topic pertains only to humans, it rests on the Grade R educator to expand the topic descriptions to animals and plants as in the scientific definitions above. The third statement, ‘Note: ensure learners never look at the sun’ (DBE, 2011a: 17) pertains indirectly to *weather* by referring to ‘sun’ but its purpose is to serve as a reminder to the educator in the interests of eye health and safety.

The Grade R Workbook 2 has a dedicated section titled ‘The weather’ (DBE, 2012b: 2- 11) which supports, in part, the curriculum’s representation of *weather* in terms of ‘temperature, humidity, precipitation, wind, visibility, and other factors, chiefly considered in terms of their effects on life and human activity’ (Morris, 1992: 2358). However, the workbook images are related to a particular context and most reflect the human perspective. The image of an igloo pertains to *climate* rather than to *weather* according to the scientific definition which distinguishes between the two (Morris, 1992). In conclusion: the Grade R science curriculum represents *weather*, in part, in terms of two or more essential attributes.

- The degree of specialisation of language

The Grade R topic ‘Weather’ (C4) and the related workbook activities (DBE, 2012b) contain some simple scientifically acceptable terms e.g. ‘clouds’, ‘sky’, ‘cold’ and ‘hot’. However, in terms of learning new knowledge and the specialisation of language the terms are too simple for most six-year-olds and most are in common use. In other words, the educator needs to extrapolate the common words into more complex scientific terms. In conclusion: the Grade R science curriculum represents *weather,* in part, in specialised terms.

• Relation of topic concept to other concepts

'Weather' (C4) is explicitly related to the Grade R science curriculum's representation of *summer, autumn, winter* and *spring* in terms of the simple scientific definition statement 'Weather affects what animals, plants and humans do (created from Morris, 1992: 2358). Each topic begins with the statement 'The weather in …' and each states thereafter:

- How nature is affected
- How animals are affected
- How people are affected – e.g. what we eat, wear, do, games we play

(DBE, 2011a: 16, 17, 19, 20).

However, the Grade R science curriculum represents *weather* in ways that counter the notions of sequence, grouping, and co-location. As pointed out in the analysis of 'Water' (C8), 'Weather' (C4) is a conceptually more complex concept and it is illogical in terms of progression to sequence *weather* before *water*. The Grade R workbooks also represent *weather* in isolation from other science concepts as follows:

- The section on 'The weather' is positioned between two unrelated empirical topics, 'Friends' (DBE, 2012a: 42-50) and 'Being safe' (DBE, 2012b: 12–21).
- The Workbook 2 statements that accompany the various images of *weather* (DBE, 2012b: 2-11) do not refer to the changes in weather in terms of *Spring, Autumn, Summer* and *Winter*.
- The four seasons are depicted in Workbook 4 in relation to *time* not *weather* (DBE, 2012d: 10).

In conclusion: the Grade R science curriculum represents the topic concept *weather*, in part, in relation to other simple science concepts.

• Relation of topic concept representation to context

According to the analysis of the essential attribute the Grade R topic concept 'Weather' (DBE, 2011a: 17) is, in principle, transferable to other scientific contexts if the educator describes *weather* in terms of a simple scientific definition. This transferability is partial because the Grade R science curriculum's representation of *weather'* does not include all living things.

In conclusion: the Grade R science curriculum's representation of the concept *weather* pertains, in part, to the neo-Vygotskian idea of content knowledge in terms of transferable attributes, specialised terms, and relations to other scientific concepts.

AI: 2. How does the Grade R science curriculum describe the structure of the science knowledge concept *weather* with regards to the relation between content and procedural knowledge?

Having established the Grade R topic concept *weather* in terms of potential content knowledge, this section considers whether the related internalising processes pertain to the neo-Vygotskian notion of procedural knowledge. Although the topic statement 'What the sky looks like – include colour and clouds' (DBE, 2011a: 17) appear to be empirical, the sky is a phenomenon that scientists have understood through observation. The Grade R Workbook 2 section on 'The weather' provides six activity pages (DBE, 2012b: 2-7) which relate to the neo-Vygotskian idea of procedural knowledge as 'operating' with the concept:

- Images of *weather* are represented in relation to questions e.g. 'What weather is shown in each picture?', 'What is today's weather? What are you wearing?' (DBE, 2012b: 2-3). The images and questions are likely to prompt discussions that describe *weather* in terms of the simple scientific definition created from Morris (1992).
- The question 'Look at the pictures and talk about what you see' (DBE, 2012b: 3) provides an opportunity for operating with the law of equivalence if the children are introduced to new ideas.
- The following activity pertains to classifying according to one essential attribute of *weather* i.e. 'temperature'*:*

  > Look at the 2 pictures and talk about how the weather is different. Say what the children are doing and what are they wearing. Circle the clothes you wear in hot weather in red, and those you wear in cold weather in blue (DBE, 2012b: 4-5).

  However, this activity is too simple to function as procedural knowledge because it counters two notions inherent to the idea of procedural knowledge i.e. 1) internalising activities should be aimed at the zone of proximal development (ZDP) i.e. the space just ahead of what children already know, and 2) the law of equivalence cannot operate in the absence of new knowledge. Acquiring *weather* as a simple scientific concept depends on the Grade R educator extending the scope of the Grade R curriculum's representation of *weather* to the unfamiliar. In conclusion: the Grade R science representation of the concept *weather* is related, in part, to the neo-Vygotskians' idea of content and procedural knowledge.

AI: 3.How does the Grade R curriculum describe the science knowledge concept *weather* with regards to the relation between simple and complex concepts?

The Grade R science curriculum's representation of *weather,* as having the potential to prompt a simple scientific description, underpins in principle the following more complex school science concepts:

- Although the Grade 1 topic 'The weather' (DBE, 2011a: 30) reiterates sections of the Grade R topic 'Weather', the concept is extended to 1) daily weather observations, 2) an additional weather condition (misty), and 3) two additional human activities.
- In Grade 3 'Space' (DBE, 2011a: 56) as in 'Earth from space – what it looks like (... clouds)' is underpinned by the Grade R statement 'What the sky looks like – include colour and clouds' (DBE, 2011a: 17). Understanding *weather* in Grade R underpins understanding 'lightening' and 'strong winds' in the topic 'Disasters and what we should do' (DBE, 2011a: 57).
- In Grade 4, 'Weather' (C4) underpins 'Air (Gas)' as in 'Wind can do useful work because it can make things move' (DBE, 2011b: 26). The Grade R terms 'sunny' and 'sun' are extrapolated in Grade 4 to 'Our place in space: Objects in the sky' as in 'The Sun...provides heat and light energy to Earth' and 'The Moon ... reflects Sunlight: no light of its own' (DBE, 2011b: 29).
- Five Grade 5 topic concepts are underpinned by 'Weather' in Grade R: 1) 'Energy' as in wind is one of the 'Renewable and non-renewable sources of energy' (DBE, 2011b: 35), 2) 'Energy we can see, hear and feel' as in understanding that the sun and wind are sources of energy' (DBE, 2011b: 36), 3) The ideas above which are built on the Grade R concept of 'sunny' are extended further in the topic 'Energy flow and biodiversity' as in the content statement 'Energy flows from the sun to plants that photosynthesis , to the animals that eat plants and carnivores that eat

animals' (DBE, 2011b: 39), 4) The Grade R concept of wind underpins the concept of 'sedimentation' in the Grade 5 topic 'Rocks' (DBE, 2011b: 43).

- The Grade R concepts 'sky', 'sunny' and 'hot' underpins two Grade 6 topic concepts: 1) 'Solar system' as in the content statements: 'The Sun is the source of heat and light energy', 'the Earth gets its heat and light from the Sun', 'The Earth has an atmosphere ...', 'The Moon does not have an atmosphere', and 'The Moon reflects light from the Sun' (DBE, 2011b: 50-51), and 2) 'Life on planet Earth' as in understanding that 'heat and light from the Sun (radiation)' are 'key elements' in 'Supporting life on earth' (DBE, 2011b: 52).

In conclusion: the Grade R topic concept *weather* underpins, in principle, more complex science concepts.

Summary

After bringing the three analytic indicators to bear on the Grade R topic 'Weather' and related internalising activities, the conclusion is that the Grade R science curriculum represents the concept *weather* as a potential scientific concept. The reasons are as follows:

- The Grade R science curriculum sufficiently represents (≥ 5/12 ≤11/12) *weather* in terms of the six key features of a simple scientific concept.
- The Grade R representation of *weather* has the potential to prompt the Grade R educator into translating the curriculum representations in terms of a simple scientific concept.

Table 4.16: Rating for the Grade R science curriculum representation of weather.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	1/2	1/2	1/2	1/2	1/2
RATING: 6/12 = Potential scientific concept					

4.2.12. Knowledge concepts: Summer, autumn, winter and spring

The four knowledge concepts are represented in the Grade R science curriculum by the following topics 'Summer' (C2), 'Autumn' (C5), 'Winter' (C6), and 'Spring' (C12):

Topic: Summer – 2 hours • The weather in summer • How nature is affected • How animals are affected • How people are affected – e.g. what we eat, wear, do, games we play (DBE, 2011a: 16).	Topic: Autumn – 2 hours • The weather in autumn • How nature is affected • How animals are affected • How people are affected – e.g. what we eat, wear, do, games we play (DBE, 2011a: 17).
Topic: Winter – 2 hours • The weather in winter • How nature is affected • How animals are affected • How people are affected – e.g. what we eat, wear, do, games we play (DBE, 2011a: 19).	Topic: Spring – 2 hours • The weather in spring • How nature is affected • How animals are affected • How people are affected – e.g. what we eat, wear, do, games we play (DBE, 2011a: 21).

The topic concepts are supported by the workbook sections 'The Weather' (DBE, 2012b: 2-11) and 'About time' (DBE, 2012d: 2-11). The Grade R science curriculum's representation of the four seasons was analysed in terms of the following scientific definitions:

> Autumn*: Astronomy*. in the Northern Hemisphere, the season that begins with the September equinox[116] and ends with the December solstice[117]; in the Southern Hemisphere, the season between the March equinox and June solstice (Morris, 1992: 192).

[116] The equinox is a time when the hours of light and darkness are of equal length; in the southern hemisphere the equinox is usually on the 20 March and 22 September.

[117] In the southern hemisphere the solstice is marked by the longest day in summer and the shortest day in winter i.e. usually the 21st or 22nd of June and December respectively

Winter: *Astronomy.* the season beginning at the winter solstice ...and lasting until the vernal equinox ...[118] (Morris, 1992: 2374).

Summer*: Astronomy.* the period between the summer solstice ... and the autumnal equinox ... (Morris, 1992: 2132).

Spring: *Astronomy.* the season between the vernal equinox and the summer solstice, in which days become progressively longer ... (Morris, 1992: 2068).

From these definitions, four simple scientific definitions appropriate for six-year-olds were compiled for the purpose of analysing the South African Grade R science curriculum's representation of *summer, autumn, winter* and *spring*[119]*.* The definitions are lengthy because they can be simplified (indicated in bold font) or extended (additional information on the equinox and solstice is in brackets):

Autumn*:* The months of the year when the earth is tilting away from the Sun and one hemisphere gets less sunlight. Autumn is the season after Summer and before Winter. In the Southern Hemisphere (the bottom half of the earth), Autumn is the time between the March equinox (the day when the hours of daylight and darkness are the same) and the June solstice (the day with the shortest hours of daylight) (based on and adapted from Morris, 1992: 192).

Winter: The months of the year when the earth is the furthest away from the Sun and one hemisphere gets the least amount of the sunlight in the year. Winter is the season after Autumn and before Spring. In the Southern Hemisphere (the bottom half of the earth), Winter is the time between the June solstice (the day with the shortest hours of sunlight) and the September equinox (the day when the hours of daylight and darkness are the same) (based on and adapted from Morris, 1992: 2374).

Spring*:* The months of the year when the earth starts tilting towards the Sun and one hemisphere gets more sunlight. Spring is the season after Winter and before Summer. In the Southern Hemisphere (the bottom half of the earth), Spring is the time between the September equinox (the day when the hours of

[118] References pertaining to the northern hemisphere have been omitted

[119] For six-year-olds, the definitions pertain only to the southern hemisphere

daylight and darkness are the same) and the December solstice (the day with the longest hours of daylight) (based on and adapted from Morris, 1992: 2132).

Summer: The months of the year when the earth is the closest to the Sun and one hemisphere gets the most amount of the sunlight in the year. Summer is the season after Spring and before Autumn. In the Southern Hemisphere (the bottom half of the earth), Summer is the time between the December solstice (the day with the longest hours of sunlight) and the March equinox (the day when the hours of daylight and darkness are the same) (based on and adapted from Morris, 1992: 2132).

A comparison between these simple scientific definitions and the topics above raised the idea of two concepts i.e. *time* and the seasons *summer, autumn, winter* and *spring*. Both ideas have been considered in the analysis.

AI: 1. How does the Grade R curriculum describe the defining features of the concepts *summer, autumn, winter* and *spring* as represented by the topics 'Summer' (C2), 'Autumn (C5)', Winter' (C6) and Spring' (C12) with regards to:

- Its attributes

The Grade R science curriculum's explicit representations of the concepts *summer, autumn, winter* and *spring* do not reflect the conceptual 'essence' described in the related scientific definitions (Morris, 1992: 2132, 192, 2374, 2068). The descriptions of the topic concepts 'Summer', 'Spring', 'Autumn' and 'Winter' (DBE, 2011a: 16, 17, 19, 21) direct the educator to the observable seasonal changes but omit the science behind the phenomena i.e. the annual changes in the earth's rotation and orbit around the sun which cause the seasonal changes on earth and subsequent effects on living things.

However, the Grade R curriculum has structured the introduction of 'Summer', 'Spring', 'Autumn' and 'Winter' at the same time as the phenomena occur and this suggests that the curriculum intends the learning of the four seasons in terms of the earth's movements in relation to the Sun and the subsequent weather changes. Whether this aspect is brought forward and made explicit depends on the Grade R educator. If the curriculum representations are taken at face value, the Grade R topics are likely to prompt context-related descriptions of the changes wrought by the prevailing weather conditions during a particular time at a particular location e.g. six-year-olds in Durban will acquire a different understanding of *summer, autumn, winter* and *spring* to six-year-olds in Cape Town because their observations and experiences will differ[120].

In conclusion: the Grade R science curriculum representation of *summer, autumn, winter* and *spring* has the potential to prompt the educator into defining *weather* in terms of its essential attributes.

- The degree of specialisation of language

The four Grade R topic concepts 'Summer' (C2), 'Autumn' (C5), 'Winter' (C6) and 'Spring' (C12) are limited to two scientific terms i.e. 'weather' and 'animals'. However, the topic statements 'How nature is affected' and 'How animals are affected' (DBE, 2011a: 16. 17. 19. 21) have the potential to prompt the educator and children into providing other specialised terms.

- Relation of topic concept to other concepts

The Grade R curriculum has positioned the four topic concepts 'Summer' (C2), 'Spring' (C12), 'Autumn' (C5) and 'Winter' (C7) in the curriculum (DBE, 2011a: 16, 17, 19, 21) so that six-year-olds can acquire each concept at a time when they can observe and experience the phenomena. This logical positioning infers relations between *weather, time,* and the four seasons s*ummer, autumn, winter* and *spring*. The Grade R science curriculum reinforces the relationship between *weather* and the *seasons* by beginning each of the four topic concepts with the statement 'The weather in ...' (DBE, 2011a: 16, 17, 19, 21).

Locating the single internalising activity (DBE, 2012d: 10) in the workbook section 'About time' (DBE, 2012d: 2-11) strengthens the relationship between *summer, autumn, winter, spring* and *time.* At the same time, this single activity counters the strengthening by representing all four seasons on one page in Term 4 (DBE 2012d: 10). In Workbook 2 the section on 'The weather' (DBE, 2012b: 2-6) provides images that represent s*ummer, autumn, winter* and *spring* but, in the absence of any references and its isolation from the single activity that explicitly represents the four seasons (DBE 2012d: 10), this relationship is weak. In conclusion: the Grade R science curriculum represents *summer, autumn, winter* and *spring,* in part, in relation to other science concepts.

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[120] This example pertains to Hedegaard's idea of an empirical concept i.e. an everyday concept that is factually correct within a particular context (2002).

• Relation of topic concept representation to context

According to the analysis of the essential attributes, the Grade R science curriculum's representation of *summer, autumn, winter* and *spring* has the potential to be translated by the educator into simple scientific content knowledge. If 'Summer' (C2), 'Autumn' (C5), 'Winter' (C6) and 'Spring' (C12) are described in terms of their essential attributes, then they are transferable, in principle, to other contexts.

In conclusion: the Grade R science curriculum's representation of the concepts *summer, autumn, winter* and *spring* pertains, in part, to the neo-Vygotskian idea of content knowledge in terms of transferable essential attributes, specialised terms and relations to other scientific concepts.

AI: 2. How does the Grade R science curriculum describe the structure of the science knowledge concepts *summer, autumn, winter* and *spring* with regards to the relation between content and procedural knowledge?

The analysis of the key content features above indicates that the Grade R science curriculum's representation of *summer, autumn, winter* and *spring* has the potential to be translated by the educator into simple scientific content. However, there is no dedicated section in the Grade R workbooks pertaining to the topic concepts 'Summer' (C2), 'Autumn' (C5), 'Winter' (C6) and 'Spring' (C12) and the single internalising activity (DBE, 2012d) particular to *summer, autumn, winter* and *spring* counters the scientific intention behind the curriculum's chronological representation. Instead of introducing each as they occur during the year the activity positions all four seasons together on one page in Term 4. In place of directing the Grade R educator towards teaching the science behind the observable seasonal changes, the activity states:

> Cut out the chart and attach a hand. Turn it to show what season it is. Tell your friend what you like about each season (DBE, 2012d: 10).

In conclusion: the Grade R science curriculum's representation of *summer, autumn, winter* and *spring* does not relate to the neo-Vygotskian idea of content and procedural knowledge as two integral parts of a simple scientific concept.

AI: 3. How does the Grade R curriculum describe the science knowledge concepts *summer, autumn, winter* and *spring* with regards to the relation between simple and complex concepts?

The potential content knowledge in 'Summer' (C2), 'Autumn' (C6) and 'Winter' (C6) and 'Spring' (C12) underpins the Grade 2 topic 'Seasons' by extending the notional of seasonal change to other contexts i.e. '... sowing, growing and harvesting ...farming e.g. sheep shearing, animal dipping …birds e.g. migration and nesting' (DBE, 2011a: 43). However, the Grade 4 topic 'Our place in space: Objects in the sky' counters the idea of scientific underpinning by stating 'The Earth moves (revolves) around the Sun once a year: causes seasons (no explanation)' (DBE, 2011b: 30). The bracketed phrase 'no explanation' infers that understanding *summer, autumn, winter* and *spring* in scientific terms is too complex for young children and therefore the Foundation Phase representations of the four seasons pertain to empirical knowledge i.e. factual but context-related concepts.

In conclusion: the Grade R topic concepts *summer, autumn, winter* and *spring* underpin more complex empirical concepts in the school science curriculum.

Summary

After bringing the three analytic indicators to bear on the Grade R topics 'Summer' (C2), 'Autumn' (C5) and 'Winter' (C6), and 'Spring' (C12) and the single related internalising activity (DBE 2012d: 10), the conclusion is that the Grade R science curriculum represents the concepts *summer, autumn, winter* and *spring* as everyday concepts. Although the positioning of the four topics concepts suggests that the curriculum intends scientific representation, the workbooks counter the intention in terms of procedural knowledge and the underpinning of more complex school science concepts.

Table 4.17: Rating for the Grade R science curriculum representation of: *summer, autumn, winter* and *spring*.

CRITERIA DESCRIPTION AND RATING SCALE					
CRITERION 1	CRITERION 2	CRITERION 3	CRITERION 4	CRITERION 5	CRITERION 6
Employs two or more essential attributes ...	Contains two or more specialised terms	... in relation to other concepts	... transferable across contexts	... two integral parts i.e. content and procedural knowledge	Underpins more complex scientific concepts
1/2	1/2	1/2	1/2	0/2	0/2
RATING: 4/12 = Everyday concept					

The following two tables summarise the analysis of the Grade R science curriculum knowledge concepts by organising the findings according to concept type.

<u>Table 4.18</u>: Summary of findings: potential scientific concepts

Grade R science topic	Concept represented by the topic concept	Rating		Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6
Reptiles (C14) Dinosaurs (C15)	Reptiles	Potential scientific concepts	**9/12**	2/2	1/2	1/2	2/2	1/2	2/2
Birds (C13)	Birds		**6/12**	1/2	1/2	1/2	1/2	1/2	1/2
Transport (C18)	Transport		**6/12**	1/2	1/2	1/2	1/2	1/2	1/2
Weather (C4)	Weather		**6/12**	1/2	1/2	1/2	1/2	1/2	1/2
My Body (C1) Sound (C1.1) Sight (C1.2) Touch (C1.3) Taste and smell (C1.4)	Human body		**5/12**	1/2	1/2	0/2	1/2	1/2	1/2
Days of the week (C17)	Time		**5/12**	1/2	0/2	1/2	1/2	1/2	1/2
Shapes and colours around us (C3)	Colour		**5/12**	1/2	1/2	0/2	1/2	1/2	1/2

Table 4.19: Summary of findings: everyday concepts

Grade R science topic	Concept represented by the topic concept	Rating		Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6
Water (C7)	Water	Everyday concepts	**4/12**	1/2	1/2	0/2	1/2	0/2	1/2
Animals and The study of one wild animal (C16)	Wild animals		**4/12**	1/2	1/2	0/2	1/2	0/2	1/2
Fruit (C8)	Fruit		**3/12**	1/2	0/2	1/2	1/2	0/2	0/2
Summer (C2) Autumn (C5) Winter (C6) Spring (C12)	Summer, autumn, winter, and spring		**4/12**	1/2	1/2	1/2	1/2	0/2	0/2
Dairy Farming (C10) Wool farming (C11)	Domesticated animals		**2/12**	1/2	0/2	0/2	0/2	1/2	0/2
Shapes and colours around us (C3)	Shape		**1/12**	0/2	1/2	0/2	0/2	0/2	0/2
Vegetables (C9)	Vegetables		**0/12**	0/2	0/2	0/2	0/2	0/2	0/2

4.3. CONCLUSION

According to this study's analysis of the Grade R science curriculum's knowledge concepts:

- Table 4.18. shows that seven of the fourteen Grade R science topics are represented as potential scientific concepts
- Table 4.19 shows that the remaining seven Grade R science topics are represented as everyday concepts.

The next chapter discusses and draws conclusions on the findings above.

CHAPTER 5: Conclusions

We cannot solve our problems with the same thinking we used when we created them

(Albert Einstein)[121]

5.1. INTRODUCTION

This chapter discusses the findings presented in Chapter 4 in relation to the literature reviewed in Chapter 2. While the literature review presented a neo-Vygotskian perspective on what forms of knowledge should be made available to six year olds if they are to acquire scientific concepts and thinking, the findings describe the actual forms of knowledge made available in selected texts. The findings and literature respond in two different ways to the question that initiated this study i.e. 'What is science for six-year-olds?'

According to the analysis, the South African Grade R science curriculum represents science for six-year-olds in terms of potential[122] scientific concepts and everyday concepts. A scientific concept is abstract and contains the essence of the concept; an everyday concept is empirical and contextualised. Table 5.1 provides an overview of the findings:

[121] http://www.brainyquote.com/quotes/authors/a/albert_einstein.html#elFa0opPC0VJWPdq.99

[122] The term 'potential' pertains to pedagogical potential i.e. the likelihood of the teacher being prompted into defining the topic concept in terms of a simple scientific concept

Table 5.1: Overview of the findings

Grade R science topic concepts	Rating benchmarks	Type of science concepts for six-year-olds
- The human body (C1, C1.1, C1.2, C1.3, C1.4)) - Colour (C3) - Weather (C4) - Birds (C13) - Reptiles (C13, C14) - Time (C17) - Transport (C18)	≥ 5/12 ≤11/12	Potential scientific concepts Each concept representation contains sufficient but not all of the features of a simple scientific concept. Although there may be some omissions and scientific countering, the representations may prompt the Grade R educator to translate an everyday concept into a simple scientific concept.
- Shape (C3) - Fruit (C8) - Vegetables (C9) - Water (C7) - Domesticated animals (C10 , C11) - Seasons as in Summer, Autumn, Winter & Spring (C2, C5, C6, C12) - Wild animals (C16)	≤ 4/12	Everyday concepts Each concept is insufficiently represented in terms of a simple scientific concept because there are instances of scientific countering, errors and omissions. An everyday concept is context dependent and derived from experience, hearsay, and observation. The notion of an everyday concept includes an empirical concept as a type of factual but context-dependent concept. This representation does not point the teacher towards pedagogic strategies that are likely to give the learners access to scientific concepts and thinking.
-	12/12	Simple scientific concepts All six of the defining features of a simple scientific concept are made explicit as in Table 3.5.

There is clearly a disjuncture between the neo-Vygotskians' theoretical understanding of science for six-year-olds as simple scientific concepts, and the Grade R science curriculum's representations of science concepts as everyday and potential scientific concepts. This disjuncture points to Sharma and Anderson's (2009) idea that recontextualising scientific knowledge into school science is challenging.

The remainder of this final chapter discusses the findings of the analysis, draws implications, and makes recommendations in relation to the research question: *How does the South*

African Grade R curriculum represent school science knowledge for six–year-old?

5. 2. DISCUSSION: the findings

The conclusions and implications below were derived with the following findings in mind:

- 50% of the Grade R science concepts are represented as everyday concepts
- 50% of the Grade R science topic concepts are represented as potential scientific concepts. However, realising a potential scientific concept as a simple scientific concept depends on the Grade R educator.

5.2.1. Everyday concepts

Seven of the fourteen Grade R science concepts presented in the curriculum were categorised as everyday concepts (>4/12), on the grounds that the description of the concept was not only incomplete with regard to key features of a simple scientific concept but also scientifically inaccurate. This means that teachers are not guided by the curriculum towards a pedagogy that potentially realises these as simple scientific concepts. Instead, the curriculum texts guide teachers of most six year olds in South Africa towards representing science in terms of everyday concepts.

The Grade R science curriculum's representation of science as everyday knowledge is problematic for three reasons:

1. Learning scientific knowledge is developmental, i.e. young children develop cognitive competencies and learn about abstraction through the process of acquiring simple scientific knowledge (Fleer, 2010; Davydov, 1990, 2008; Hedegaard, 2002). In other words, in the absence of the teaching and learning of simple scientific concepts young children are unlikely to acquire the knowledge and skills necessary for formal schooling.

2. Acquiring everyday concepts in lieu of simple scientific knowledge is counter-indicative in the light of the following research findings:

- Preschool children can think abstractly and are more competent than indicated by 20th century theorists (Winkler-Rhoades, Carey, & Spelke, 2013, Haynes. & Murris, 2012; Fleer, 2010; Ginsberg & Golbeck, 2004; Egan, 2002).

- Limited exposure to science in the early years and less than ideal pedagogical practices result in negative perceptions and beliefs in older school children which, in turn, create barriers to the later learning of science (Mantzicopoulos et al, 2008).
- Early science contributes to a quality early education (Sylva et al, 2004).
- Children who have had a quality preschool education are significantly advantaged in adulthood (Schweinhart, 2003).

3. The curriculum's everyday representations of science steer the educator away from the idea that 'School science should ideally relate more closely to the scientists' idea of science' (Larkin, 2013; Ramnarain, 2010; Sharma & Anderson, 2009; Davydov, 2008; Hedegaard, 2002). In other words, the many open-ended empirical descriptions and images in the Grade R science curriculum counter the scientific stance taken by scientists and the neo-Vygotskians. The following points state the scientific perspective (in italics) followed by an example from the Grade R curriculum which illustrates ways in which the recontextualisation of scientific knowledge into school science for six-year-olds deviates from this scientific perspective:

- *Scientists are concerned with understanding the 'essence' of the concept, i.e. the essential features that are integral to and uniquely define the concept from all other concepts.* The Grade R science curriculum represents 'Fruit' (C8) according to how *fruit* tastes, looks and feels in place of providing the educator with a simple scientific definition, e.g. *fruit* is the seed-bearing embryo that develops in some plants after the flower has died (created from Morris, 1992).

- *Scientists are concerned with the acquisition of new knowledge.* Most of the terms employed by the Grade R science curriculum are likely to be familiar to six-year-olds. In the absence of the unfamiliar and the challenging, new knowledge is not acquired. According to the neo-Vygotskians, activities that are too simple do not target the child's zone of proximal development (ZPD), and familiar activities do not engage the law of equivalence by which something new is understood in relation to what the child already knows. Two examples illustrate this idea. The curriculum employs terms such as 'head', 'tummy' and 'an animal that we do not have on earth any more' (DBE, 2012a: 19; DBE, 2012d: 39) in the absence of introducing 'skull', 'stomach', and 'dinosaurs are extinct reptiles'. 'Summer' (C2), 'Autumn' (C5), 'Winter' (C6), and 'Spring' (C12) are represented in empirical terms, i.e. how seasonal change affects humans and plants, but the curriculum omits the science that lies behind the observable changes, i.e. the earth's movements in relation to the sun.

- *Science strives towards universal understanding of any given concept and therefore scientific representations are explicit, accurate, couched in specialised terms, and systematically ordered on the scientific knowledge continuum.* Of the fourteen concepts, the curriculum's definition of *reptile* as 'Characteristics of reptiles – cold-blooded, scaly body, lays eggs' (DBE, 2011a: 21) relates most closely to this idea. However, the scientific stance initiated by 'Reptiles' (C14) is undermined by omissions and everyday representations, e.g. 'Reptiles' is not positioned in relation to other concepts[123] (DBE, 2011a), a tortoise is unscientifically depicted in a train embraced by a hippopotamus (DBE, 2012c), and in place of the terms 'extinct reptile' and 'dinosaur' the workbooks employ the term 'an animal we do not have on earth any more' (DBE, 2012d: 39). In terms of relations to other concepts[124], the Grades 1– 6 science curricula generally counter the notion of the Grade R science concepts as entry level concepts on the scientific knowledge continuum, e.g. the Grade 4 topic concepts 'Living and non-living: Characteristics of living things. Plants and animals' and the 'Basic structure of plants – roots, stems, leaves, flowers, fruits, seeds' (DBE, 2011b: 21) are illogically introduced after the Grade R topic concepts 'Fruit', 'Vegetable', 'Birds', 'Reptiles', 'Dinosaurs' and 'Wild animals' & 'Finding out about one wild animal' (DBE, 2011a: 19-21). The conclusion is that the idea of school science knowledge as simple scientific concepts positioned on the scientific knowledge continuum is established in Grade 4 with the introduction of the Intermediate Phase *Natural Sciences and Technology* curriculum (DBE, 2011b).

The implications drawn from the discussion of everyday concepts are that the disjuncture between the way in which scientists view the world and the way in which Grade R science is

[123] There are no descriptions such as: 'Reptiles are animals. Reptiles are vertebrates, like birds and mammals because they have bones inside their bodies'.
[124] Table 3.3 in Chapter 3 provides an explanation of each kind of relations to other concepts.

represented is not in the best interests of children's development. It would be preferable to adopt a more scientific stance right from Grade R rather than deferring this to Grade 4.

5.2.2. Potential scientific concepts

Although the Grade R science curriculum does not represent concepts in terms of simple scientific concepts, the remaining seven Grade R topic concepts were rated as potential scientific concepts (≥ 5/12 ≤11/12). The seven potential concepts have some scientific features and are represented in ways that could prompt the Grade R educator into translating everyday representations into simple scientific terms. The following representations may prompt a simple scientific definition[125]: 1) a topic title that is unfamiliar to the Grade R learners, 2) a pertinent question, e.g. 'What is a wild animal?' (DBE, 2011a: 21), 3) images of the concept in relation to the open-ended statement 'Look at the picture and talk about ...' (DBE, 2012a: 3, 13; DBE, 2012c: 3, 13, 23, 42; DBE, 2012d: 3, 33), and 4) having to explain the workbook activities to six-year-olds who cannot read. If the curriculum's lexicon is very simple the Grade R educator may also be prompted into sharpening the concepts into more scientific terms.

The above points to what lies at the heart of a potential scientific concept: the translation of the everyday into the scientific *rests on the Grade R educator*, e.g. 'Weather' in Workbook 2 (DBE, 2012b) provides images of snow that can be translated for children in two ways: 1) 'In winter, when the earth tilts away from the sun, the weather becomes colder and in some places rain becomes snow' (a simple scientific definition), or 2) 'It snows in winter' (an empirical concept which is scientifically erroneous because it does not snow in winter in all geographical areas). Educators' responses cannot be easily predicted but the following suggest that this dependency is problematic:

In the absence of explicit scientific definitions and related scientific procedures in the Grade R curriculum, the educator is likely to translate the Grade R science curriculum representations according to his/her own science knowledge, understanding of a six-year-old's competencies, and approach to early science education. This translation is likely to be limited to the empirical for the following reasons. There are no Grade R graduate posts currently available in public schools in South Africa. Many Grade R educators have an 18 month part-time Level 4 or 5

[125] A simple scientific concept comprises two integral parts: content knowledge and procedural knowledge. A simple scientific definition describes the content of a simple scientific concept

Certificate in Early Childhood Education (ECD) and have been drawn from the field of educare where the focus is on health, safety and the child' emotional and social well-being; few are graduate pre-primary specialists (Drew in Umalusi, Centre for Education Policy Development (CEPD) & Wits seminar report, 2010). Reeves and Robinson (2010) indicate that a lack of content knowledge in teachers can have an adverse impact on students' acquisition of concepts. Muller's concurs in his response to an interview question asking him to name the 'three biggest challenges facing South African education today. 'Teachers, teachers and teachers. And, unlike most of my colleagues, I don't think it's what the teachers can't do that matters; it's what they don't know that makes the critical difference. (Of course those are connected).' (Muller, 2014)

In addition, most ECD educators have a limited understanding of science (Biersteker, 2012; Olgan, 2008; Kallery & Psillos, 2001). The above is significant in relation to research which has shown that

1) qualified teachers and early science contribute to a quality primary school education (Sylva et al, 2004), 2) limited exposure to science in the early years create barriers to the later learning of science (Mantzicopoulos et al, 2008), 3) a quality early education makes a qualitative difference to adulthood (Schweinhart, 2003), and 4) children from resourced schools are likely to do better academically than children from poor schools (HSRC, 2011).

The implications drawn from the discussion on potential scientific concepts are:

1) The Grade R educator determines the type of science knowledge acquired by learners in the Grade R classroom. This is problematic because it is idiosyncratic and scientific concepts cannot be idiosyncratic.

2) The curriculum representations are likely to be taken at face value by many of the Grade R educators resulting in the teaching and learning of everyday knowledge, not scientific knowledge.

3) Poor children are less likely to acquire simple scientific knowledge than children from advantaged communities because well-trained specialist teachers are likely to be located in well-resourced schools. A lack of quality schooling in early childhood is likely to impact in negative ways on disadvantaged children's later schooling and adulthood.

Furthermore, as the Grades 1, 2 and 3 science subject area *Beginning Knowledge* is structured in a similar way to the Grade R science curriculum, it is likely that the implications drawn above pertain to the Foundation Phase science curriculum. If the acquisition of simple scientific knowledge begins in Grade 4 it is understandable that South African school children score poorly on international rating scales (TIMSS, 2011) and that there is a dearth of Grade 12 maths and science learners (DBE, 2011d).

5.3. RECOMMENDATIONS

The following recommendations with regards to Grade R school science knowledge have been drawn from the discussions above:

- Reframe the Grade R science curriculum representations so that the learning and teaching of Grade R school science is brought closer to how scientists' generally understand the world.
- Support Grade R educators in understanding and facilitating simple scientific knowledge by providing Grade R educators with: 1) a simple scientific definition for each topic concept, and 2) training in how to mediate simple scientific concepts according to the neo-Vygotskian approach to school science for six-year-olds.
- Employ simple scientific concepts for the meaningful and integrated teaching of mathematics, literacy and critical thinking skills.
- Investigate a neo-Vygotskian approach to the *learning and teaching* of simple scientific knowledge.

5.4. CONCLUSION

This study has brought a particular focus to school science knowledge for six-year-olds and responds to Sharma and Anderson's recommendation that 'If we want our children to learn science ….then we will have to meet the challenge of recontextualisation head on and find ways to make science discourse internally persuasive …' (2009: 1271). Three novel ideas have emerged from the study. The first is a neo-Vygotskian description of the South African Grade R science curriculum concepts. The second is a conceptual framework that recontextualises the essential principles of a neo-Vygotskian approach to school science into the notion of a simple scientific concept as a unit of school science knowledge for six-year-olds. The third is a language of description that can be employed to analyse knowledge concepts for six-year-olds. All are likely to be useful in relation to what research is telling us about young children today and will contribute to the current debate on school knowledge. The 'profoundly empirical' nature of the formal-logic approach is problematic in schools because it limits theoretical thinking, i.e. ‘It does not enable cognition to distinguish between phenomena and essence’ (Davydov, 2008: 77). Fleer’s idea that there is ‘... disjunction between science education and early childhood education’ (2001: 43) is still valid in relation to Egan (2002) and Haynes & Murris’ (2012) ideas on the current move away from the 20th century perspective of children as deficit, vulnerable and developmentally incomplete. This study reflects Davydov’s (2008), Hedegaard’s (2002) and Fleer’s (2001) concern that school science should be based on scientific rather than empirical knowledge.

In response to the question of *How does Grade R curriculum represent school science knowledge for six–year-olds,* the study finds that the Grade R science curriculum pertains mostly to everyday knowledge. If taken at face value, the Grade R science curriculum bears little resemblance to the neo-Vygotskian idea of simple scientific knowledge for six- year-olds, calling into question the developmental trajectories of students in relation to science.

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Appendices

Appendix 1

SCIENTIFIC DEFINITIONS (Morris, 1992)

Word/concept	Definition	Page
Air	*Chemistry.* The invisible, odourless, and tasteless mixture of gases forming the earth's atmosphere. At sea-level pressures, dry air consists of (percentage by volume) nitrogen 78.00%, oxygen 20.95%, ...	61
Animal	*Zoology*. any member of the kingdom that is generally characterized by the power of voluntary movement, specialized sense organs that provide rapid motor response to stimuli, limited capacity for regenerative growth, the lack of rigid cell walls, and the inability to manufacture nutrients from inorganic substances. These qualities and others distinguish the animal kingdom from the plant kingdom.	117
Animalia	*Systematic*. one of the five basic categories, or kingdoms, in the taxonomic hierarchy, and including ...organisms that feed by ingesting other organic matter and are capable of spontaneous movement.	117
Atmosphere	*Meteorology*. The envelope of gases surrounding the earth and held to it by the force of gravity. It consists of four distinct layers ...	175
Autumn	*Astronomy*. in the Northern Hemisphere, the season that begins with the September equinox and ends with the December solstice; in the Southern Hemisphere, the season between the March equinox and June solstice.	192
Aves	*Vertebrate Zoology*. the class of vertebrates that includes all bird, characterized by being warm-blooded and egg-laying and having feathers and wings.	194
Biology	Biology is the study of the properties and history of living organisms and of their interactions with the non-living world.	261
Bird	*Vertebrate Zoology*. any of the many vertebrates in the class Aves; all are warm-blooded, lay eggs, and have wings and feather, and most can fly.	264
Blue	*Optics.*1. the colour sensation that corresponds to radiation in the 455 to 492 nanometer wavelength of the light spectrum and lies between violet and green on the color spectrum.	282

Body	*Biology*. the complete physical substance and structure of an organism, living or dead. *Zoology*. the trunk of an animal, excluding the head, limbs, and tail.	285
Botany	*Biology*. 1. the branch of biology that is concerned with the study of plants and plants life	295
Chemistry	the science that deals with the composition, structure, properties, interactions, and transformation s of matter.	411
Circle	*Agriculture.* the practice of agriculture.	807
Form	-	-
Free form	-	-
Fruit	*Botany*. the fully matured ovary of a seed plant, including the seed or seeds, connecting tissues, and any covering.	888
Gas	*Physics. O*ne of the three fundamental forms of matter, along with liquids and solids, unlike a solid (and like a liquid), a gas has no fixed shape and will conform in shape to the space available. Unlike a liquid, it has not fixed volume and will conform in volume to the space available. In comparison with solids and liquids, gases have widely separated molecules, are light in weight, and are easily compressed ...*Chemistry*. any such substance (e.g. hydrogen, oxygen) or a mixture of such substances (e.g. air, carbon dioxide).	904
Geology	the study of the earth in terms of its development as a planet since its origin, including the history of its life forms, the materials of which it is made, the processes that affect these materials, and the products that are formed of them.	923
H_2O	The chemical formula for water.	1032
human	*Vertebrate Zoology*. 1. A member of the species *Homo sapiens*, especially the modern subspecies *Homo sapiens sapiens*, the group of mammals characterized by an erect stance, a large, highly developed brain, and the use of tools and language.	1051
Insect	*Invertebrate Zoology.* 1. a member of the class Insecta, such as a fly, ant ,bee, wasp, mosquito, beetle, grasshopper, or flea...	1115
Insecta	*Invertebrate Zoology.* a class of air-breathing arthropods usually having a segmented body with chitinous exoskeleton, a pair of compound eyes, a pair of segmented antennae, three pairs of mouth parts, three pairs of legs, and two pairs of wings.	1115
Kingdom	*Systematics.* The highest of the principal or obligatory ranks in the taxonomic hierarchy, above phylum or division.	1182

Materials science	the scientific study of the structure, properties, and performance of metals, ceramics, polymers, and semiconductors.	1324
Meteorology	1. the scientific study of the earth's atmosphere, especially as this relates to weather and climate. 2. The weather conditions of a particular place.	1362

Molecule	*Chemistry.* the smallest unit of matter of a substance that retains all the physical and chemical properties of that substance, consisting of a single atom or a group of atoms bonded together e.g., Ne, H_2, H_2O.	1403
Month	-	-
Names of each month of the year	-	-
Nature	*Science.* 1. A general term for all aspects of the physical world other than humans, such as animal and plant life, features of the earth, and so on.	1444
Night	-	-
Object	*Optics.* 1. the figure seen through or the image (real or virtual) formed by an optical system. *Mathematics*. 1. A member of the class that, together with the sets of morphisms, makes up a category. 2. anything that can be transformed from one set of coordinates to another. (Morphism. *Mathematics*. a member of a class Hom (X,Y) of mappings between two objects X and Y of a category)	1494 1415
Old age	*Medicine.* an imprecise term for the later period of life...	1506
Part	-	-
Partial	*Science*. not total or general; incomplete.	1579
Particle	*Particle Physics.* a minute subdivision of matter such that it is a fundamental constituent so small that it cannot be divided further.	1580
People	-	-
Physics	*Science.* the scientific study of matter, energy, motion and force.	1643
Plant	*Botany*. 1. Any member of the kingdom Plantae, generally characterized by the ability to produce food by photosynthesis, thick cell walls containing cellulose, a lack of power of locomotion, and a relatively open growth pattern.	1664
Plantae	*Botany*. The plant kingdom; in most systems, ... organisms that have cellulose cell walls, are capable of producing their own food, are not capable of spontaneous movement, and lack obvious nervous or sensory organs ...	1664
Pyramid	... having a square base and four sloping triangular sides that meet at the apex. *Science*. 1. anything having this shape. 2. anything having sides that taper to meet at the apex.	1762
Rain	*Meteorology.* Precipitation in the form of water drops, usually having diameters greater than 0.5 mm, except then the drops are widely scattered and may be smaller; the intensity of rainfall at any given time and place is classified as very light, light, moderate, or heavy.	1792

Red	- (refer to the term 'blue' as there seems to be one scientific definition that can be applies to all the other colours)	-
Reptile	*Vertebrate Zoology*. any cold-blooded vertebrate animal belong to the class Reptilia including extinct dinosaurs as well as crocodilians, turtles, lizards, snakes, amphisbaenids and tuatara. (See Reptilia below) Amphisbaenidae. *Vertebrate Zoology*. the worm lizards ...	1836 100
Reptilia	*Vertebrate Zoology.* the reptiles, a class of aquatic or terrestrial , cold-blooded vertebrates having bodies covered with horny scale or plates, breathing by means of lungs, and usually laying eggs outside the body.	1836
Science (definition)	1. the systematic observation of natural events and conditions in order to discover facts about them and to formulate laws and principles based on these facts. 2. the organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation. 3. any specific branch of this general body of knowledge, such as biology, physics, geology, or astronomy.	1926
Science (quote)	*Science* connotes both the knowledge contained in such disciplines as astronomy, physics, chemistry, biology, and geology and the activities involved in obtaining it. (Charles Gillispie, Professor of History of Science Emeritus, Princeton University).	1926
Scientific	1. of or relating to science. 2. Employing or based on the methods or theories of science. 3. Of technical or practical activities, carried out in a manner that is thought of being comparable to science, as by being systematic, highly accurate, painstaking, and so on.	1926
Seasons	*Meteorology.* a division of the year characterized by regularly occurring phenomena or weather conditions specific to a given area, e.g. the rainy season and the dry season in the tropics.	1938
Shape	-	-
Sight	*Physiology.* The ability to see, or the process of seeing; vision.	1986
Smell	*Physiology.* 1. the sensation recognised by the olfactory receptors in the nasal mucus membranes and a specialized area of the cortex. 2. the characteristics of substances that stimulate this smell sensation. 3. to recognize a substance by its smell.	2013

Soil	*Geology.*1. all loose, unconsolidated, weathered, or otherwise altered rock material above bedrock. 2. a natural accumulation of organic matter and inorganic rock material that is capable of supporting the growth of vegetation.	2026
Solstice	*Astronomy.* the moment that the sun reaches its greatest extent in declination, north or south	2032
Sound	*Acoustics.* 1. a pressure disturbance that propagates through a medium due to stress or displacement of the medium from its equilibrium state. 2. the auditory perception that is induced by such a disturbance; something heard by the ears.	2038
Sphere	*Science.* a round body or figure. *Mathematics.* the mathematical description of such a figure; the set of points in a metric space that are a constant distance, called the radius, from a fixed point...*Physics.* any globular or rounded object approximating the form of a geometric sphere. *Astronomy.*1. any planet or star.	2054
Spring	*Astronomy.* the season between the vernal equinox and the summer solstice, in which days become progressively longer in northern latitudes and progressively shorter in southern latitudes.	2068
Square	*Mathematics.* 1. a quadrilateral having all four sides and all four angles equal; ...	2070
Summer	*Astronomy.* the period between the summer solstice ... and the autumnal equinox ... *Meteorology*. The characteristic climate associate with this season in a given area, which tend to vary with latitude. Near the tropics, the summer is nearly always hot but may be markedly wet or dry; moving poleward, the intensity of storm systems becomes a crucial characteristic; and near the poles, the greater duration of sunlight is the most important factor.	2132
sun or Sun	*Astronomy.* the star that is the central celestial body in the solar system; it has ...	2133
sunlight	*Astronomy. t*he direct light from the sun.	2133
Taste	*Physiology.* 1. the quality by which food, drink, and other substances are described when taken into the mouth; technically, the impression produced by stimulating the gustatory receptors in the tongue and oropharynx. 2. the sense of perceiving food and other substances in this way. In Western cultures, the taste of something is generally describe as being bitter, sweet, salty or sour.	2173

Time	*Physics.* 1. a fundamental dimensional quantity by which physical events can be place in an ordered sequence. 2. A given instant within this sequence that may refer to a specific event 3. A continuous process made up of the complete range of such instants, regarded as constantly advancing and irreversible in nature.	2223
Today	-	-
Tomorrow	-	-
Touch	*Physiology.* 1. the tactile sensation; the ability to perceive that one's finger, hand or other body part is in contact with some external object or surface. 2. the examination of an object employing this tactile sense.	2238
Transport	*Engineering.* equipment used for transporting or conveying something from one place to another.	2252
Triangle	*Mathematics.* a plane polygon with three sides; equivalently, a plane polygon with exactly three (noncollinear) vertices. Collinear. *Mathematics*. lying on the same line. Plane. A flat or level surface...*Mathematics*. 1. a surface S with the property that the straight line joining any two points of S is also contained in S. ...2. a term used to indicate that a given geometric object can be embedded in the plane e.g. ...plane polygon. Vertices – (in the Oxford Concise dictionary (2010:) -	2259 467 1662 -
Vegetable	*Agriculture*. 1. Any plant whose fruit, seeds, roots, tubers, bulbs, stems, leaves, or flower parts are used as food. 2. The edible part of such a plant. *Botany*. of or relating to plants.	2321
Water	*Chemistry.* H_2O, a colourless, odourless, tasteless liquid having a melting point of 0^oC and a boiling point of 100^oC at standard atmospheric pressure, and having the allotropic forms of ice (solid) and steam (vapour).	2352
Weather	*Meteorology*. 1. The short-term state of the atmosphere, as distinguished from the long-term condition of climate; this includes temperature, humidity, precipitation, wind, visibility, and other factors, chiefly considered in terms of their effects on life and human activity. 2. In a surface weather observation, a category of atmospheric phenomena that are used to identify a localized atmospheric state at the time the observation is taken; this includes conditions such as rain, sleet, snow, tornado, and thunderstorm.	2358

Week	*Astronomy.* a period of seven successive days, generally considered to begin with Sunday and end with Saturday.	2360
Wild	-	-
Wildlife	*Zoology*. 1. a general term for all undomesticated animals that live free in nature.	2370
Wind	*Meteorology.* air that is in motion, especially horizontally, in relation to the earth's surface.	2371
Winter	*Astronomy.* the season beginning at the winter solstice, approximately December 22, and lasting until the vernal equinox, about March 21.	2374
Year	*Astronomy.* one revolution of the earth around the sun reckoned by any of several time markers, such as vernal equinox passage, relative the stars, and so on: in common usage, 365.25 days. See also TROPICAL YEAR, LUNAR YEAR, and so on.	2388
Yesterday	-	-
Zoology	Zoology is the study of animals. It is the subdivision of biology, which is the study of all living things.	2397

Appendix 2

KEY CONCEPTS

CAPS: Curriculum and Assessment Policy Statement.

Classification: Refers to "… a distribution of objects and phenomena of a certain type 'by groups and subgroups in relation to their similarities and differences from one another'" (Davydov, 1990: 10.). Classification is also commonly known as 'sorting' or 'grouping'. According to Davydov teaching children to classify and to use the knowledge in another context is one of the main tasks of instruction for mastering a concept (Davydov, 1990: 11).

Concept formation: Humans understand the world through forming ideas. Concept formation starts in young children with the simple naming of an object e.g. seeing a dog and saying the word 'dog'. Einstein's equation $E=mc^2$ is also a concept but it is more complex, abstract and involves understanding many other concepts such as the speed of light and mass. The notion of scientific, academic or authentic concept formation involves identifying the essential integral attributes of an object or phenomena e.g. a bird is an animal that has a beak, feathers, two wings and legs. Female birds lay eggs.

Concept: "A combination of two, three, or more abstract and general attributes which is formed by the significance of a certain word (most often by means of a *definition*) is usually called a *concept*" (Davydov, 1990: 7). Concepts can be divided into two basic types: everyday and scientific concepts. A scientific concept can be simple e.g. a triangle is a shape with three sides and three angles, or complex e.g. $E = mc^2$.

Conception: "Thus a conception as a form of knowing allows one to find similar, coincident, 'important' attributes in a group of objects and to separate them from the individual 'secondary' attributes" (Davydov, 1990: 9). Conception centres on the external visible attributes of an object or phenomenon and not on the essential attributes integral to the object or phenomenon e.g. a child identifies a triangle from a group of geometric shapes by *seeing that it visibly matches* other triangular shapes; not *by checking that it has is a shape with three sides and three angles* i.e. the essential attributes of a triangle.

Deductive: A term describing a specific approach to learning and teaching whereby the abstract and general concept is introduced to children first followed by specific concrete application activities which facilitate the mental internalisation of the abstract concept. For example: the teacher first tells the children 'Plants need light and water to grow' before providing and mediating experiments with growing plants in the dark and with and without water. The neo-Vygotskians advocate a deductive approach.

Discovery: A term describing a specific approach to learning and teaching. The teacher provides and mediates specific concrete experiential opportunities for children to explore and make their own discoveries which leads to the internalisation of the abstract and general concept. For example: the teacher sets up plant growing experiments involving light and water. The teacher asks open-ended questions which direct the children to discover and make their own realisation that 'Plants need light and water in order to grow'. Piaget and his followers advocate the discovery approach.

Everyday knowledge: Refers to the commonsense required for everyday living e.g. how to make supper. Everyday knowledge is context dependent and is usually acquired by experience and observation

Empirical knowledge: Refers to a particular type of everyday knowledge. Empirical knowledge is factual within a particular context e.g. the statement 'it snows in winter' is a fact but it only pertains to some geographical areas.

First generation neo-Vygotskian: The Russian colleagues and disciples of Vygotsky e.g. Galperin, Luria, Davydov, Zaporozhets, and Leontiev

General genetic law of cultural development: Learning first occurs on the social and external plane before it is internalised mentally within an individual, i.e. "... *human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them*" (italics by Vygotsky, 1978: 88).

Generalization: Generalisation is the identification of a phenomenon or object as belonging to a certain class based on a particular attribute or attributes. "During generalization what occurs is, on the one hand, a search for certain invariant in an assortment of objects and their properties, and a designation of that invariant by a word, and, on the other hand, the use of the variant that has been singled out to identify objects in a given assortment" (Davydov, 1990:5). Generalisation is closely related to classification for "The process of generalization is finding a given 'general' element and forming a class as its carrier" (italics by Davydov, 1990: 22).

Grade R: The year before Grade 1

Grade R science curriculum: A general term to indicate the official directives, knowledge topics and internalising activities pertaining to the subject area *Beginning Knowledge* in the current CAPS curriculum document (DBE, 2011a) and supporting CAPS workbooks (DBE, 2012a; DBE, 2012b; DBE, 2012c; DBE, 2012d)

Higher order thinking: Mental functions that have developed beyond the very young child's basic mental ability to think, recall and to react. Examples of higher order thinking are logical memory, problem solving, reflection, analysing, and prediction.

Law of equivalence: Vygotsky's idea that human beings acquire new knowledge by comparing the new to something known. "... any concept can be formulated in terms of other concepts in a countless number of ways" (1962: 112).

Leading developmental activity: "... a leading activity is an action–orientated motive that is dominant in a particular cultural community for individual s at a particular point in time. A leading activity is framed in relation to how societies organize the institutions of family, preschool and school"(Fleer, 2011: 225). The leading developmental activity in industrialised societies for preschool children is *socio-dramatic play* and for school children *learning through instruction*. For six-year-olds, who are at the conception stage of development and who are in transition from preschool to formal schooling, the leading developmental activity is an integration of *play* and *school instruction*.

NCS: National Curriculum Statement.

Older preschooler: A term used by the first generation neo-Vygotskians. The term refers to a child who is six turning seven years old (Yendovitskaya in Zaporozhets & Elkonin, 1971: 108).

Perception: The immediate concrete-sensory perception of external attributes. Perception does not require language or mediation by others.

Perception-conception-concept scheme "... describes the formation of every new piece of generalized knowledge" (Davydov, 1990: 12).

Play: The term 'socio-dramatic play' is used in this study to describe the Vygotskian notion of play which is a purposeful, rule-bound, imaginative activity which develops self-regulation, and is the portal to abstraction. Socio-dramatic play also functions as the leading developmental activity for preschool children. The Vygotskian notion of play does not relate to the image of children running around freely in the garden, nor to the Western notion of play as differentiated into stages i.e. manipulative play, solitary play, parallel play, shared play and fantasy play.

Potential scientific concept: A school science concept that has the potential to becomes a simple scientific concept because it is represented in a way that is likely to prompt the educator into describing the concept in simple scientific terms.

Procedural knowledge: A neo-Vygotskian idea that refers to the particular activities and mental processes that lead to the internalisation of content knowledge. procedural knowledge involves classification, targets a child's zone of proximal development, and engages with the law of equivalence e.g. a child learns about the concept 'fruit' by *comparing* and *sorting* a number of objects (tomato, apple, potato, orange, spinach, avocado, eggplant, cucumber) using the *essential attributes of fruit as the classification criteria*, and d*rawing conclusions*.

RNCS: Revised National Curriculum Statement for Grades R- 9.

School knowledge: Used in this study to refer to selected scientific and empirical knowledge recontextualised for the purpose of teaching children about the world (Hedegaard, 2002).

School science: A narrowed down form of school knowledge that pertains only to selected aspects of the natural sciences chosen by appointed officials for the express purpose of transferring preferred historical knowledge to children (Hedegaard, 2002). The South African official 'school science' subject for children six to nine years old is the study area

Beginning Knowledge in the *Curriculum and Assessment Policy Statement: Life Skills, Foundation Phase Grades R-3 text* (DBE, 2011a). In the Intermediate Phase 'school science' for ten to 13 year olds is the CAPS curriculum subject *Natural Science and Technology* (DBE, 2011b). In high school 'school science' is differentiated into different subjects such as biology, chemistry and physics.

Science: A loose overarching term that is commonly used to refer to what scientists know about the world.

Scientific knowledge: What scientists and academics know about the world. Scientific knowledge is a broad term that refers to the human accumulation of systematically ordered academic knowledge about the universe that has been handed down by each human generation. Scientific knowledge seeks to be exact and truthfully representative within the current historical context, and therefore is constantly being re-evaluated, elaborated upon, extended or revised subject to academic consensus. According to Davydov the difference between everyday and scientific knowledge is that "Science aspires to pass from the description of the phenomena to the disclosure of essence as their internal bond" (1990: 36).

Scientific concept: A single unit of scientific knowledge. Each scientific concept has two integral parts i.e. 1) content, and 2) procedure i.e. the particular processes related to the acquisition of the scientific content. Specific criteria are employed to differentiate a scientific from an everyday concept. Scientific concepts underpin more complex concept e.g. understanding speed underpins understanding the speed of light and $E= mc^2$

Simple scientific concept: A single unit of scientific knowledge that is scientifically acceptable but it is differentiated from other scientific concepts by being couched in terms that six-year-olds can understand.

Second generation neo-Vygotskians: The Western Vygotskian theorists who are followers of Vygotsky e.g. M. Hedegaard and M. Fleer

Six-year-olds: Refers to children who are five turning six years old. In this study the terms Grade R children refers to six-year-olds.

Vygotskian: A broad term used to indicate that the idea or approach source originated from Vygotsky

WCED: Western Cape Education Department

ZDP: Zone of proximal development

Zone of proximal development (ZPD): "... *the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*" (italics by Vygotsky, 1978: 86). In simple terms: according to Vygotsky the ZDP is the potential learning space between what the child already knows and can do, and the new knowledge and skills which the child could acquire if supported by a knowledgeable adult.

Appendix 3

PRIMARY DATA: The Grade R science curriculum topic concepts

These knowledge data segments for analysis are coded sequentially from C1 to C18 (the code C pertains to Knowledge Concept) in the table below, and are reproduced exactly as is from the South African Curriculum Assessment Policy Statement (CAPS) Foundation Phase Life Skills document (DBE, 2011a: 15-21).

Text type & CODE	DATA SEGMENT DESCRIPTIONS
TOPIC C1	Topic: My Body – 2 hours • Identify and name body parts – include how many of each • Functions of different body parts • Who may or may not touch my body • What my body needs to keep healthy (DBE, 2011a: 16).
TOPIC C1.1	Topic: Sound – 2 hours • Sounds we hear • What makes the sounds we hear • Music I like • How hearing keeps us safe • Looking after my ears (DBE, 2011a: 18).
TOPIC C1.2	Topic: Sight – 2 hours • Things around me • Light, dark and shadows • How being able to see keeps us safe • Looking after my eyes Note: Adapt curriculum as necessary for learners who are blind or partially sighted. (DBE, 2011a: 18).
TOPIC C1.3	Topic: Touch – 2 hours • Different things feel different • Introduce new words: hard, soft, smooth, rough, cold, hot warm, cool

	• Experiencing different temperatures and textures (DBE, 2011a: 18).
TOPIC C1.4	Topic: Taste and smell – 2 hours • Tastes and smells I like • Tastes that are new to me • Safety when tasting • Different smells around us • Where smells come from (DBE, 2011a: 18).
TOPIC C2	Topic: Summer – 2 hours • The weather in summer • How nature is affected • How animals are affected • How people are affected – e.g. what we eat, wear, do, games we play (DBE, 2011a: 16).
TOPIC C3	Topic: Shapes and colours around us – 2 hours • Look at and name different shapes • The shapes that make up different objects • Look at and name the different colours • Shades of colours – e.g. light, dark (DBE, 2011a: 16).
TOPIC C4	Topic: Weather – 2 hours • What the sky looks like – include colour and clouds • Hot days, cold days, sunny days, rainy days, windy days – include what we wear on these days Note: ensure learners never look at the sun (DBE, 2011a: 17).
TOPIC C5	Topic: Autumn – 2 hours • The weather in autumn • How nature is affected • How animals are affected • How people are affected – e.g. what we eat, wear, do, games we play (DBE, 2011a: 17).

TOPIC C6	Topic: Winter – 2 hours • The weather in winter • How nature is affected • How animals are affected • How people are affected – e.g. what we eat, wear, do, games we play (DBE, 2011a: 19).
TOPIC C7	Topic: Water – 2 hours • Objects that float and sink • Things that live in the water • Mixing different things in water to change what it looks like • Pouring and measuring water • Saving water (DBE, 2011a: 19).
TOPIC C8	Topic: Fruit – 2 hours • Different types of fruit • Tastes and textures of fruit • Where fruit comes from • Colours and shapes of fruit (DBE, 2011a: 19).
TOPIC C9	Topic: Vegetables – 2 hours • Different types of vegetables • Tastes and textures of vegetables • Where vegetables come from • Colours and shapes of vegetables (DBE, 2011a: 20).
TOPIC C10	Topic: Dairy farming – 2 hours • Dairy products and the animals they come from • How we get butter (DBE, 2011a: 20).
TOPIC C11	Topic: Wool farming – 2 hours • A sheep farm • Where wool comes from Uses • of wool (DBE, 2011a: 20).

TOPIC C12	Topic: Spring – 2 hours • The weather in spring • How nature is affected • How animals are affected • How people are affected – e.g. what we eat, wear, do, games we play (DBE, 2011a: 20).
TOPIC C13	Topic: Birds – 2 hours • Different types of birds • General characteristics of a bird – feathers, two legs, beak, lays eggs • Bird that cannot fly – ostrich, penguin • Nests (DBE, 2011a: 21).
TOPIC C14	Topic: Reptiles – 2 hours • Different reptiles – e.g. crocodile, snake, lizard • Characteristics of reptiles – cold-blooded, scaly body, lays eggs • Find out more about at least one reptile (DBE, 2011a: 21).
TOPIC C15	Topic: Dinosaurs – 2 hours • Different dinosaurs • How dinosaurs lived • How we know about dinosaurs today Note: use picture books from the library (DBE, 2011a: 21).
TOPIC C16	Topic: Wild Animals – 2 hours • What is a wild animal? • Types of wild animals • Where we find wild animals • How wild animals live Topic: Finding out about one wild animal – 2 hours • Choose one animal to study • What the animal looks like • Where it lives • What it eats • Babies and where they are born An additional interesting fact (DBE, 2011a: 21).