Developing pedagogical content knowledge for teaching science to young learners

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DECLARATION

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I hereby confirm that I have proofread and edited the following thesis, including the bibliography.

Title of thesis

Developing pedagogical content knowledge for teaching science to young learners

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ABSTRACT

The 21st century with all of its technological advances also brings about challenges for science teaching in preparing the adults of tomorrow for the challenges of the future. Science, technology, engineering, art, and mathematics education has become crucial in the preparation of the future citizens of the modern world.

The rationale for this study is to obtain an in-depth view of the development of the young child in terms of the possibility of scientific reflection, as well as identifying possible methodology and content in the teaching and learning of science relevant to specific age phases. Based on this information, a framework for the teaching and learning of science by the young child is created. The framework should enable the learning of science that can be utilised by future policy developers of curricula, not only in South Africa but also in an international context.

The cultural-historical activity theory of Vygotsky and the post-Vygotskians is used for studying the development of the young child in terms of physical, mental, emotional, and social development. Vygotsky's constructivist theory defines age in terms of specific changes that take place in the structure of the child's mental processes and the major developmental accomplishments that emerge as the child is growing up in a unique social situation of development. Without the child's needs, inclinations, incentives, and motives to act, there will never be any advance from one stage to the next. Each advance from one age-related level to another relates to an abrupt change in motives and incentives to act.

The methodologies investigated for the development of scientific reflection of the young child was play, playworlds or scientific playworlds, and inquiry-based science education. Play is defined by Vygotsky and other post-Vygotskian scholars, such as Leontiev and Elkonin, as dramatic or make-believe play. Make-belief play has the following three components: creating an imaginary situation; taking on and acting out roles; and following a set of rules determined by specific roles.

The concept of playworlds was coined by Lindqvist and based on Vygotsky's theory. Lindqvist made use of stories and the dramatisation of stories, where the stories had traces of basic conflict situations. Children often relate to their surroundings in a dramatic way. Play is a dynamic meeting between the child's internal activities (emotions and thoughts) and external ones. Scientific playworlds begin with a collective imaginary situation, drawing on a cultural device relating to the science to be learnt, and make it necessary for children to go on a scientific journey, producing the dynamic imaginary scientific context. Children then need to build a scientific narrative to solve scientific problems. The imaginary play is the context, the motive, and the narrative, binding together science learning for children.

The third pedagogy considered for science teaching of the young child is inquiry-based science education. Scientific inquiry represents the diverse ways in which scientists work to generate and validate knowledge. It involves the gathering of evidence, the consideration of possible explanations, and is about performing experiments and making observations.

Content for a science curriculum was investigated to identify content that would be applicable for children in the different age groups. The possible content can be divided into physics, chemistry, biology or ecology, and planets, systems, and electronic control.

Key terms: Age phases, inquiry-based science education young child, make-believe play, playworlds, scientific reflection.

OPSOMMING

Die 21ste eeu met sy die tegnologiese vooruitgang hou ook uitdagings in vir die onderrig van wetenskap om môre se volwassenes voor te berei vir die uitdagings van die toekoms. Opvoeding in wetenskap, tegnologie, ingenieurswese, kuns en wiskunde is noodsaaklik om toekomstige burgers van die moderne wêreld te ontwikkel.

Die doel van hierdie studie is die verkryging van ’n diepgaande begrip van die ontwikkeling van die jong kind met betrekking tot wetenskaplike besinning asook die identifisering van moontlike onderrigmetodes en inhoud vir wetenskaponderrig in die verskillende ouderdomsgroepe. Op grond hiervan word ’n raamwerk vir die leer en onderrig van wetenskap vir die jong kind ontwikkel. Die raamwerk kan ook in Suid-Afrika en internasionaal deur toekomstige kurrikulumbeleidsontwikkelaars gebruik word.

Die kultuurhistoriese aktiwiteitsteorie van Vygotsky en sy navolgers is gebruik as basis vir die studie van die jong kind se ontwikkeling met betrekking to fisieke, verstandelike, emosionele en sosiale ontwikkeling. Vygotsky se teorie definieer ouderdom aan die hand van spesifieke veranderings in die struktuur van ’n kind se verstandelike ontwikkeling as gevolg van die kind se ontwikkeling in ’n unieke sosiale omgewing. Die kind se ontwikkeling en beweging na ’n volgende ontwikkelingsvlak word toegeskryf aan sy of haar behoeftes, gesindhede, aansporing en motiewe. Elke beweging na ’n volgende vlak van ontwikkeling veroorsaak ’n skielike verandering in motiewe en motivering om te handel.

Drie metodes van onderrig is ondersoek, naamlik speel, speelwêreld en navorsinggebaseerde wetenskaponderrig. Speel word deur Vygotsky en sy navolgers Leontiev en Elkonin as dramatiese speel of verbeeldingspeel gedefinieer. Om as verbeeldingspel te kwalifiseer, moet speel aan drie vereistes voldoen, naamlik die ontwikkeling van ’n verbeeldingsituasie, die vertolking van ’n rol en die nakom van reëls vir die spesifieke rol.

“Speelwêreld” as konsep is deur Lindqvist ontwikkel, gebaseer op Vygotsky se teorie. Lindqvist gebruik stories en die dramatisering van stories. Die stories bevat konfliksituasies wat kinders op ’n dramatiese wyse kan beleef. Speel is ’n dinamiese sameloop van die kind se interne aktiwiteite (emosies en gedagtes) sowel as eksterne aktiwiteite. Speelwêrelde begin met ’n gemeenskaplike verbeeldingsituasie, en maak gebruik van ’n kulturele voorwerp wat verbind kan word met die wetenskap wat geleer moet word. Dit is dan nodig vir die kind om op ’n wetenskaplike reis te gaan, en in die proses word ’n dinamiese denkbeeldige wetenskaplike konteks ontwikkel. Die kind moet ’n wetenskaplike verhaal skep om wetenskaplike probleme op te los. Die verbeeldingspel word die konteks, motief en verhaal wat die wetenskaponderrig vir kinders saambind.

Die derde pedagogiek wat vir die wetenskaponderrig van die jong kind oorweeg word, is navorsinggebaseerde wetenskaponderrig, wat die verskillende wyses wat wetenskaplikes gebruik om kennis te skep en te bevestig, verteenwoordig. Dit sluit die versameling van bewyse, die evaluering van moontlike verduidelikings en die uitvoer van eksperimente en waarnemings in.

Moontlike inhoud vir die wetenskapkurrikulum is nagevors. Moontlike inhoud geskik vir jong kinders kan geklassifiseer word as fisika, chemie, biologie of ekologie en planete, stelsels en elektroniese beheer.

Sleutelbegrippe: Jong kinders, navorsinggebaseerde wetenskaponderrig, ouderdomfases, speelwêreld, verbeeldingspel, wetenskaplike besinning.

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List of acronyms/abbreviations

CAPS	Curriculum and Assessment Policy Statement
CHAT	Cultural-Historical Activity Theory
IBSE	Inquiry-Based Science Education
ICT	Information and Communication Technology
NCF	National Curriculum Framework
STEAM	Science, Technology, Engineering, Art, and Mathematics
STEM	Science, Technology, Engineering, and Mathematics
TPACK	Technological Pedagogical Content Knowledge
ZPD	Zone of Proximal Development

CHAPTER 1: INTRODUCTION

1.1 Introduction and background

The 21st century brings unique challenges in terms of education and, specifically, science education. Children are growing up in a world with unique complex global issues, great scientific discoveries, and technological advances. The adults of the future will have to deal with complex situations such as climate change and artificial intelligence.

Scholars such as Trna and Trnova (2015) reveal that not only science but also technology, engineering, and mathematics (STEM) education is becoming more important for facing economic, environmental, and social challenges. STEM literacy is necessary for all children, not only to ensure there are enough highly gifted individuals to enter scientific and engineering careers but also that all children have the knowledge and skills necessary for everyday life. Because of the development of information and communication technology (ICT), there is more pressure for coding and computational thinking in early childhood education.

Cabe Trundle (2015) points out that, young children have a natural disposition to enjoy, observe, and think about nature. Their range of capacities and their disposition to observe, explore, and discover the world enable young children to solve challenging problems (European Commission, 2015). As young children are motivated to explore the world around them, early science experiences can capitalise on these inclinations. Consequently, developmentally appropriate engagement with quality science learning experiences is vital to assist children in understanding the world, collecting and organising information, applying and testing ideas, and developing a positive attitude towards science (Cabe Trundle, 2015).

The European Commission (2015) states that quality science education uses children’s everyday experiences and settings and makes links to what is taught. The Commission concludes that any opportunities missed teaching science in early childhood and school education result in people not attaining the minimum levels of core skills necessary to cope with the complexities of life and work in the 21st century.

The primary goal of science education is identified by Klahr, Zimmerman, and Jirout (2011) as teaching children to think scientifically. Thinking scientifically includes domain-general reasoning and domain-specific content knowledge. Scientific thinking is part of the 21st-century skills that will prepare children for participation in the knowledge society.

The report of the European Commission (2015) further highlights that in order to prepare people for lifelong employability, they should leave compulsory education with knowledge of and about science and its culture and values and with a positive attitude towards and willingness to learn more about science. Curiosity about the world around us, learning to act and think like a scientist and an innovator, and understanding the nature of science provide a foundation for future success.

Creative Little Scientist (2014), a 30-month European Union-funded comparative study across nine participating countries, adopted a rationale for science education that focused on children's role as citizens and highlighted science and environmental awareness as a part of their life in general. This study (Creative Little Scientist, 2014) found that teachers' viewpoints regarding the rationale for science learning were, in practice, more holistic than what has been found in the policy documents in many partner countries. Learning aims and objective were conceptualised by teachers as primarily contributing towards affective and social aspects of learning, such as increasing interest in and a positive attitude towards science and science learning. This contrasted with the emphasis in many official policy documents on the development of knowledge and understanding of science and ideas and on skills associated with scientific inquiry, especially in primary education. In other words, for children to develop the necessary scientific literacy skills, teachers will have to adjust their teaching.

Zimmerman (2007) identifies one of the goals of contemporary science education as the production of science-literate adults, which means having the skills and tools to reason about scientific concepts. While the modern world requires children to become scientifically literate, researchers have identified a lack of interest in science learning among learners. Rocard (2007) points out that, studies have highlighted an alarming decline in young people's interest in key science and mathematics studies. This decline in interest among young people for studying science is blamed on the way science is taught in school. Van Keulen and Oosterheert (2011) are of the opinion that enthusiasm for science and technology should be created by the teachers of young learners. Yoon and Onchwari (2006) echo this idea by stating that the quality of science teaching depends heavily on the teacher for creating an environment that is rich in science learning opportunities. According to Kornelaki and Plakitsi (2018), the teacher is the catalyst of science learning, enabling the learner to understand and enjoy finding out about the natural world (small ideas) to later become big ideas through broad generalisation (Harlen & Léna, 2011).

Effective science teaching for the pre-school and Foundation Phase learner depends not only on the teacher's attitude to science (Cho, Kim, & Choi, 2003) but also their motivation to implement opportunities for science learning (Barenthien, Opperman, Anders, & Steffenskya, 2020). Gerde, Pierce, Lee, and Van Egeren (2018) point out that teachers with high self-efficacy have more positive expectations for learner achievement and better learner outcomes.

The implication of all of this is that there should be a concerted effort to develop a range of types of knowledge necessary for a teacher to successfully teach science. Ball, Thames, and Phelps (2008) identify different types of knowledge necessary for teaching. They state that the teacher's content knowledge of science and of the curriculum and knowledge of the children will promote the learners' understanding of and reasoning about science. The pedagogical content knowledge of the teacher is the primary knowledge necessary for teachers to help learners reason about specific science content. The currently experienced deficit in knowledge related to content and pedagogy regarding the teaching and learning of science for very young children is an international problem that needs to be pursued.

1.2 Rationale for the study

Studies on the quality of science teaching in the South African Foundation Phase have shown that during this crucial phase of teaching, several factors have a negative impact on science learning (Du Preez, 2016). Du Preez (2016) has found that pedagogical content knowledge of the teaching of Beginning Knowledge education in the Foundation Phase in South Africa is still facing challenges and is not yet on par with the most recent findings and recommendations of international scholars on how to sufficiently teach science to the young child.

Beni, Stears, and James (2012) point out the lack of specific content prescriptions in the South African curriculum related to teaching the sciences in the early years, which include teachers' lack of content knowledge, teachers' lack of confidence to teach science, and the fact that science is integrated into the life skills learning programme. According to Beni et al. (2012), these are some of the factors contributing to the insufficient level of science teaching in South Africa.

The two curriculum documents dealing with science learning for the young child in South Africa are the *National Curriculum Framework* (NCF) (Department of Basic Education, 2015) and the *Curriculum and Assessment Policy Statement* (CAPS) (Department of Basic Education, 2011). The NCF (Department of Basic Education, 2015) contains the curriculum for children from birth to four years of age, while the CAPS document (Department of Basic Education, 2011) sets out the curriculum for children from pre-school to Grade 3. Beni et al. (2012) observe that there is little clarity on content and especially on a teaching methodology for teaching the young child science. This is accompanied by a lack in teachers' content knowledge.

In the NCF (Department of Basic Education, 2015), no specific content or methodology is prescribed. It only broadly states that children should explore and investigate the world, design and make items, and use technology. In the CAPS document (Department of Basic Education, 2011), the subject life skills in the Foundation Phase (Grades R-3) has been organised into four study areas: Beginning Knowledge, Personal and Social Well-being, Creative Arts, and Physical education. The content and concepts of Beginning Knowledge have been drawn from social sciences (history and geography), natural sciences, and technology. In Grade R to 2, the areas Beginning Knowledge and Personal and Social Well-being are allocated two hours per week and in Grade 3, three hours per week. These two hours in Grade R to 2 and Grade 3 need to be divided among all the sub-strands of science content.

Cabe Trundle (2015) points out that quality science learning in early childhood education provides a solid foundation for the consecutive development of scientific concepts which will form the foundation for the learner's further academic development. These basic concepts also lead to the development of abstract ideas. With this limited scope reflected in the South African Foundation Phase documents dealing with science education, the result is that South Africa is not preparing its young learners for science learning in the rest of their school careers. These learners enter the Intermediate Phase (Grade 4-6) with limited science knowledge or understanding. In Grade 4 to 6 (Intermediate Phase), the subject natural sciences and technology has four strands, namely life and living, matter and material, energy and change, and planet earth and beyond. The limited scope of science teaching during the first three years of schooling means that learners entering the Intermediate Phase face a huge challenge. Apart from the contextual backlogs, there is also a real demand for the acquisition of an extended scientific vocabulary that they have to deal with. On top of this, many of these learners also face the added challenge of switching from their mother tongue (non-English) to English as the language of instruction and learning.

Based on all of the information provided above, it would be worthwhile to consider the overall developmental capacity of young children to study science as it relates to the two most important aspects of teaching and learning, namely content-specific focus and suitable teaching methodology. The rationale for this study is to get an in-depth understanding of the overall development of the young child in terms of the possibility of scientific reflection by identifying appropriate content and methodology in the teaching and learning of science relevant to specific age phases. Once these questions have been addressed, a possible framework for the teaching and learning of science, which can be utilised by future policy developers, teachers, and others involved in teaching science (not only in the South African context but also internationally), will be suggested.

1.3 Purpose statement

The purpose of the study is the identification of the scientific-reflective capacity of young children living in the 21st century. This includes the delineation of their physical, emotional, mental, and social development as related to their capacity to engage in scientific reflection. It also involves the identification of appropriate science content and teaching methodologies that are suitable in different age phases of development. The final purpose is utilising the acquired knowledge to develop a framework that could assist different practitioners in the field of science education for the young child.

1.4 Research questions

1.4.1 Primary research question

What is the teaching and learning potential of young learners regarding their scientific-reflective capacity?

1.4.2 Secondary research questions

Sub-question 1

What is the overall capacity (mental, emotional, physical, and social) of learners in different age phases (birth - 1 year, 1-3 years, 3-6 years, and 7-9 years) of doing scientific reflection? The aim of this investigation will be to describe the competence of demands of scientific reflection in different age phases.

Sub-question 2

Which teaching methodologies could be most suitable to assist in the development of scientific reflection for every age phase (birth - 1 year, 1-3 years, 3-6 years, and 7-9 years)? The main teaching methodologies that will be investigated are play, playworlds, and inquiry-based science education (IBSE).

Sub-question 3

What would be suitable content domains to access and develop scientific reflection in different age phases while utilising the overall capacity of young learners? The aim of this investigation will be to identify and define appropriate content domains related to the specific capacity of the young learner in different age phases (birth - 4 years, 5-6 years, and 7-9 years) in terms of the four science domains – (i) “How can I make it move?” referring to experimentation that explores basic concepts in the area of physics; (ii) “How can I make it change?” referring to exploring concepts in the area of chemistry; and (iii) “How does it fit?” and (iv) “How do I fit?” which explore concepts in the area of biology and ecology or planets.

Sub-question 4

What framework can be proposed for the teaching and learning of the sciences while supporting scientific reflection of the young learner, while progressing through four different age phases (birth - 1 year, 1-3 years, 3-6 years, and 7-9 years)? The aim will be to utilise the above-mentioned findings (sub-questions 1-3) to design a working framework for supporting the teaching and learning of science in four different age phases in the South African context.

A framework will be presented, reflecting the methodologies, including play, playworlds, and IBSE, and considering science-related content domains. The methodology and content domains must be applicable for four age phases, namely birth to one year, one to three years, three to seven years, and seven to nine years.

1.5 Aims and objectives

The aim of this study is to describe in an interrelated way the connection between age and the teaching and learning potential of young learners regarding their scientific-reflective capacity. The research objectives were as follows:

- Identifying the overall capacity (mental, emotional, physical, and social) of learners in different age phases (birth - 1 year, 1-3 years, 3-6 years, and 7-9 years) of doing scientific reflection.
- Identifying the teaching methodologies that would be the most suitable to assist in the development of scientific reflection for every age phase (birth - 1 year, 1-3 years, 3-6 years, and 7-9 years).
- Identifying the content domains to access and develop scientific reflection in different age phases while utilising the overall capacity of young learners. The aim of this investigation will be to identify and define appropriate content domains related to the specific capacity of the young learner in different age phases (birth - 4 years, 5-6 years, and 7-9 years) in terms of the four science domains – (i) “How can I make it move?” referring to experimentation that

explores basic concepts in the area of physics; (ii) “How can I make it change?” referring to exploring concepts in the area of chemistry; and (iii) “How does it fit?” and (iv) “How do I fit?” which explore concepts in the area of biology and ecology or planets.

- Proposing a framework for the teaching and learning of scientific reflection of the young learner moving through the different age phases (birth - 1 year, 1-3 years, 3-6 years, and 7-9 years).

1.6 Conceptual gap in the body of knowledge

There are three main focus areas that form the bulk of this research, namely (i) age phases and relevant development, (ii) suitable teaching methodologies for the sciences, and (iii) suitable content domains for teaching the sciences. Although many of these issues are dealt with extensively by scholars, little evidence can be found of an analysis that deals with the total, integrated picture of combining all three of the focus areas in a synthesis. In all three of these focus areas, in general, it is found that there are gaps in the body of existing knowledge. This is what motivated the researcher of this thesis to do a document analysis to investigate the breadth and depth of this problem by putting together an overall picture of the pros and cons when attempting to teach sciences to the very young.

Jirout and Zimmerman (2015) mention that curiosity, asking questions, and exploration seems to develop spontaneously in children. However, how this development influences the development of science in young children is not always clearly explicated. To investigate how the young child’s development is influencing his or her ability for scientific reflection, it was necessary to identify a theory of development. Theorists such as Erikson, Piaget, and Vygotsky have theorised how children develop. Donald, Lazarus, and Lolwana (as cited by Donald et al., 2010) mention that Erikson defines eight stages of psychosocial development that relates to people’s progressively emerging emotional needs in interaction with expanding social relationships. According to Slobodchikov and Tsukerman (2003), Erikson’s theory does not provide basis for setting up spaces conducive to development and, especially, cognitive education. Erikson’s theory lacks balance and incompleteness, because the stages are based on a limited set of basic concepts.

Vianna and Stetsenko (2006) identify similarities and differences between the theories of Piaget and Vygotsky. Both Piaget and Vygotsky recognise the importance of social interaction that involves cooperation and collaborative problem solving. While Piaget is of the opinion that social transmission influences primarily the content of knowledge, Vygotsky views social transmission as influencing the essence of the thinking process. Both of them believe that young learners are capable of abstract thinking. However, while Piaget describes the development changes as occurring in distinct stages, Vygotsky proposes a set of less well-defined periods and extrapolates that the restructuring of the child's mind takes place during the periods of transition from one stage to another. Vygotsky places less emphasis on the unique characteristics of each stage. For Vygotsky, higher mental functions involve logic, abstract thinking, and self-reflection. Vygotsky (1998c) describes the stages of development as taking place in a unique social situation of development. The stages identified by Vygotsky are based on the physical, mental, emotional, and social development of the child. The previously mentioned theories of Vygotsky and the post-Vygotskians will be used as the lens to investigate the development of scientific-reflective capacities.

The next gap that emerges involves the appropriate teaching methodologies required and the related skills linked to specific science domains. Zimmerman (2006) identifies one of the main goals of contemporary science as producing scientifically literate adults. It implies that children should be able to acquire and finally possess the required skills and tools to reason about scientific concepts. Harlen (2010) adds that specific and appropriate teaching methodologies are required to develop the skills related to science domains. These teaching methodologies should be suitable for the age and phase of the child, considering the physical, cognitive, social, and emotional development of the child at a specific time in his or her development (Harlen, 2010). As children are constructing knowledge from birth, Harlen (2010) recommends that the selection of topics and activities for science teaching should be a progression from phenomena in their everyday lives towards key ideas, empowering them to understand these phenomena in the natural world and the relevance thereof to their daily lives.

Chaillé and Britain (2003) pose four questions that can be used to identify possible content for science during the early years of development, namely: How do I make it move? – physics; How can I make it change? – chemistry; How does it live? – biology and ecology; How does it work? – planets, systems, and digit and electronic control. These content areas proposed by Chaillé and Britain (2003) are informative in the sense that they deal with the lacunae that are found in many of the science content curricula prescribed for the early years of development.

1.7 Methodology

According to Snyder (2019), building one's research on and relating it to existing knowledge are the building blocks of all academic research activities. As a document analysis, this research was building on the existing knowledge of other researchers. Bowen (2009) identifies document analysis as a systemic procedure for reviewing and evaluating documents. While Bowen (2009) points out that document analysis requires data being examined and interpreted to elicit meaning, gain understanding, and develops empirical knowledge, Niewenhuis (2009) declares that qualitative research is concerned with the process and the social and cultural contexts that underlie various behaviour patterns with quality and depth of information.

In the current study, the development of the young child in terms of social interaction has been studied to identify the young child's reflective scientific capacity at different ages. Niewenhuis (2009) mentions that different document helps researchers to uncover meaning, develop understanding, and discover insight relevant to the research problem. For the document analysis and qualitative research, the researcher used an extensive range of academic document to investigate the research questions of this study.

According to Bowen (2009), document analysis is an efficient method because it is less time-consuming as it requires data selection rather than data collection and because electronic resources (documents) are readily available. This study has mainly been done through the use of electronic resources in the investigation of the research questions by means of identifying electronic journals and other academic publications applicable to this research.

Bowen (2009) also points out that when data analysis is used as the research methodology, the data have already been collected and the researcher only needs to evaluate the quality of the documents evaluated. Electronic journals and academic publications applicable to this research was identified through the use of key terminology, including phrases. The following terms and phrases were used: “phases of development”, “leading activity”, “mental development”, “cognitive development”, “emotional development”, “social development”, “higher mental functions”, “make-believe play”, “self-regulation”, “imagination”, “scientific reflection”, “play worlds”, “IBSE”, “scientific playworlds”, and “early years of development”.

Another advantage of document analysis identified by Bowen (2009) is the stability of the documents, which means that documents can be reviewed repeatedly. Documents provide broad coverage, as they cover a long span of time, many events, and many settings. The research questions on child development, existing research on possible teaching methodologies for teaching science to young children, and possible content for the teaching and learning of science could be investigated through these electronic resources. The electronic resources examined span information from the early 1900s to the most recent research on these topics in 2020.

One of the disadvantages of document analysis identified by Bowen (2009) is low retrievability, which means that some documents are not retrievable or retrievability is difficult. In the case of this study, retrievability per se was not a problem, but some writings of Russian and Scandinavian scholars that were used were only accessible as translated documents.

1.8 Chapter division

The following outline of this inquiry briefly states the central ideas of the chapters.

Chapter 1 – Introduction and background

This chapter aims to create an understanding of the importance and content of the current study by stating the background to and rationale and purpose of the study. It also states the research questions, aims, and objectives of the study, the gaps in the body of knowledge, and the methodology used for the study. It also addresses the limitations of the research.

Chapter 2 – The nature of the child under the age of ten years

Chapter 2 investigates the young child (birth - 9 years old) in terms of physical, mental, emotional, and social development, and the impact of this development on scientific reflection. During the pre-school years, make-believe play is responsible for the creation of the zone of proximal development, facilitates the separation of thought from actions and objects, and facilitates the development of self-regulation. These developments have an impact on the child's motivation and facilitate cognitive decentring, the development of imagination, and the development of language.

During the first six years of a child's life, major development is taking place, physically, mentally, emotionally, and socially. At birth, infants are totally dependent on their caregivers, but during the first year, a spurt of physical and mental development takes place while they are emotionally interacting with their caregivers. During the first year, the infant learns to walk and talk and develops affect and will. The toddler (1-3 years) learns the culturally determined use of objects through adult-mediated object-orientated activities. During the pre-school (3-7 years) period of make-believe play, the school child needs to learn to be a student.

The overall development of the child, as described in this chapter, needs to be considered against the background of choosing possible scientific content to be taught to children in specific age phases as well as teaching methodologies (pedagogies) that need to be employed at a specific age.

Chapter 3 – The importance of play for teaching and learning scientific reflection

In Chapter 3 the development of play and the importance of play are described, while it is investigated as a method of science teaching in Chapter 4. Play is important for the development of the young child and forms a major component of the overall development trajectory of the very young child, from birth into the early years of schooling (Pramling et al., 2019). El'konin (1978) identifies stages of development, describing how play develops through social interaction from play initiated by caregivers to mature play. "Mature play" is the term used by El'konin to describe the type of play identified by Vygotsky (1967) as play that contributes to learning. Play not only promotes the development of both mental and social abilities but also creates a zone of proximal development that separates thought from actions and objects, while developing self-regulation, imagination, and motivation.

Chapter 4 – Teaching methodologies for science teaching of young children

This chapter focuses on the teaching methodologies that would be the most suitable to assist in the development of scientific reflection for every age phase (birth - 1 year, 1-3 years, 3-6 years, and 7-9 years). The main teaching methodologies that are described are play, playworlds, and IBSE. While most scholars agree that play is an important mediator of emergent competence in early childhood, there is still disagreement on how to define children's play theories. Vygotsky identified dramatic or make-believe play as contributing to learning. He identified three components of make-believe play, namely an imaginary situation, taking on and acting out roles, and following a set of rules determined by the role.

Chapter 5 – The content of the science curriculum for the early years

This chapter focuses on the issue of suitable content domains to access and develop scientific reflection in different age phases. Utilising the overall capacity of young learners is investigated too. The aim of this investigation is to identify and define appropriate content domains related to the specific capacity of the young learner in different age phases (birth - 4 years, 5-6 years, and 7-9 years) in terms of the four science domains – "How can I make it move?" referring to experimentations that explore basic concepts in the area of physics; "How can I make it change?" referring to exploring concepts in the area of chemistry; and "How does it fit? and "How do I fit?" which explore concepts in the area of biology and ecology.

The young child of the 21st century is growing up in a world with electronic devices, requiring children to become digitally literate. This technologically changed world will influence and change the content and outcomes of education in general and science education specifically.

Chapter 6 – Summary, conclusion, recommendations, and further research topics

This chapter contains a summary of the findings of the thesis. It also provides a framework for future science teaching in different phases of development, as well as further research topics.

1.9 Limitations or gaps in the study

Although the importance of technology, engineering, art, and mathematics (STEAM) is recognised, the purpose of this research was only to investigate the scientific-reflective capacity related to mainly science content.

This thesis does not include research on the assessment aspects of any of the science domains.

Many documents involving the research of international scholars from Russia, the Scandinavian countries, and other European countries, were used. Consequently, the researcher had to rely on translated documents.

Although the problems caused by teachers' lack of content knowledge are referred to in Chapter 5, teacher training is not addressed in this thesis.

1.10 Concept clarification

The clarification of the concepts used in this study is provided in table format below

Concept	Clarification
Early years	Child between birth and nine years old. Nine years is the age when children in South Africa are in Grade 3, the last year of Foundation Phase.
New-born	Child from birth to two months old.
Infant	Child between two months and one year old.
Toddler	Child between the age of one and three years.
Pre-schooler	Child between the age of three and six.
School child	Child between the age of seven and nine.

Concept	Clarification
Grade R	In South Africa, the year before primary school, equivalent to kindergarten (United States of America) or Grade K (Australia).
Science	Body of knowledge and activities that give rise to knowledge about the real world.
Scientific reflection	A complex multisensory experience, taking place in the social environment of the young child’s home, day care centre, or other social situations. Young learners are capable of scientific thinking or sensory experience because of their ability for creative thinking, problem solving, experimentation, and invention.
Leading activity	An activity being driven by a leading motive specific to producing development accomplishments, providing the basis for their transition to the major next period or leading activity.
Cultural-historical activity theory (CHAT)	Originally from the collaborative investigative project by Vygotsky, Leontiev, and Luria (troika) and several others in the early 20th century. It was extended by the neo-Vygotskians following CHAT principles. Bodrova and Leong (2007) theorise that meaning exists first in a shared state. In the shared state, cues are combined with the strategies used by the adult to support meaning.
Higher mental functions	Specific mental function of development necessary in the young child to reach the goal of scientific literacy. The higher mental functions can be further diversified into self-regulation or will, thinking, memory, emotion, and cognition.
Zone of proximal development	The zone of proximal development is defined by Vygotsky (1978, p. 86) as “the distance between the actual development 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”.
Scientific reflection	Scientific reflection is a complex multisensory experience, taking place in the social environment of the young child’s home, day care, and other social situations.

CHAPTER 2: THE NATURE OF THE CHILD UNDER THE AGE OF TEN YEARS

2.1 Introduction

The development trajectory of learning to do science is a long process that starts when the child is born. Many of the necessary mechanisms of science learning, such as curiosity, asking questions, and exploration, seem to develop spontaneously in children (Jirout & Zimmerman, 2015). Even so, most of these proses and skills require support, scaffolding, and instruction to mature into the final ability to reason and reflect in a scientific way about the world in which we live (scientific reflection).

Because of the fast-developing world of the 21st century and the ever-expanding influence of artificial intelligence and other technologies that permeate the workplace, skills such as critical thinking, creativity, and problem solving are gaining in importance. A crucial question that arises is: How should the young child of today be prepared to acquire scientific knowledge and wisdom to be ready for this high-tech workplace of the future? To answer this question, one should start by looking at who this young child is who is facing the demands of this fast-evolving world.

According to Morris, Croker, Masnick, and Zimmerman (2012), conflicting results are obtained from empirical research reports on this topic. While Gopnik, Glymour, Sobel, Schulz, Kushnir, and Danks (2004) call young children "little scientists", others such as Chen and Klahr (1999), Kuhn (1989) and Zimmerman (2007) hold opposing opinions. In their studies, they have found that older children have difficulty with scientific reasoning. For example, children have difficulty with systematically designing controlled experiments, drawing conclusions based on the evidence, and interpreting evidence.

Although science process skills show a linear age trend, Jirout and Zimmerman (2015) reveal that some skills require more scaffolding and specific instructional guidance than others. The ability to effectively ask questions develops over time, and young children discover causal relationships through play. Pre-schoolers by the age of five can recognise patterns, interpret evidence, and comprehend how the evidence relates to the hypothesis. Science process skills develop over time, and children will learn more by asking questions, collecting information, observing, and reasoning about evidence to find possible answers.

For children to be able to think creatively and critically, they need to be able to formulate inquisitive questions, solve problems, argue, and use various other scientific skills. Kornelaki and Plakitsi (2018) claim that in this way, children can develop the scientific skills required to become scientifically and technologically literate. In other words, the development of scientifically and technologically literate citizens starts with a safe and stimulus-rich environment. Sensory information is transformed into ideas, and interaction with adults and peers improves linguistic and cognitive abilities.

Science can be understood as a body of knowledge and activities that gives rise to knowledge about the real world (Chaillé & Britain, 2003; Eshach, 2006; Zimmerman, 2005). Chaillé and Britain (2003) reveal that reflection involves the use of appropriate language and the senses with which the young child experiences the world. Young children are capable of scientific thinking because of their ability to apply creative thinking, problem solving, experimentation, and invention. This again points to the complex nature of scientific reflection as being a complex multisensory experience, taking place in the social environment of the young child’s home, day care centre, or other social situations.

The most general goal of scientific investigation is to extend one’s knowledge of the world. Scientific investigation broadly defines procedural and conceptual activities, such as asking questions, hypothesising, designing experiments, making predictions, using apparatus, observing, measuring, and being concerned with accuracy, precision, and error.

Like many other researchers in the field, Kornelaki and Plakitsi (2018) suggest that scientific skills that will build a modern, active citizen who is scientifically and technologically literate already begin to develop in the early years of education. These skills include creative and critical thinking, the ability to formulate inquisitive questions, problem solving, argumentation, and so forth. Young children explore their environment with their senses to create ideas and structure knowledge. As they grow older, interaction with peers and adults will affect children's cognitive and linguistic abilities.

To understand the development of scientific skills and reasoning of the young child, it is necessary to investigate the overall development of the young child. This overall physical, mental, emotional, and social development of the young child is an all-important aspect that contributes to the total development of very young children in the 21st century. Their ability to maintain themselves currently will to a large extent be dependent on their ability to navigate the high-tech world that will demand, among other things, their reflective (reasoning) capacities. To start to answer the question "How should the young child of today be prepared to acquire scientific knowledge and wisdom to be ready for this high-tech workplace of the future?", it is important to revisit current views held by important proponents of early child development and relate these to their ability to become future citizens who are capable of reflective scientific reasoning.

This chapter has two foci, namely (i) explicating the importance of the overall general development during particular age phases in conjunction with (ii) the emergence of specific competencies that form underlying aspects leading to the development of intuitive scientific reflection capacities. To study the development of scientific knowledge, Zimmerman (2005) points out that it is essential to differentiate between knowledge about scientific concepts and the activities to nurture this knowledge.

2.2 Theoretical perspectives related to child development

Two of the most prominent scholars of the last century, namely Vygotsky and Piaget, and their collaborators have developed theories that represent and embody transactional, relational, and contextual modes of thinking about human development (Vianna & Stetsenko, 2006). Although both Piaget and Vygotsky are constructivist thinkers, it does not mean they agree on all aspects. There are important commonalities but also important differences in their theories that need to be considered when looking at the individual contributions they have made to the dearth of knowledge available relating to the development of the young child.

Bodrova and Leong (2007), Karpov (2005), and Vianna and Stetsenko (2006) refer to the following points of agreement:

- Both Piaget and Vygotsky view child development as a series of qualitative changes that cannot merely be viewed as expanding a repertoire of skills and ideas
- For both Vygotsky and Piaget, the mind is not just a container that stores memories and knowledge but represents a dynamic system formed and expressed in actions.
- Piaget believes that social transmission influences primarily the content of knowledge, and Vygotsky views social transmission as influencing the essence of the thinking process.
- Piaget and Vygotsky both believe that young learners are capable of abstract thinking.
- Piaget describes formal operational thinking as abstract, logic, reflective, and hypothetical deductive, and for Vygotsky, higher mental functions involve logic, abstract thinking, and self-reflection.
- For both scholars, social interaction involves cooperation and collaborative problem solving, while conflict and communication are important.
- Piaget describes the development changes as occurring in distinct stages, while Vygotsky proposes a set of less well defined periods and extrapolates that the restructuring of the child's mind takes place during the periods of transition from one stage to another. Vygotsky places less emphasis on the unique characteristics of each stage.

Although Vygotsky and Piaget agree on several important aspects of child development, they also differ on important aspects. Bodrova and Leong (2007) point out the following differences between the two scholars:

- Piaget is firmly grounded in a biological worldview and postulates the essence of human development in adapting to the environment, while Vygotsky's view is that people do not adapt to their world but collectively transform it (Vianna & Stetsenko, 2006). Piaget views intellectual development as a universal nature independent of the child's cultural context. In other words, development is linked to age.

For Vygotsky, the cultural context determines the very type of cognitive processes that emerge. Cultures that do not employ formal reasoning extensively will not foster the development of formal operations in their young (Bodrova & Leong, 2007).

- Piaget emphasises the role of the child's interaction with physical objects in developing mature forms of thinking. He believes that objects and the child's actions on objects are of primary importance. He does not view peers as an integral part of the learning process, but is of the opinion that peers may create cognitive dissonance.

  Contrary to Piaget, Vygotsky focuses on the child's interaction with people. Also, a child's actions on objects are beneficial for development only if these are included in a social context and mediated by communication with others (Bodrova & Leong, 2007).
- For Piaget, language is a by-product of intellectual development and can increase the power of thought in range and rapidity. The way the child talks merely represents the stage of the child's cognition.

  However, for Vygotsky, language plays a major role in cognitive development and forms the core of the child's mental functions (Bodrova & Leong, 2007).
- Piaget views the child as an independent discoverer who learns about the world by creating his or her own construction (Bodrova & Leong, 2007). He believes that only the discoveries children make independently reflect their current intellectual status. Knowledge of how children acquire or apply knowledge that is transmitted by adults is not relevant in determining a child's development level.

  Vygotsky, however, emphasises the importance of cultural context in learning (Bodrova & Leong, 2007). Everything to be discovered by the child is a product of human history and culture. Vygotsky believes that the appropriation of cultural knowledge is key to a child's cognitive development. A child's shared performance is as valuable as his or her independent performance for determining his or her intellectual status.
- In Piaget's view, children acquire knowledge by interacting with the physical environment. Cognitive development occurs through assimilation and accommodation. In assimilation, the child interprets the environment in terms

of his or her present way of thinking; accommodation is the child changing and expanding on what he or she already knows. Piaget views play as providing the child with a multitude of opportunities to interact with materials in the environment and construct his or her own knowledge about the world; therefore, play is one of the primary contexts in which cognitive development occurs (Zigler & Bishop-Josef, 2006). According to Piaget, children develop, learn, and achieve knowledge by adapting to existing conditions to "fit in" better with these and the environment. Mind and knowledge evolve from actions through which people adapt to the world and through goals and the processes of adaptation (Vianna & Stetsenko, 2006).

In Vygotsky's theory, instruction is important in cognitive development, as it provides the culturally evolved cognitive or psychological tools, namely language, signs, and symbols (Karpov, 2003). Humans are not born with these tools – they are invented by human society and acquired by children during interpersonal communication with adults and more experienced peers. Once such a tool is internalised by the child, it is mediated and advances the child's cognitive functioning. Vygotsky calls these mediated processes "higher mental processes".

Both Piaget and Vygotsky have made valuable contributions to understanding the development of the young child, but it is the work of Vygotsky and the post-Vygotskian proponents that will form the basis for further discussion in this study.

It is important to take cognisance of the theories of development as proposed by different specialists. The developmental phases will form the basis for the alignment with appropriate scientific-reflective demands, as it will manifest in the choice of content and pedagogy for a child of a particular age.

2.3 Theories of development

A very important aspect of describing child development during the lifespan of the early years is the delineation of the so-called phases of development that occurs within these early years of development. This is important in light of the fact that there are particular milestones young children should reach, after which they are required to build on these achieved milestones to reach the next stage of overall development.

Apart from Piaget and Vygotsky, Erikson is another scholar who has done a lot of work on the idea of lifespan and explicitly takes social context into account. Erikson (as cited by Donald et al., 2010) defines eight stages of psychosocial development that relates to people's progressively emerging emotional needs in interaction with expanding social relationships. Even though this is an important contribution, Slobodchikov and Tsukerman (2003) are of the opinion that Erikson's theory does not provide a basis for setting up spaces that are conducive to development and especially cognitive education. Slobodchikov and Tsukerman (2003) go further to criticise Erikson's theory as incomplete and lacking balance, because his stages are based on a limited set of basic concepts.

2.3.1 Vygotsky's concept of ages or phases

Vygotsky (1998) defines age in terms of specific changes that take place in the structure of the child's mental processes and in terms of the major developmental accomplishments that emerge as the child is growing up in a unique social situation of development. Vygotsky (2016) declares that without the child's needs, inclinations, incentives, and motives to act, there will never be any advancement from one stage to the next. Each progression from one age-related level to another relates to an abrupt change in motives and incentives to act. Vygotsky (1998) distinguishes five stages of development, namely infancy, early childhood, pre-school, school age, and adolescence (see Table 2.1 below). These stages identified by Vygotsky are based on the physical, mental, emotional, and social development of the child.

Table 2.1: Child development stages according to Vygotsky (adapted from Van der Veer, 1986)

Period	Age
Infancy	0, 2-1
Early childhood	1-3
Pre-school	3-7
School age	7-13
Adolescence	13-17

Vygotsky (1984) also introduces the theoretical concept of two phenomena within these ages, namely crisis and stable periods. Polivanova a current Russian scholar explains that the opposition between the internal and external conditions of development, the structure of personality, and the social situation of development leads to the differences between the stable and critical periods. Polivanova (2015) further reveals that the stable periods make up the biggest part of childhood, and development occurs mainly through microscopic changes in the child's personality. Both Polivanova (2015) and Vygotsky (1998) indicate that these microscopic changes accumulate and then manifest as age-related neoformation. These neoformations are the reorganisation of a whole system of functions. The changes are characterised by the reconstruction of the conscious personality of the child and are the result of development on the specific age level. During each period, there is an emergence and formation of new functions that were not present in the previous stages.

Each period is further characterised by a specific structure, reflecting a coherent complex of psychological functions. Van der Veer (1986) states that functions such as perception, speech, and memory become intertwined in a way specific to that period. Therefore, consciousness is based on the inter-functional relationship among these functions. The changes in these inter-functional relationships can account for the development of consciousness in the child.

Vygotsky (1998) describes the mental processes arising towards the end of a given age as leading the reconstruction of the whole structure of the child's consciousness. The whole system of relations to external reality and the child him- or herself are changed. It creates the need for change in the social situation of development. The change in the social situation results in the child's transition to a new period of development. The development in each age period prepares the child for the transition to the next period of development. Once the neoformation has appeared in the conscious personality, it brings about a change in the personality in such a way that the child's social existence will also change. This implies that once the structure of personality has been changed, the child's social existence will change as well. The social situation of development at the beginning of the age is different from that at the end of the age. Development is recognised by comparing the beginning and the end of the stable period, with the maturation of neoformations taking place at the end of each age level.

Vygotsky (1998c) describes the crisis as abrupt, with major shifts and displacements, changes, and discontinuities in the child's personality, concentrated in a relative short time. The crisis period is an act of development with a "stormy, impetuous, sometimes revolutionary current of events both in rate of changes occurring and in significance of the alterations taking place" (Polivanova, 2015). Vygotsky (1998c) distinguishes between crises that occur at birth, in the first year, the third year, the seventh year, the thirteenth year, and the seventeenth year.

According to Polivanova (2015), volition is always the condition for the beginning of a new stable period. In other words, an action of volition is a reaction to an external stimulus, requiring the analysis of the situation of the action. Consequently, the older the child becomes, the greater the degree to which the child can act with volition, and not spontaneously. This is important when it comes to later abilities to work on science content in a self-directed way.

Polivanova (2015) views neoformations as being derived from actions of volition and can be united under the general term "volition". The following neoformations can be identified during the different crisis ages: during the one-year crisis, it is personal action; during the three-year crisis, pride in accomplishment; and in the seventh-year crisis, it is volition. The motivational idea can be the image of an object that compels the child to act even when the object itself is outside the field of immediate perception. The motivational idea is the psychological function in which some idea of maintaining goals, even if only short-term, is expressed.

One of Vygotsky's students, Daniil El'konin, expanded on Vygotsky's ideas of development in his own version of the different phases of development.

2.3.2 El'konin's age periods

El'konin (1999) describes each period of a child's life as many-sided, and the activities his or her life is composed of, as varied. As new sorts of activity appear, the child forms new relations with his or her surroundings. When a new activity becomes dominant, it does not cancel all previously existing activities; it merely alters their status within the overall system of relations between the child and his or her surroundings, which thereby becomes increasingly richer. In other words, the leading activities El'konin identifies are the result of development and not the only important activity in that period of development.

El'konin (1999) divides the periods of child development in two categories. The first is characterised chiefly by assimilation of the objectives, motives, and norms of human relations and, on that basis, by the development of the need-motivational sphere. The second category is characterised chiefly by the acquisition of socially evolved modes of action with objects and, on that basis, the formation of the child's intellectual and cognitive powers and operational and technical capabilities. El'konin has formulated a hypothesis that the periods in which the child's needs motivational sphere predominantly develops alternate regularly with periods in which prominent development of operational and technical abilities occurs.

El'konin identifies the following age periods: infancy, toddlerhood, pre-school, and the elementary grades. These age periods and consecutive leading activities and developmental accomplishments are illustrated in Table 2.2.

Table 2.2: Leading activities and developmental accomplishments in childhood (adapted from Bodrova & Leong, 2007)

Age period	Leading activity	Development/Accomplishments
Infancy	Emotional interaction with caregivers	Attachment and object-orientated sensorimotor actions
Toddlerhood (early childhood)	Object-orientated activity	Sensorimotor thinking and self-concept
Pre-school and kindergarten	Make-believe play	Imagination, symbolic function, ability to act on an internal mental plane, integration of thinking and emotions, and self-regulation
Elementary grades (young school age)	Learning activity	Theoretical reasoning, higher mental functions, and motivation to learn

One of the very important contributions of El'konin to the work of Vygotsky is the identification of the so-called leading activities for all the age phases.

2.3.3 Leading activities

Post-Vygotskians Alexei Leontiev and Daniil El'konin specify the distinct features of leading activities characteristic of children at different ages (Bodrova, Leong, Germeroth, & Day-Hess, 2019). Based on Vygotsky's ideas, El'konin – a student of Vygotsky – developed his theory of leading activities (Bodrova et al., 2019; Slobodchikov & Tsukerman, 2003). Karpov (2003) contrasts the views of Vygotsky and El'konin in terms of the characteristics of developmental periods. In contrast with Vygotsky's belief that each period is characterised by age-specific relationships between the children and the social environment, El'konin regards periods of development to be characterised by a leading activity. Leading activities are the optimal activities for development at any age period. Although children can and do learn from other activities within their zone of proximal development, leading activities are the most beneficial (Bodrova et al., 2019).

Karpov (2003) describes leading activities as driven by a leading motive specific to the particular age period in each culture. A leading activity can be defined as an activity being driven by a leading motive specifically to produce development accomplishments, providing the basis for the transition thereof to the major next period or leading activity. During mediation in the leading activities, new leading motives, mental processes, and abilities are developed, outgrowing the current leading activity. In other words, the very nature of mediation leads to a range of new developments in different aspects of development.

The psychological neoformations and leading activities constitute the zone of proximal development for the young child, as indicated by Kravtsova (2009). Psychological neoformations and leading activities are indicators of mental development. In the leading activity and neoformations, children can be described as becoming "a head taller" than themselves; their aggregated self is exactly what characterises and assigns zone of proximal development. An analysis of the relationship between age-related psychological neoformation and leading activity showed that they relate to each other in complex, equivocal ways. At the start of a developmental period, a child has two neoformations – one with the development period that has just passed and another that is characterised by the incipient period of development.

More recent scholars, such as Bodrova and Leong (2007a, b), Kravtsov and Kravtsova (2010), and Glozman, Kurdiukova, and Suntsova (2020), are extending the work of Vygotsky. Through the furthering of research on child development, they have contributed additional information to the theories on child development.

The development of the young child was investigated and described based on the cultural-historical activity theory (CHAT). The mental development of the young child, as identified in the CHAT, has remarkable similarities with the embodiment cognition theory. Smith and Gasser (2005) state that traditional theories of intelligence concentrated on symbolic reasoning. Kiefer and Trumpp (2012) describe the embodied cognition theory as cognition essentially being carried out in the sensory and motor brain system. Neurophysiological recording techniques provide direct evidence for the involvement of modality-specific sensory and motor systems during cognitive tasks – a critical prediction of embodied cognition theory.

2.3.4 Recent post-Vygotskian scholars

Based on the work of Vygotsky, Bodrova and Leong (2007a, b) have proposed four basic principles that can be identified that extend Vygotsky's theories for the 21st century. They summarise these four principles as follows:

- Cognitive construction is socially mediated – children need physical manipulation and social interaction for the development and construction of understanding.
- The child's social world shapes what he or she knows and thinks.
- Learning can lead development – not only development or maturation but also teaching plays a role in development, as teaching as imitation and instruction brings human qualities of the mind and leads the child to new developmental levels.
- Language plays a central role in development – language is instrumental in the development of cognition and part of the cognition process.

Bodrova and Leong (2007b) have used Vygotsky's theory in theorising that the purpose of learning, development, and teaching is more than acquiring and transmitting a body of knowledge; it involves the acquisition of tools. Children are taught to equip themselves with tools, and children appropriate these tools to master their own behaviour, gain independence, and reach a higher developmental level through the use of mental tools and the emergence of higher mental functions.

Bodrova and Leong (2003) identified the following four themes in the child's development during the pre-school years:

- The child's mind as a dynamic system of mental functions is formed with the changing of lower mental functions into higher mental functions.
- Development of the child's mastery of his or her own behaviour occurs through self-regulation.
- Development is a holistic process with emotions and cognition acting in unity and affecting each other.
- The social situation of development is the basic source of development.

Mental development in the pre-schooler's development is very important and can be divided into lower and higher mental functions.

2.3.4.1 Formation of the child's mind

Vygotsky (1994) makes an important distinction regarding lower and higher mental functions and the impact thereof on development. The first or lower mental functions are the natural development of behaviour, tightly bound up with the processes of general organic growth and maturation, and mental functions such as involuntary attention, rote memory, and sensory-motor thought. Lower mental processes are mediated to become higher mental functions (Karpov, 2003). Children use language to transform their perception and transform their attention, memory, imagination, and thinking (Bodrova & Leong, 2003).

Bodrova and Leong (2015) describe the development of higher mental functions as a gradual process in which there is a transition from inter-individual (inter-mental) to individual (intra-mental) activities. They highlight that this is deliberate, mediated, and internalised behaviour. Higher mental functions first appear in the form of actual relationships among people before becoming higher mental functions (Bodrova & Leong, 2003; Kravtsov & Kravtsova, 2010). At the same time, Kravtsov and Kravtsova (2010) make it clear that how developmental the environment is will depend on the communication between the adults in the environment and the children.

The second line of development as seen by Vygotsky (1987b) deals with the cultural improvement of the psychological functions and the development of the higher mental functions such as voluntary attention, logic memory, and will. Higher mental processes are shaped by the acquisition of language and language-based means, such as categorising. Bodrova and Leong (2015) point out that according to the Vygotskian view of development, the interplay between the lower and higher mental functions is created by the interaction of the growing individual and other people. Bodrova and Leong (2011) identify the main changes of lower mental processes as the modified relations between the functions, resulting in higher mental functions with a complex and dynamic nature. These higher mental functions are essential for understanding the features of personality development (Kravtsov & Kravtsova, 2010). The natural functions become cultural functions, as they are mastered through self-regulation.

In the process of their development, higher mental functions go through a sequence of stages along the continuum from social to individual, which Vygotsky associates with the formation of a new structural-functional system (Bodrova, Leong, & Akhutina, 2011). In the process of development, the connections among the functions will become changed and modified.

2.3.4.2 Defining higher mental functions

Defining the higher mental functions also points to the importance of specific mental functions on the development necessary in the young child to reach the goal of scientific literacy. The higher mental functions can be further diversified into self-regulation or will, thinking, memory, and emotions and cognition.

2.3.4.2.1 Self-regulation or will

The mastery of one's own mind and behaviour (or self-regulation) is described as a unit of emotion and cognition and the social situation as key moments in the development of higher mental functions in Vygotsky's theory (Kravtsov & Kravtsova, 2010). Bodrova and Leong (2003) describe the ability to master one's own "natural" behaviour, no matter what form it takes, as leading towards human, cultural development. During the pre-school years, children master their own behaviour by overcoming their dependence on environmental stimuli and becoming capable of intentional behaviour using self-regulatory private speech and participation in make-believe play. Self-regulation is a strong asset that the young child will need, not only in working in groups but also working independently when solving problems in science-related activities.

2.3.4.2.2 Thinking

Current Russian scholars Glozman, Kurdiukova, and Suntsova (2020) define thinking as the ability to transcend the bounds of graphic signs of perceived objects and phenomena of the surrounding reality. To be able to solve problems, the child is confronted with the fact that seeing, hearing, feeling, and memorising is not enough to identify connections and relationships among phenomena, for example, why a small wooden ship does not sink but a small pin does. The ability to understand these concepts requires thinking at a sufficient level.

Glozman et al. (2020) describe thinking as correlating the data from sensation and perception and comparing, differentiating, and uncovering the relationships among surrounding phenomena. Thinking makes it possible to:

- arrange, analyse, and synthesise information;
- assign received facts to particular categories;
- transcend the bounds of received information; and
- draw inferences from received facts and arrive at conclusions by logical means, even without first-hand facts, and by proceeding from received verbal information (from other people's experience).

Glozman et al. (2020) identify the products of thinking activities as concepts, judgements, and conclusions, and categorise the basic forms of thinking, according to the means and methods of problem solving used, as visual action, visual-figurative action, and verbal-logical thinking. This means that the young child needs to have developed the ability to use a range of thinking skills to be able to not only comprehend the science content he or she will experience but also represent and transfer these solutions to other science domains.

2.3.4.2.3 Memory

Memory can be described as one of the central mental functions, a function on which the creation of all other functions depends (Suntsova & Kurdiukova, 2020a). Memory plays an important role in the development of other mental functions such as perception thinking and speech. The development of memory is important for success in teaching.

Suntsova and Kurdiukova (2020a) distinguish between three memory processes, namely memorisation, retrieval, and forgetting.

- Memorisation is a memory process that consolidates new information by linking it to previous knowledge and forms of behaviour. The retention of information depends on the motives, goals, and modes of activity of the individual.
- Retrieval is a memory process resulting in the actualisation of consolidated information by transferring it from long-term memory to operational memory.
- Forgetting is the process of preventing memory from getting overloaded. The more seldom material is incorporated into activity, the deeper forgetting seems to be.

The process of memory development can be described as changing from involuntary memorisation of information, based on perception, to voluntary memorisation, based on giving meaning to memorised material (Suntsova & Kurdiukova, 2020a). To be able to reflect on their science experiences, young children need memory to connect with previous knowledge to build new concepts.

2.3.4.2.4 Emotions and cognition

Child development is a holistic process with emotions and cognition acting in unity and affecting one another. Vygotsky describes mental development as going beyond thought and language to include issues such as the integration of emotions and cognition at the end of the pre-school years and a complex interplay of emotional and cognitive components in make-believe play (Bodrova & Leong, 2003). In addition, Kravtsov and Kravtsova (2010) identify the unity of affect and intellect as necessary for the development of personality. The development of personality is ensured through the unity of affect and intellect. A child's concrete developmental environment and the extent to which the environment is developmental depend on the communication between the child and the adults who surround him or her.

A positive relationship between the child and adults in the teaching and learning of science will have a positive influence on the child's attitude towards science and science reflection.

2.3.4.3 Social development of the child

Vygotsky (1978) emphasises that the social environment influences the cognitive development of children. The adult models behaviour or provides verbal instructions. Vygotsky refers to it as "cooperative or collaborative dialogue". The child seeks to understand the actions or instruction provided by the adult and internalises the information, using it to guide or regulate his or her own behaviour.

Vygotsky's colleagues and followers El'konin, Leontiev, and Zaporozhets point out the crucial importance of joint activities with adults and peers in the development of higher mental functions. The adults and peers supply the psychological tools, mediating the mental processes that serve these activities (Karpov, 2003). Social knowledge, such as scientific vocabulary and the child's observations in interaction with the adult, is necessary for the forming of new scientific concepts.

2.3.5 Phases of development and the relation thereof to scientific reflection

Science can be understood as a body of knowledge and activities that give rise to knowledge about the real world (Chaillé & Britain, 2003; Eshach, 2006; Zimmerman, 2005). Reflection involves the use of appropriate language as well as senses with which the young child experiences the world. Young children are capable of scientific thinking (reflection) because of their ability to be able to exhibit creative thinking, problem solving, experimentation, and invention (Chaillé & Britain, 2003). Therefore, the development of scientific reflection is a complex, multisensory experience, taking place in the social environment of the young child's home, day care, and other social situations.

The different development phases will be investigated through the lens of scientific reflection, viewing the beginning of the phase, the leading activity in that phase, and the physical, mental, emotional, and social development. The development of scientific reflection through development in the phases will be explored.

2.3.5.1 Infancy (first year of life)

2.3.5.1.1 Birth crisis

At birth, the new-born is totally dependent on his or her mother for feeding, physical care, and movement. Van der Veer (1986) and Vygotsky (1998d) explain that while the infant is only showing instinctive movement connected with cold, thirst saturation, and so forth, real social interaction with the new-born is hardly possible because the infant cannot yet distinguish between internal sensations and external influences, or differentiate between physical and social stimuli. Due to their physical development, infants are physically dependent on adults and, through emotional interaction with adults, infants will develop physically and mentally.

2.3.5.1.2 Leading activity

The leading activity for infants is their emotional interaction with their caregivers. Especially one-on-one interaction with parents or caregivers is regarded as crucial by

Vygotskians. Bodrova and Leong (2007a) identify interaction in the social context as necessary for learning and development. Primary caregivers have a crucial role in infants' development, as infants' sensorimotor, object-orientated actions develop in emotional communication with their caregivers. An infant's shared experience structures the perception focusing on separate objects and their properties. Caregivers will demonstrate how to use toys while using descriptive words to describe the toys and other objects. By using words such as "big", "small", "far", and so forth, perceptual and relational characteristics are communicated. These emotional interactions will positively influence the development of exploratory behaviour.

Apart from emotional interaction (support) from caregivers (nurture), the exploratory behaviour of the infant depends on the physical development (nature). As physical and spatial development enables the child to handle objects, more exploration with the perception of the physical world will become possible.

2.3.5.1.3 Physical development

(i) Spatial development

Suntsova and Kurdiukova (2020b, p. 57) define spatial concepts as "concepts of spatial and space-time characteristics and relationships: the size, form, and relative position of objects". The extremely complicated formation of spatial concepts starts in the infant and progresses during the development of the young child. The perception and processing of spatial traits and relationships are some of the most complex mental reflection activities. These mental activities are crucial to adaption to the world of objects relative to one another, phenomena following one another, and the arrangement of words and phrases. The emergence of spatial concepts relates to different systems of orientation in space, for example visible and imaginary. In the process of development, the spatial concepts formed in infancy are later important for successful learning in school in terms of the ability to learn to count, write, draw, and read, as well as other disciplines.

Suntsova and Kurdiukova (2020b) identify the first phase in the infant's formation of special concepts of his or her own body as starting with the sensation of tensing and relaxing muscles and the interaction with external space and with caregivers. These experiences form a sense of space in the infant, as the concept of one's own body (somatotopic concepts) and of the position of external objects relative to the infant's own body begins to form. The child begins to grasp the meaning of "faster", "at the top", and "next to you" only after the infant's body understands it as a result of the change of corporeal-gnostic space into visual-gnostic space.

When an infant reach for a rattle, he or she begins the forming of the concept of the own body and the position of external objects relative to it. Suntsova and Kurdiukova (2020b) point out that this process is ongoing through the process of crawling and walking. The understanding of spatial relations will be advanced even further by the development of language.

The development of concepts such as "faster", "at the top", and "next to you" attributes to the start of scientific reflection as the genesis of physics concepts.

(ii) Sensory and perception development

The child's physical development during the first year of life is a complicated pattern of development. Zaporozhets (2002b) points out that at birth, the infant reacts to the environment with different unconditioned reflexes, due to relatively well-developed analyser systems. These very imperfect responses of the new-born are differentiated significantly during the first months of life.

Zaporozhets (2002b) distinguishes between the sensory processes and perception abilities. The sensory processes are crucial for the control of human movement, while the perception abilities enable the experiencing of one's environment. Perception continues to develop (mature) through practical experiences and learning (adaptation). Sensory processes and perception are responsible for complex orientating actions to stimuli of sense organs. The unconditioned orientating reflexes consist of the movement of receptor organs towards stimuli, fixating on stimuli or following the movement of the stimuli. Initially, the orientating reactions are extremely basic but develop into quite complex sensory effects. Constant object-orientated perceptual images that are necessary for the control of complex and changeable forms of behaviour are still lacking.

The infant's orientating and executing actions (leading to practical results) are described by Zaporozhets (2002b) as still insufficiently separated. In the process of familiarisation with the object, grasping motions and practical manipulations play an important role. At the age of three to four months, the child performs only the simplest practical actions related to grasping and manipulating objects, motioning in space, and so forth. These actions are achieved by the hands, legs, and so forth, without the aid of tools. Sensory functions and practical actions become orientating-researching perceptual actions. The change in examination methods in the young child causes changes in the formation of sensory images.

It is assumed that the visual system is already basically formed at birth, with an almost full set of programmes for processing visual information. Zaporozhets (2002b) indicates that there is evidence that while the visual system is still underdeveloped and incomplete, the infant can respond to the distribution of brightness, a change in the time contour of brightness, an objects orientation in the field of vision, and movement. The developing of visual operational thought starts in the first year of life. Already during the first months of life, the infant can recognise differences in size, colour, and form. When infants are exposed to a new shape, they will direct their eyes to the new object. As early as three to four months, it is possible for infants to elicit orientating differences in complex stimuli, such as geometric figures.

The relationship between the hand and the eye is complex, contradictory, and constantly changing during development. Zaporozhets (2002b) explains that during the first months of life, orientation reactions of the hands and eyes form the basis for perceptual actions. The movements of the hand as it feels the object and movement of the eye tracing a visible contour are examples of orientating actions that play an important role in the perceptual actions in these early stages. During the first months, eye-orientating movements reach relatively high levels, fulfilling the function of orientating setting, thereby setting a receptor for a specific kind of signal.

Zaporozhets (2002b) identifies the hand as an organ of perception and action. At first, the hand serves as the dominant sensory organ. Tactile information from the hand becomes the foundation for visual comparisons. The eye will follow the hand and store the accumulated experience in order to, over time, start to function on its own. The eye serves as an orientation organ, inspecting the object. The inter-sensory relationship between the hand and the eye changes as the eye becomes the main perceptual organ. The eye will take over the role of the hand to solve perceptual tasks following the silhouette of figures, forming an image by reproducing the object features. These movements are critical to ensure that sensation and perception support the forming of accurate mental images. During the early stages of development, a correct reflection of reality can only be achieved as a result of practical actions with objects; during these stages, sensory processes play dependent secondary roles.

Sparaci and Volterra (2017) explain that at four weeks, the grasp reflex appears, during which the infant will make groping movements with the hand towards a stimulus. The purpose of these grasping reflexes is identified by Zaporozhets (2002b) as considering their place, size, and form models; thus, movement of the hand is used to investigate space characteristics. These reflex movements are replaced at the age of four to five months with a grasp reaction (Sparaci & Volterra, 2017). These orientating reactions become the basis for perceptual actions, as explained by Zaporozhets (2002b). The perceived object is examined to form an adequate image of the object. The transformation of orientating reactions into object-related orientating-investigation actions is a long and complex process from infancy to pre-school age.

The development of motor development, such as unsupported sitting, reaching, crawling, and walking, allows the infant to encounter new and diverse objects, tools, and social contexts that will shape and redefine grasping (Sparaci & Volterra, 2017). Precision grasping develops with other motor and cognitive skills, linked to locomotion and visual guidance, proprioception, and the role of objects, tools in the task spaces in building possibilities for actions.

Zaporozhets (2002b) stresses the importance of perception in development. Before the child can think, activity partially prepares the child for the emergence of rational orientation towards the real world for which the right kind of experience and knowledge is necessary. The nature of that experience must itself change to conform to a change in the child's activity. Inter-functional relations between perception and memory are formed. New stimuli presented will connect with stimuli reproduced from memory and stored as mnemonic images from previous experience. Due to this connection, relative constancy of the magnitude, form, and colour of perceived objects is maintained.

Through throwing and dropping objects, the genesis of physical concepts such as gravity, size, and mass is experienced. All these concepts are crucial perception modes that play an important part in the intuitive development of future scientific concepts, such as position in space, motion, shape, perception, and so forth.

2.3.5.1.4 Mental development

Van der Veer (2011) stresses that although the infant has not acquired speech yet, mental functions are illustrated by the fact that the infant can remember and recognise faces, can search for objects, and can imitate movements. The infant's development is seen in the ability to progress from observing objects to intellectual operations.

The infant's first conceptual development is described by Glozman, Kurdiukova, and Suntsova (2020) as everyday pre-concepts. During the first months of life, the infant develops nonverbalised concepts; for example, when the infant cries, he or she will be picked up. In this initial stage of development, the role of exploratory behaviour, for example grouping and investigating objects, is extremely important.

Two important mental developments occur during infancy, namely thinking and language.

(i) Thinking

The infant's mental functions or intellectual development and specifically thinking ability are dependent on interaction with caregivers (Bodrova & Leong, 2007a; Glozman et al., 2020). The presence of objects alone is not enough to stimulate development; they also need interaction with other people or caregivers (Bodrova &

Leong, 2007a; Glozman et al., 2020). Caregivers introduce objects while communicating about the phenomena of nature and society. Glozman et al. (2020) point out that remembering facts and passive understanding of knowledge cannot yet ensure the proper development of infants' thought. Zaporozhets and Lukov (2002) call these emerging thoughts "visual-operational thought". Social interaction with adults is necessary for infants to make sense of the objects in their social environment. Communication with adults is necessary to think about objects in nature.

(ii) Language

Language development is a gradual process. Vygotsky (1987a) coined the term "preverbal thought" to indicate pre-intellectual speech to describe the development of speech before it intersects with thinking. Vygotsky (2011) explains that when the adult points out the visible features of the environment, the infant is introduced to an environment that is segmented by words into different objects and categories. By learning and using speech, the child will become able to solve problems.

Building on the work of Vygotsky, Kurdiukova and Suntsova (2020) state that, the term "preverbal stage" is used to indicate the process of interacting with others to create the conditions that subsequently enable the child to learn speech. First, the infant must develop a selective receptiveness to the speech of others and develop the ability to identify language from other sounds as well as a more clear distinction of speech-related stimuli compared to other sounds (Kurdiukova & Suntsova, 2020). Speech development is the result of the toddler learning to use his or her vocal apparatus and the understanding of others' speech, leading to interactive speech. The toddler will form a relationship between a sound and the response to the sound and will grasp basic words or expressions provided by adults. Passive speech emerges when the infant produces babbling sounds. Using speech enables the child to solve problems. Language assists the development of thinking and, in that way, indirectly affects the scientific reflection capacity, as it enables the child to solve scientifically related problems.

2.3.5.1.5 Emotional development

Emotional interaction with caregivers evolves throughout infancy. During the first four weeks, the infant shows no emotional reaction to adults. Bodrova & Leong (2006) explain that it is up to primary caregivers to establish emotional contact, using feeding and changing for talking, fondling, and smiling, thereby establishing a warm, caring relationship with the caregiver that later becomes the foundation for learning in the social context.

The first emotional exchanges between the infant and caregiver will be followed by emotional exchanges or dialogues over objects, such as smiling after shaking a rattle. Bodrova and Leong (2007a) mention that purely emotional exchanges include interactions that occur when a baby smiles or coos to a loving voice, and the more physical interaction is when a baby happily responds to hugging, bouncing, patting, or tickling. The emotional exchanges over objects between the child and the caregiver introduce the infant to scientific concepts that will lead to scientific reflection, for example the sound of a rattle.

2.3.5.1.6 Social development

Due to the physical development of the infant, social interaction in the first year of life cannot be based on mutual understanding; it is, to a large extent, an emotional, affective bond. Van der Veer (1986) identifies two social reactions that can be distinguished during the first year of a child's life, namely vocal reaction and smiling.

First, during the first weeks of life, unconditioned reflexes are converted to conditioned vocal reflexes elicited by various unconditioned stimuli linked to different innate reactions of the child. Vygotsky (1987a) identifies cry as an unconditioned vocal reflex. The vocal reaction becomes a conditioned reflex of social contact, while the child's voice becomes the tool substituting for speech. At one month, a trained vocal conditioned reflex appears as a response to vocal reaction originating from the people around the child. The trained vocal conditioned reflex together with the emotional reaction fills the same role with respect to the social contact with people around the child. The child's voice becomes his or her tool of speech in its most elementary form.

The infant's vocal reaction is an organic part of a whole group of reactions. Vygotsky (1997b) identifies it as only one part or one element of a series of movements. As the vocal reaction relates to specific external impressions from the unorganised whole which it is part of, an independent vocal reaction gradually develops. In the first year, a differentiated vocal reaction is isolated from a multitude of unorganised movements of which the vocal reaction is part. This reaction begins to acquire a central significance by eliminating some of the movements.

The second social reaction – the social smile – appears at approximately four weeks and is also indicative of the end of the new-born crisis. Vygotsky (1998d) indicates the fifth week as the start of the infantile period, characterised by reciprocal interaction between the child and adults. Two social reactions can be distinguished: the child starts smiling at an adult smiling at him or her, and the ceasing of crying when an adult approaches. Karpov (2003) indicates that this social reaction is extended during the second and third months when the infant starts to smile at its own initiative (social smile) and demonstrates a positive attitude towards adults in other ways, such as vocalising.

Karpov (2003) underlines the importance of mediation in the social environment by stating that the development of mental processes in each period of children's development is determined by mediation in their social environment. The infant's positive attitude towards adults becomes the basis of attachment with the primary caregiver. After six months, infants have developed a specific need for social interaction, as shown by their protest when the adult walks away. The infant's emotional communication with adults facilitates the infant's in the external world. By the end of this phase, it results in an interest in the external world, which becomes stronger than their emotional communication with adults. Infants accept adults as mediators with the external world.

The development of language starts in infancy through the social exchange between the infant and the caregiver (Vygotsky, 1987a). The use of language arises out of need, the need to communicate with other people (Leontiev, 2005). At the end of the first year, non-verbal communication is no longer adequate for the object-centred joint activity between the adult and the toddler, promoting the development of speech (Karpov, 2003; Vygotsky & Luria, 1994).

During the first year of life, an infant develops from a new-born with instinctive reactions only, to a young toddler with the ability to walk, talk, and demonstrate will. The ability to move autonomously, paired with motoric and sensory development, enables the child to investigate and discover more of the world he or she is living in. Through the development of language in cooperation with adults, more objects will be named, and the child's understanding will improve. In other words, the basis for scientific reflection is laid in the first year of life already.

2.3.5.2 Toddlers (1-3 years old)

2.3.5.2.1 First-year crisis

After approximately a year, a new period of crisis or transition starts – what once was of the greatest value to the infant has now almost ceased to interest the toddler (Vygotsky, 2016). Three main phenomena have been identified by Vygotsky (1987) in this period: the child starts to walk, shows the first signs of speech, and starts developing affect and will. El'Koninova (2017) reveals that these three main phenomena – walking, talking, and will – are involved in the child's differentiation of "real" and "pretend" activities. Vygotsky (2016) describes the three phenomena as enabling the toddler to become more independent and learn from social interaction.

2.3.5.2.2 Leading activities of toddlers

For toddlers (1-3 years), the leading activity is adult-mediated object-orientated activities. During infancy, they treated objects as physical bodies capable of rolling, bouncing, and so forth, but now they learn about the culturally determined use of objects, for example eating with a spoon or brushing hair with a brush. The function of objects needs to be illustrated by adults (Bodrova & Leong, 2003). The toddler needs the presence of adults in object-orientated actions. A toddler will only pretend her doll is a baby and feed it with a spoon after it has been suggested by the caregiver (Karpov, 2003). This has implications for any content one wants the young child to learn. In other words, it is important to recognise that exposure to a range of experiences at this stage can lay the foundation for a rich future scientific exploratory world.

2.3.5.2.3 Physical development

The toddler's new ability to walk also means the possibility of reaching, examining, and exploring more objects and places. Bodrova and Leong (2003) explain that toddlers explore their environment by using tactile investigation, eye movement, and a combination of visual and tactile exploration and auditory discrimination. The development of fine motor skills enables the toddler to handle objects in more complex ways.

The toddler's consciousness is developed through the unity between sensory and motor functions. All objects in the toddler's environment seem to affect him or her. According to Vygotsky (2016), objects dictate to the child what he or she must do. Vygotsky (1998a) has found that toddlers are active exclusively in the concrete situation, doing what the surrounding nudges him or her to do, and describes the two-year-old as wanting to touch everything. Vygotsky (2016) indicates the toddler's need for action by stating that doors need to be opened and closed, bells must be rung, and objects have an inherent motivating force. Therefore, it can be stated that objects arouse motivation in the child to either manipulate it or not by either attracting or repelling but in some way provoking an action.

The toddler is greatly influenced by visual stimulation, and what the toddler says cannot be inconsistent with observed reality. This is illustrated in an experiment by Slavina (cited in Vygotsky, 1998a, p 262) where it was found that two-year-olds could repeat sentences such as "the dog is running" without difficulty. However, if Tanya was sitting in the child's visual field, they found it difficult to say "Tanya is walking". The toddler almost cannot lie because he or she is not capable of invention at this stage. The consciousness of the toddler is characterised by the unity between sensory and motor functions.

Vygotsky (1930) identifies toddlers' practical intelligence as enabling them to reconstruct their perception. Language and perception are linked, even when the toddler solves a problem without talking. He or she categorises perceptions as part of a dynamic system of behaviour. The relation between transformations of perceptual processes and transformation in other intellectual activities is of crucial importance.

The toddler's improved physical abilities enable multisensory experience of different phenomena. The toddler, in general, improves his or her ability to solve problems and, in this way, allows for the development of an understanding of scientific concepts linked to objects and the movement of objects related to the body.

2.3.5.2.4 Mental development

Vygotsky (1997d) observes that as toddlers move from object-orientated joint actions to independent actions, they acquire tools for exploring and processing the properties of objects and situations. Nonverbal (sensorimotor) thought begins to merge with spoken language. Toddlers do not think in words; their words are associated with particular actions but do not form the basis of thinking. Words are integrated into thinking, but the child depends on the physical manipulation of objects to support problem solving.

Vygotsky (1998a) points out that in infancy, thinking is strictly visual and does not mean remembering. For the toddler, thinking means investigating, that is, visual perception is directly transferred into action. This description of this development has similarities with Piaget's description of the period as "sensorimotor thinking". Piaget's sensorimotor stage is described by Donald, Lazarus, and Lolwana (2013) as follows: at first, the infant's schemata (building blocks of intelligent behaviour or set of linked mental representations) are simple and limited to what the child can explore through the different senses; when the child starts to move around the mental representations, these will become more complex. In the young child, active exploration is crucial for mental development.

Karpov (2003) and Vygotsky (2011) stress that human mental processes (understanding) are mediated by psychological tools such as language, signs, and symbols. Language serves as a facilitating link in the activity of understanding and immediately conditions of activity. The toddler's first cognitive or "understand" functioning is dominated by perception, while higher mental functions, such as memory, attention, and thinking, are not yet separated.

The toddler uses his or her senses to make sense of the sensorimotor environment, while nonverbal thought begins to merge with spoken language. The child's multisensory experiences add to his or her experiences with scientific phenomena in his or her social environment and the development of scientific reflection.

(i) Language and speech

Due to the limited vocabulary of toddlers at this stage, they will initially use gestures supporting their limited language usage (Leontiev, 2005). During the second year of life, toddlers will develop active speech. Glozman et al. (2020), remark that the toddler will now pronounce his or her first words and elementary phases. Caregivers have a crucial role in the assimilation of speech and the rate of development. During interaction between the child and adults, this emotional contact is infused with verbal elements. The toddler uses words and sound combinations as a means of verbal interaction. Speech development takes place through imitation.

Mahn (2003) explains that toddlers master the external connections between the word and the object, while the word and the object both serve as stimuli. Simultaneously, new words serve as conditioned reflexes for toddlers – when the toddler hears a word spoken by the people around him or her, it must relate to an object and the child needs to pronounce it. The toddler's vocabulary increases rapidly, as he or she realises that everything has a name. Vygotsky (2011) identifies this extension of vocabulary as the point when speech starts to act as an overall, universal means by which the child can order and organise content perceived during activity. This allows for acceleration in development and communication about all physical phenomena, including simple scientific issues such as cause and effect.

The meaning of language is learnt by constructing meaning through shared activity, resulting in talking becoming the toddler's form of communication (Vygotsky, 1987b). Mahn (2003) explains that toddlers talk to people about what they see around them. Due to the urge to name objects, the connection between objects and the relationship to the objects develops. The result is a new relation between perception and thinking, where perception no longer just functions on the affective-motor plane.

Glozman et al. (2020) identify the beginning of the third year as the period of forming speech structure. Bodrova & Leong (2007a) and Glozman et al. (2020) stress the influence of interaction between toddlers and adults in the forming of grammatical structures, the expansion of vocabulary, the forming of more complex grammar constructions, and clearer pronunciation. Through their interaction with adults, toddlers assimilate the conceptual substance of a word and learn how to use words to convey increasingly complex and abstract information (Glozman et al., 2020). The lexical and grammatical richness of their language depends on interaction.

An important theory that underlines the study of children's development is the CHAT (cultural-historical activity theory). It originated from the collaborative investigative project by the "troika" Vygotsky, Leontiev, and Luria, and several others in the early 20th century. This theory was extended by the neo-Vygotskians (Stetsenko, 2005) and is presently still used for psychological and educational research.

Following CHAT principles, Bodrova and Leong (2007a) theorise that meaning exists first in a shared state. In this shared state, cues are combined with the strategies used by the adult to support meaning. For example, when an adult asks a toddler to point to the bird on a page containing several pictures, the pictures serve as contextual cues for the child as to what a bird is. The child understands "bird" in that context but may not possess the same meaning for the word as the adult does; for example, the toddler may indicate the leaping frog as the bird. If a child uses a word in familiar contexts while communicating with familiar adults, understanding is enough to maintain conversation. Only when a child tries to apply meaning to different contexts and with different people does the difference between the child's understanding and that of the adult become visible; for example, calling a niece "aunty" because she is older. Children and adults may use the same words but with different meanings. As the child interacts with different people in different contexts and over different tasks, he or she restructures his or her initial personal meaning over and over. Eventually, the meaning becomes like the culturally adopted or conventional meaning.

Cole, Levitin, and Luria (2010) mention that the understanding of verbal instructions is also a process of development. In their investigations, they have found that a one-and-a-half-year-old toddler cannot follow verbal instructions if these are not linked to feeding. Even in the feeding situation, the intonation components of the stimulus and their place in the situation, rather than word meaning, are clearly decisive in regulating the child's behaviour. Only by singling out the object named and moving it, can one make it more attractive for the child. The child is influenced by the physical features of the situation. Verbal instructions become decisive only when children are about two years old.

Bodrova and Leong (2003) indicate that toddlers' ability to use speech for communication with others is necessary for forming their first generalisations. Glozman et al. (2020) specify the learning of the names of objects in a toddler's surrounding as pivotal for the formation of the first generalisation. For example, when adults use a word such as "table" to indicate different tables, the toddler, in imitating the adult, begins to use words in a generalised meaning, mentally consolidating a set of similar objects. In their early years, children base their generalisations on the external similarity between things. Bodrova & Leong (2003) identify the function of the first generalisation as helping to build a constant picture of the world around the toddler. When toddlers start to use words, their thought becomes liberated from the limitations of what is immediately perceived, and perception loses its dominant position in their minds.

In other words, toddlers' rapid development of language can change and extend the way they will build understanding and knowledge of their environment. This has an impact on not only their physical exploration of scientific content embedded in the environment but also their ability to reason about this phenomenon.

(ii) Thinking

By age two, the toddler's speech has developed to a level that it becomes the overall means by which the child orders and organises content perceived during activity. Podd'iakov (2012c) explains that as soon as the toddler grasps the initial principles of constructing thoughts, it will result in the restructuring of all cognitive activity. In this way, the toddler's conceptualisation and understanding of the surrounding world develop. Although Glozman et al. (2020) describe the toddler's thinking as depending on direct perception till age three, Bodrova and Leong (2007a) indicate the merging of speech and thinking between the ages of two and three. With the merging of speech and thinking, speech gains a new purpose, as it now is used intellectually and not only for communication.

Mahn (2003) points out that Vygotsky (1998c) has identified two distinct interrelated aspects of speech in toddlers, namely (i) the internal unification of speech and thinking as the toddler makes meaning through verbal thinking, and (ii) the external construction of perception in relation to thinking, the transition from nonverbal perception to verbal perception, and the move from visual thinking to verbal thinking. According to Vygotsky (cited in Mahn, 2003), when speech and perception get intertwined, interpretation is added, resulting in the incorporation of visual impressions and thinking processes. Perception is central in the mental structures of the toddler. Perception and its interrelationships with other functions account for a new system of consciousness. The child, whose perception is directed by speech, now makes meaning of his or her social reality.

The change from nonverbal to verbal perception is an important development, as the toddler uses language to make sense of the world, and language is part of his or her mental functions and not only communication. This development is very important for the future ability to use language as a tool in the explication of scientific ideas.

(iii) Reasoning

The reasoning of young children is naïve and at odds with reality due to their incomplete experience and lack of skills in using mental operations (Glozman et al., 2020). For example, when a toddler sees a plant being watered, he or she makes the inference that a stuffed rabbit should also be watered "so that he can grow big". Under the adult's guidance, the toddler can learn new facts, specifically facts that are conflicting with his or her conclusions, and can gradually restructure his or her reasoning in accordance with reality and learn to validate it more correctly.

The toddler's development is important for scientific reasoning, as language becomes even more important in the development of thinking. Language now becomes the medium of thinking and reasoning.

2.3.5.2.5 Emotional development

Fleer (2013) theorises that everyday social situations can create scientific encounters. Such social situations are emotionally charged and are socially mediated in actions and activities. Early childhood (toddlerhood) settings provide opportunities for developing young children's scientific self-awareness and, through it, the knowledge of what it means to act scientifically. Working scientifically brings about conceptual understanding and the possibilities for emotional engagement and commitment.

A positive emotional experience for the toddler leads to a positive attitude in the older child. A positive attitude is important for future interest in experimenting, learning about the scientific world, and solving problems.

2.3.5.2.6 Social development

During the transition from infancy to toddlerhood, the social situation of the child is submitted to major changes. With toddlers' bigger independence due to their motor development, their relationship with parents and caregivers change. Also, toddlers' development of language adds to their independence, as they can ask for desired objects or actions that are not present (Bodrova & Leong, 2003). This has implications for the way in which parents deal with discipline in managing and restricting the toddler's behaviour. Through private speech, toddlers will learn to control their own behaviour and internalise adults' restrictions.

Toddler's social situation has a major impact on their language development as it can either stimulate or impede their speech. Luria (2002) describes speech as the vehicle for the transformation of the child's intellectual operations. In other words, the social situation of the toddler will play an important role in his or her development of language and intellect.

During the imitation of adults' actions, language is used as social mediation. Bodrova and Leong (2011) use the example of a toddler learning to feed him- or herself with a spoon, where his or her concept of a spoon is formed because of a combination of experiences: the toddler learns about the function of a spoon as a tool by associating kinaesthetic control with food and develops a general image of a spoon associated with its verbal label. The toddler hears the adult saying the word "spoon" as he or she uses it, manipulates it, puts it in his or her mouth, or bangs it on the table. The meaning of spoon is shaped by language as a means of social mediation. Through interaction with adults, toddlers also learn other social skills using objects.

Karpov (2003) draws attention to the fact that the toddler's interest shifts from the world of social objects to the world of human relations. For example, at the age of two years, girls will imitate concrete actions such as feeding a doll with a spoon, while three-year-olds will imitate the mother-daughter relationship of loving and caring. By the end of the third year, children's involvement in object-centred joint activity results in their having developed a strong interest in human relations and already having started to imitate these relations during their play with toys. Through joint activity with adults, the toy is transformed from an object into a toy.

Vygotsky (1998a) identifies two stages in the toddler's movement to the social situation. In the first stage, there is a "great-we" consciousness that precedes the concept "I". The child seems to take account of what he or she understands and what others understand. Vygotsky (1998a) compares this to Piaget's view that the child thinks that adults know his or her every wish. When the toddler wants something, he or she expects adults to understand him or her, and if they do not understand, the toddler becomes angry. Although adults will ask questions to understand the toddler, the toddler does not seem to understand that adults may not understand him or her. Adults interpret the behaviour of the child in order to guess what he or she wants. According to Piaget, the toddler's view is that the adult should understand him or her, that is, the child's consciousness is the same as that of the adult.

In the second stage of social development, the expression "I myself" appears (Vygotsky, 1998a). It can also be called "the stage of the external 'I' in the 'we'". The child opposes his or her independent actions to cooperative actions with adults, but in terms of consciousness, the child remains in the "great-we" state. The child cannot yet put his or her thoughts and ideas in motion; the environment is controlling the child. When the child is active in the situation, it relates to the involvement of others. This means that adults in their mediating role should provide toddlers with an environment that will support their development, preparing them for scientific reasoning.

The physical, mental, emotional, and social development of the toddler prepares the child for scientific reflection. Physical development makes more sensory experiences possible, while language development and thinking contribute to mental development and reasoning skills. Positive emotional experiences will have a positive influence on future scientific reflection as the child becomes more independent in thinking and in understanding his or her scientific environment.

2.3.5.3 Pre-schoolers (3-7 years old)

2.3.5.3.1 Third-year crisis

Vygotsky (1998b) states that after the second year, a period of internal and external conflict begins, with deep shifts in the affective needs of the child's personality. The more complex emotional regulation of behaviour becomes the new social motivation for activity. Mahn (2003) describes the crises at age three as the result of the child's reacting to people. As a result of the development of speech and social interaction, the child has become aware of the subjective environment. This awareness alters the way, the child perceives, experiences, and appropriates social interactions. The child's personality undergoes changes, leading to a challenging attitude. Kravtsova (2009) explains that the three-year crisis is characterised by the toddler's awareness of "I" and imagination. Vygotsky (1998b) identifies four characteristics of this stage, namely negativism, stubbornness, obstinacy, and wilfulness.

During the third-year crisis, children have the desire to act according to their own judgement, resulting in characteristic action (Van der Veer, 1986). At the same age, personal action leads to accomplishments that are valued by the adult and are meaningful to the child.

2.3.5.3.2 Leading activity

Make-believe play becomes the leading activity of the pre-school (kindergarten) period. This type of play promotes the development of both mental and social abilities (Bodrova & Leong, 2003) (see Chapter 3). During the pre-school years, make-believe play, as leading activity, creates a zone of proximal development that separates thought from actions and objects while developing self-regulation and motivation. In the social environment of make-believe play, using their imagination, children can use scientific reflection to solve problems, for example, developing a "cooling down" machine for the three bears to cool their porridge (see Chapter 5).

2.3.5.3.3 Physical development

In research on the development of perception and sensory processes, Zaporozhets (1965, 2002a, 2002b) has found that pre-schoolers need to visually acquaint themselves with objects for later recognition. For younger pre-schoolers, visual inspection will be very brief before they start to handle and physically manipulate the object, while older pre-schoolers spend time on a detailed visual examination, resulting in better sensory problem solving. The three-to-four-year age group needs practical operation with objects to distinguish the features of the object. During practical operations, they will be able to distinguish various features of the object as well as the relation of the features.

Zaporozhets (1965) has found that three- to four-and-a-half-year-old children acquaint themselves with objects with practical actions, such as rolling, pushing, and pulling it, knocking with it, and so forth. Later, the hand movements are of a fixing character, and not exploratory. For six- to seven-and-a-half-year-old children, tactile images become more diverse and more closely corresponding with the properties of the object. This is achieved tracing the outline of the object and determining how solid it is and the material it is made of.

Zaporozhets (2002b) concludes that the sensory perception of reality is the start of cognitive development. Thought develops from direct perception of a reality to a deeper understanding of that reality. Thus, it involves the development of the child's personality, changes in the child's relationships in his or her real-life situations, and the development of the child's activity in general.

For pre-schoolers to become independent, self-motivated learners, they need to overcome the external and internal difficulties of voluntary movements. Also, in this process, the adult plays an important role, as described by Kravtsov (2006). Voluntary actions (movements) arise in a process through the child's relationship with adults, passing through several successive stages in development.

Suntsova and Kurdiukova (2020b) identify the development of spatial concepts in pre-school-age children as learning to orientate themselves in schematic space, such as the space of a sheet in the notebook. The final phase of the formation of spatial concepts consists of orientation in quasi-space; this would be the structure of the systems of signs and symbols such as musical notation and concepts of time and an understanding of logical-grammatical construction. The levels of spatial conceptual development are interacting with one another. Spatial concepts are crucial for the formation of higher mental functions such as praxis, gnosis, oral and written speech, visual-spatial memory, and thinking.

The embodied cognitive theory also emphasises the importance of the physical world in the development of higher mental functions. Smith and Grasser (2005) point out that the movement of pre-schoolers over things, by things, and into things, is responsible for new patterns of spatiotemporal relations. Hand-eye coordination, sitting, crawling, and walking bring pre-schoolers in contact with new multimodal regularities.

Pre-school children's sensory perception of objects in their environment forms the foundations for cognitive development. Scientific reflection develops through the perception of scientific phenomena in the total environment of the child.

2.3.5.3.4 Mental development

Bodrova and Leong (2003) identify attention, memory, and imagination as mental functions, starting with the process of transformation during pre-school age that allows for the acquisition of their deliberated and mediated forms during primary school years.

(i) Attention

The child's attention changes through a series of perceptual fields that form successive, dynamic structures over time (Vygotsky, 1930). The acquisition of speech results in a fundamentally restructuring of the psychological field. Vygotsky and Luria (1994) point out that after the acquisition of speech, attention becomes a function of active selection and intellectual recollection. This additional language capacity enables the child to focus attention, which will most definitely have an impact on the improvement of scientific-reflective skills.

(ii) Memory

By age five to six, mechanical memorisation is replaced by conscious memorisation or recall (Suntsova & Kurdiukova, 2020a). The development of memory proceeds mainly along a path of mediated memorisation. At first, mechanical memorisation is dominant, but mechanical memorisation through repeating is not a productive way of improving memory. Memory will, over time, move from the mechanical to become semantic memorisation. This semantic memory phase will then assume a mediated, logical character. A child who memorises using auxiliary tools uses signs and auxiliary operations in a non-mechanical way. This new memory that is created allows for the establishment of new connections and structures. The result is a more logical memory, rich in imagination and well-developed thinking structures.

The ability to store and retrieve images of the past is greatly enhanced using language, which makes it possible to use experience in a variety of situations, from communication to problem solving, placing memory at the centre of the cognitive functioning of pre-schoolers (Bodrova & Leong, 2003). This extensive development of memory will make it possible for the child to connect present experiences with previous ones. This will also support the important idea of linking causes with effects when reasoning about scientific phenomena emerging from their environment.

(iii) Imagination

Vygotsky (2004) views imagination as not just an idle mental amusement and not merely an activity without consequences, but as a function essential to life. In combinational or creative activities, mental pictures are created in one's imagination. This allows for linking, for example, what has happened in the distant past to situations emerging in the future. These mental pictures are possible because of the brain's ability to store and retrieve one's previous experience, while it is also the organ that combines and creatively reworks elements of this experience and uses them to generate new propositions and new behaviour. This creative activity is based on the ability of the human brain to combine elements, which is called "imagination" or "fantasy" in psychology. Imagination, as the basis of all creative activity, is an important component of all aspects of cultural life, enabling artistic, scientific, and technical creations. Great discoveries are the result of an enormous amount of previously accumulated experience.

Vygotsky (2004) identifies four basic ways (laws) in which the development of fantasy is associated with reality. The first and most important law governing the operation of imagination is that the creative activity of the imagination depends directly on the richness and variety of a person's previous experience. In other words, every act of imagination starts with this accumulation of experience, allowing for richer experiences to evolve in richer acts of imagination. Fairy tales, myths, legends, and dreams are fantastic creations that are nothing other than a new combination of elements that have ultimately been extracted from reality and undergone the transformational or distorting action of our imagination.

The second linkage, the one between fantasy and reality, is a more complex relationship (Vygotsky, 2004). In this linkage, an image is constructed based on the study of somebody else's experience. This includes, for example, stories of historians or travellers. The image is not the product of what was perceived in previous experiences but is created by the rework of elements of reality and experience; for example, concepts of sand, water, and open spaces are necessary for understanding the concept of a desert.

The third type is the relationship between the functioning of imagination and reality, which is emotional. Vygotsky distinguishes between two types of relationships. Firstly, feelings and emotions seek emotions corresponding to these. Emotions have the capacity to select impressions, thought, and images that resonate with the mood experienced now, for example, joy or grief. The emotion has an external, physical expression and an internal expression. For example, fear is experienced as trembling, having a dry throat, and so forth (physical), but also thoughts (internal) that are infused by the feelings that take over the person.

Vygotsky (2004) point out that imagination also influences emotion. Every construct of imagination influences one's feelings, and if the construct does not correspond to reality, the feelings are still real. For example, when a child enters a dark room, the clothes hanging in the room may create the illusion of a robber. The image of the robber, created by the child's imagination, is not real, but the fear and terror the child experiences are completely real – the child's true experience.

The passions and fates of characters, including their joys and sorrows, influence humans emotionally even though they know that these events are not real (Vygotsky, 2004). The emotions that take hold of us from the artistic images on the pages of books or from the stage are completely real and we experience them truly, seriously, and deeply. Complex feelings can also be experienced by listening to music or viewing artwork.

Vygotsky (2004) describes the fourth and last type of association between imagination and reality as a construct of fantasy that represents something substantially new, never encountered before in human experience, and without correspondence to any object that exists. The new object is created and influences other things. In this way, machines, technical devices, or instruments are created.

Creativity in children and its significance to children's general development and maturation is regarded by Vygotsky (2004) as one of the most important areas of child educational psychology. One of the places to see these creative processes is in the play acts of children’s play. Vygotsky (2004) views fantasy as depending on memory, using the content in different combinations between reality and fantasy; for example, fairy tales contain some elements of reality and fantasy.

Vygotsky (2004) indicates the implications of imagination for education as the ability to assist in the building of a relatively strong foundation for a child’s creativity through broadening the experiences provided to the child. In other words, the more children see, hear, and experience, the more they know and assimilate, and therefore, the more elements of reality they will have in their experience, and the more productive will be the operation of their imagination.

Many concepts, and especially the utilisation of models and modelling in science, can only be understood through imagination. Imagination allows for the co-experiencing from others’ experience, leading to authentic discoveries as the result of these merged accumulated experiences.

iv. Language

Language that has started to develop in the toddler will become more coherent and exact in the pre-schooler. Glozman et al. (2020) point out that the pre-schooler can now use language in dialogue. This coherent and contextual speech will be expanded and grammatically constructed. Vygotsky (2011) and Zen’kovskii (2013) identify particular roles of language, such as cognitive development and being the carrier of values, information, and worldviews.

Language enables the child to master different forms of thinking, mastering systems of ideas and beliefs, and to improve the understanding of the world (Zen’kovskii, 2013). The continuous development of word meaning, speech, and verbal activities now enables the child to reflect on the variety of the surrounding world using verbal tools. In other words, language becomes a primary mental tool as it is used for specific mental functions. The mastering of language also means the mastering of social traditions, ethical thinking, and moral judgement.

Glozman et al. (2020) draw attention to their finding that at age three, the prerequisites for mental operations emerge, but only when this operation is verbalised to adults. For example, when looking at pictures and hearing from an adult “flower, flower, flower, mushroom. Which one does not fit?” the three-year-old will be able to identify the mushroom as the picture that does not fit. This is the child’s first mental operation of generalisation and exclusion. By age four, the pre-schooler can eliminate one object that differs from others based on primary characteristics and comparison, for example, bigger, higher, and alike.

Another development is the toddler’s ability to use egocentric speech. However, Vygotsky and Piaget disagree regarding egocentric speech, in terms of the function and duration thereof. Vygotsky (2011) points out that Piaget has hypothesised that egocentric speech is unintelligible, because young children are unable to take another’s point of view and will gradually replace it by social speech. Vygotsky refutes these views; he notes that egocentric speech is absent or greatly reduced when children are alone or, for example, surrounded by deaf children. Egocentric speech is meant as social communication; it rises when the child is confronted with unexpected problems, as speech has some function in the solution of problems. He has also noticed that egocentric speech becomes less intelligible as children grow older. Vygotsky concludes that egocentric speech originates in normal, commutative speech, has the function to steer the child’s behaviour when the need arises, and becomes less and less intelligible to outsiders until it becomes proper inner speech. He reveals that the introduction of speech changes one’s way of thinking, changing from social speech via egocentric speech to inner speech when introduced in social interaction.

Language as a primary mental tool changes children’s general way of thinking and, consequently, their scientific thinking as well.

(v) Thinking

Zaporozhets (2002d) describes thinking as a complex activity, emerging and developing as the child develops. Glozman et al. (2020) stress the importance of adults in the development of this complex activity. Adults introduce the child to the surrounding reality and communicate the first information about the phenomena of nature and society, without which the development of thought would have been impossible.

According to Zaporozhets (2002a), activity and orientation to the real world are necessary for the development of thought. Glozman et al. (2020) describe visual-action or practical-action thinking as a form of thinking that is demonstrated in many practical tasks. For example, between the age of three and five, when the melody of a toy phone stops playing, the child will immediately act by pulling, twisting, pressing, tugging, shaking, or hitting something. Visual action can also be used to solve complex problems that arise in the activities of scientists. The visual-action thinking of pre-schoolers is promoted by activities with picture puzzles or assembly toys. This aspect needs to be considered when planning activities to develop scientific thinking.

Podd’iakov (2012c) identifies models and diagrams as important in the development of thinking in children. He expands on this by stating that in the process of understanding the relationship between the original and the model of verbal thinking, the logical-grammatical structure thereof is of great importance. He explains that schematic images are created in the pre-schooler’s activity with models in the form of thought that arises within a system of broader understanding by a child of the entire situation and individual elements. The intrinsic meaning of an image emerges as thought about an existing object, and the image carries the stamp of a logical thought structure; the logic thought structure is the source of the interpretation and close interrelationship of the logical and figurative sources of thinking in children. Podd’iakov (2012c) reasons that the continuous development of word meanings in speech and verbal activities emerges and creates a unique ability to reflect the unlimited variety of the surrounding world using verbal tools. Children often use an arbitrary word to denote a new object that they have already seen but which remains largely undefined for them.

When pre-schoolers observe articles, they identify properties such as shape, colour, and size, as well as word meanings, as playing a decisive role in understanding actual relationships between the properties of objects and the words to describe the objects (Podd’iakov, 2012a). In other words, their understanding of the world is mastered through language (Zen’kovskii, 2013). Language and thinking merge and the pre-schooler thinks in words (Vygotsky, 1997). When children can think as they talk, speech becomes a tool for understanding, clarifying, and focusing on what is in their minds.

Vygotsky views fantasy and reality (imagination and realistic thinking) as integrated, stating that imagination is an integral aspect of realistic thinking. No thinking is possible without imagination. Vygotsky (1987c, p. 349) states that "no accurate cognition of reality is possible without a certain element of imagination, a certain flight from the immediate, concrete, and solitary impressions in which the reality is presented in the elementary act of consciousness".

Thinking in pre-schoolers is illustrated by solving problems through practical action. Language and thinking merge and the meaning of scientific concepts is developed through language as verbal tools.

(vi) Reasoning

Pre-schoolers perform different mental operations that rely on not only perception but also concepts of previously perceived objects and phenomena. For the pre-schooler, thinking assumes the character of logical reasoning, which becomes independent of the manipulation of objects (Glozman et al., 2020). This means that the pre-schooler is now able to solve cognitive, thinking problems, such as riddles and brain teasers. It also implies that in the process of problem solving, the pre-schooler can now compare judgements to draw conclusions.

Due to their limited experience in thought and deficit mental operations, younger pre-schoolers' reasoning is often naïve and incompatible with reality. Glozman et al. (2020) use the example of the young pre-schooler's supposition that a large piece of candy floss is heavier than a small iron object. This supposition is based mainly on external characteristics such as the shape and size of the candy floss. As time passes, the pre-schooler starts to consider other properties of an object such as candy floss, for example the material that was used to manufacture it.

Pre-schoolers will also learn to generalise objects and phenomena based on essential characteristics and specific features thereof. Glozman et al. (2020) point out that a five-year-old can group a helicopter, cart, car, ship, and boat together, not based on appearances but because “you can ride them”. On the visual-figurative level, the child forms the concept of “transport”, even if such a generalising word is not yet in the child’s vocabulary. As the pre-schooler learns new facts and adapts to phenomena of reality, he or she will start to reason consistently, avoid mistakes and contradictions, and formulate logic deductions. This means that in his or her reasoning, the child relies on visual images of concrete, unique objects and phenomena. For example, a pre-schooler knows that various wooden things float. Furthermore, the pre-schooler’s generalised knowledge about these phenomena is formulated through language.

The ability to reason using the correct language is the foundation for logical deductions and enables the child to be less dependent on visual images. As many concepts in science are not visually observable, scientific reasoning is crucial for the understanding of these concepts.

(vii) Self-regulation (will and intent)

Bodrova et al. (2011) point out that executive functions in the cultural-historical theory constructs are associated with self-regulation. The self-regulation have been primarily framed in terms of (i) the development of voluntary behaviours and associated with children (make-believe play) and (ii) gaining control of their previously involuntary behaviours by using cultural tools, mostly of a linguistic nature (self-regulation).

Smirnova and Gudareva (2017) distinguish between two terms in the mastery of behaviour, namely “voluntariness” and “self-regulation”. Voluntariness is the awareness of one’s own behaviour, independence, responsibility, self-control, and inner freedom. Bodrova and Leong (2005a) define self-regulation as deep, internal mechanisms that underlie mindful, intentional, and thoughtful behaviour of children. It implies that children can delay gratification and suppress their impulses long enough to foresee the possible outcome of their actions or consider more appropriate actions. Self-regulation is also the capacity to control one’s impulses and either stop doing something one wants to continue doing or start something even if one does not feel like doing it.

Bodrova et al. (2011) refer to Luria's explanation that as adults' control of behaviour is replaced by the child's own speech, it becomes a system of self-regulation. This self-regulation is responsible for voluntary movement and the voluntary movement to self-regulate. According to Smirnova & Gudareva (2017), unless children develop voluntariness, they will remain dependent on adults.

Smirnova (2015) identifies the following three stages in the self-regulation functions of speech:

- In the earliest pre-school years, language follows action, with the result that the impression is created that language is the result of action.
- Speech accompanies action and parallels it.
- The verbal formulation of a task begins to determine how well it is performed. Speech moves closer to action and becomes a steppingstone to action; speech has a planning and regulating function.

The development of self-regulation helps the child to focus on making sense of scientific phenomena and develop scientific reflection.

2.3.5.3.5 Emotional development

Iakovleva (2003) defines emotion as an inherently physiological reaction corresponding to one of the basic adaptive biological processes. Emotions can be described as adaptive mechanisms facilitating an individual's survival on all levels. Emotional experiences depend on personal experiences, while emotions stem from the individual's evaluation of the environment.

Iakovleva (2003) points out that there is an association between emotions and cognitive states. Affects and emotion are the main organising and controlling forces in consciousness, self-consciousness, and self-conception. Emotions reflect needs, become motives, and are associated with core personality formation. The way emotions are socialised plays a major role in the development of a child's personality;

for example, if parents permit and encourage play and exploration, curiosity may develop.

The curiosity of the pre-schooler should be utilised by the teacher and parents to build positive emotional experiences for the pre-schooler. It will ensure a positive attitude to science reflection in the later years.

2.3.5.3.6 Social development

By age three, the young pre-schooler has mastered language and is able to use it as a social tool. Social relations are important for pre-schoolers; they become aware of the environment through speech and social interaction.

Pre-schoolers observe scientific phenomena through sensory perception. Mental development will add to the development of scientific reflection through abilities such as attention, memory, and imagination. Reasoning is important for logic deductions and will start to develop in pre-schoolers. Their awareness of the environment should be utilised to help them think creatively about problems.

2.3.5.4 School children (7-9 years old)

2.3.5.4.1 Seventh-year crisis

Vygotsky (1998e) describes the seven-year-old as presenting difficulties with respect to teaching. The negative content of this age is apparent primarily in the disruption of mental equilibrium and instability of the will, mood, and so forth. The child becomes more independent and his or her relationship with other children changes. Seven-year-olds lose naivety and directness in their behaviour and in their relationships with others. They become less understandable in all aspects than before.

Polivanova (2015b, p.78) describes the six- to seven-year-old child as “a social functionary”. The child is reproducing “adult” forms of behaviour outside of real conditions or the real, total situation of action. One of the blocks of behaviour is called “deliberate maturity”. For these kinds of reactions, children pay attention to their external state, hold “grownup” discussions, and exhibit empty verbosity. All of these point to the child's desire "to grow up" at that very moment, simply by copying someone else's behaviour.

2.3.5.4.2 Leading activities

School learning is the leading activity of the child in the primary grades (Davydov, 1988; Elkonin, 2005a; Karpov, 2003). This means that for the school-age child to be ready to learn implies specific developmental achievements. Dolya (2010) describes school readiness as being ready to learn how to read, write, and count. Kudriavtsev and Fattakhova (2015) also indicate other developmental requirements to be ready to learn in a formal school setting. School readiness also requires changes in the personality of the pre-schooler. Knowledge, abilities, and skills in this process perform the most important instrumental function. These changes create a broad foundation for mastering the "tools" of any type of activity in the present and future. School learning and educational activities presuppose that children are gaining an understanding and awareness of themselves as the subject of these changes.

The main purpose of school learning is identified by Bodrova and Leong (2003) as learning to become a student. With the assistance of the teacher, the child should learn how to learn as an effective student, capable of undertaking the difficult and diverse knowledge base he or she should acquire to become a productive adult in a technological society. During the first years in school, children should develop cognitive, linguistic, social, and emotional proficiency.

Bodrova and Leong (2003) define learning activity as child-initiated activity driven by inquiry motivation (intellectual curiosity). It starts as a process modelled and guided by adults about specific content that is formalised, structured, and culturally determined, such as learning parts of speech. At first, the learning activity is not carried out by individuals but rather unfolds as a group activity in groups. In a more mature state, the learning activity is something in which children can engage in various contexts and situations, not limited to the classroom only. Cognitive, social, and emotional development ensures that children are ready to learn when they reach school age.

2.3.5.4.3 Mental development

The learner should not merely be a doer of teacher instructions but a participant of cognitive actions as well. Zuckerman (2003) views learning as shared by the teacher and the learner. Bodrova and Leong (2007a) theorise that learning should move away from the goal of getting an answer correct and concentrate on the specific process that was used to get that answer. By the age of six or seven years, the process of voluntary memorisation should have formed, and the young school child should be seeking to use logical connections in material for memorisation (Suntsova & Kurdiukova, 2020a). In school, children confront the necessity of memorising voluntarily.

Vygotsky (1998f) draws attention to the fact that learning in primary school depends, to a large extent, on memory. Thinking is mainly done through remembering and primitive thinking, which constitute three different functions in undifferentiated form, namely remembering, imagining, and thinking.

According to Vygotsky (1997a), the early maturation of scientific concepts can be explained by the unique form of cooperation between the child and the adult – the central element of the education process is knowledge being transferred to the child in a definite system. The level of development of scientific concepts forms a zone of proximal development for everyday concepts. At any single stage in the development of a child, differing strengths and weaknesses in scientific and everyday concepts are found.

In school-age children, learning depends largely on memory, which implies that scientific reflection can now make use of previous experiences that are remembered. It should be remembered though that cooperation between teachers and children is important in the teaching and learning of scientific concepts at this phase.

2.3.5.4.4 Social development

The main problem of first-graders and their teacher is the introduction of these children into a new social situation of development (Kudriavtsev & Fattakhova, 2015). Being a school learner is a specific “life position” in the newly emergent, evolving, and changing social situation of development. The child now needs to master “school techniques”.

Bodrova and Leong (2005a) identify two aspects of school readiness, namely (i) the social situation itself, including societal practices of schooling and expectations associated with the role of the learner, and (ii) the child’s awareness of these expectations and the ability to meet them. For the child to gain this awareness, it is necessary to participate in school activities and to enter specific social interactions with teachers and other learners.

School readiness is formed during the first months of schooling and not before school entry (Bodrova & Leong, 2005a). The accomplishment of pre-school skills, such as self-regulation, and the integration of emotions and cognition make it easier for children to develop school readiness. These prerequisites enable the child to make the transition from learning that “follows the child’s own agenda” to learning that “follows the school agenda”. The change from pre-school to school involves major changes in the social situation of the child. The child must participate in these changes and interact in schooling and the expectations associated with the role of the learner. How adults interact with the child and what is expected from the child change from pre-school to primary school.

According to Bodrova and Leong (2005a), the young school child is aware of both the expectations with regard to school and his or her ability to meet these expectations. The change in the school child includes participation in interaction as well as change in the child’s ability to interact. For children to adjust to social situations, they need to be aware of new expectations and have the capacity to meet these expectations. Children can only become aware of the expectations through their participation in school activities in social interaction with their peers. Their development to meet the new challenges is scaffolded by social interaction.

School children need to learn how to be students. This process starts in their first school year by developing cognitive, linguistic, social, and emotional proficiency. This development takes place in cooperation with the teacher in a group with the child's classmates.

2.6 Summary

During the first six years of a child's life major development is taking place physical, mentally emotionally and socially. At birth, the infant is totally dependent on his/her caregiver, but during the first year a spurt of physical and mental development is taking place while they emotionally interacting with their caregivers. During the first year the infant learns to walk, talk, and develop of affect and will. The toddler (1-3 years) learns the culturally determined use of objects through adult mediated object-oriented activities. During the preschool (3-7 years) period make-believe play is responsible for the creation of the zone of proximal development, facilitate the separation of thought from actions and objects, facilitate the development of self-regulation, impacting on the child's motivation, facilitate cognitive decentring, development of imagination and development of language. The school child needs to learn to be a student.

The development of the child as described needs to be considered in the choice of possible scientific content to be taught to children in specific age phases as well as the choice of the type of teaching methodologies (pedagogies) that needs to be employed at a certain age. The young child is ever evolving and constantly changing physically, socially, emotionally, and cognitively.

Make-believe play was identified by Vygotsky as important for the development of the young child. Make-believe play is the leading activity of the preschool (kindergarten) period. This type of play promotes development of both mental and social abilities. Make-believe play creates a zone of proximal development that separates thought from actions and objects, while developing self-regulation and motivation. In the social environment of make-believe play, children use their imagination.

Make-believe play as described in detail in chapter 3 is necessary for the development of the child for the next stage namely school learning.

CHAPTER 3: THE IMPORTANCE OF PLAY FOR TEACHING AND LEARNING SCIENTIFIC REFLECTION

3.1 Introduction

From the previous chapter, it is clear that play forms a major component of the overall development trajectory of the very young child, from birth into the early years of schooling. Although play is currently widely recognised as an integral part of the development and exploration of young children's worlds, many scholars differ about what behaviour and attitudes qualify as play (Pramling et al., 2019). In other words, they are not always in agreement regarding the definitions of play as such. In addition, they disagree on the reasons why children engage in play and what the role of play is in teaching and learning of, among other things, the sciences during the early years of development.

Pramling et al. (2019) define play by dividing the theories with regard to play into two main types, namely classical and modern theories. They define classical theories as taking different forms, by viewing play in terms of energy, with surplus energy "blowing off steam". This is exemplified by the work of Friedrich Schiller and Herbert Spencer, who view "play as an activity deriving from an energy deficit" (Mellou, 1994, p. 91). Bateson (2011) mentions other classical theories that view play in terms of strengthening instincts needed for the future or play as recapitulation based on the ontogeny of phylogeny exemplified by Karl Groos and Stanley Hall. The main objective of the classic theorists was to define the nature of play and its consequential effect on the education of the very young child.

Modern theories can be subdivided into the psychoanalytical theory, the meta-communicative theory, and theories concerned with play and cognitive development as coined by Piaget and Vygotsky (Pramling et al., 2019). Pramling et al. (2019, p. 32) view the psychoanalytic theory, according to which play is important to a child's emotional development, as having a "cathartic effect, which allows children to rid themselves of negative feelings associated with traumatic events". They also consider the importance of meta-communicative theory, emphasising that in play, children learn to operate simultaneously at two levels, namely the make-believe meanings of objects and actions, and incorporating their own identities, the other players' real identities, and real-life meanings of objects and actions used in their play activities. Furthermore, Pramling et al. (2019) state that the theories of Piaget and Vygotsky are examples of theories concerned with play combined with cognitive development. The discussion about the claims and bases of Piaget's and Vygotsky's theories primarily develops around the question with regard to the nature of the relationship between play and learning.

3.2 Early proponents who researched the role of play

Some of the important earlier proponents at the beginning of the 20th century who researched the role of play and aimed to define play were Mildred Parten, Johan Huizinga, Jean Piaget, and Lev Vygotsky. An overview of their theories is given to show the historical development in the thinking of these leading figures that still has an impact on the way in which play is considered in the 21st century.

3.2.1 Mildred Parten

Parten (1932) has observed that social participation among pre-schoolers (2-5 years old) increases with the child's age. She defines six sequential participation categories dealing with play, namely unoccupied behaviour, solitary play, onlooker behaviour, parallel play, associative play, and cooperative play. During the first four stages, play is independent, while in the last two stages, play is cooperative and involves significant interaction. She also focuses on the social interactions between children during play activities while noting onlooker behaviour in younger children participating in the most social types of play. Depending on circumstances, children may engage in any of the different types of play. Parten's stages can be viewed either as a developmental continuum, moving from minimal involvement with others, or as types of play behaviour in which children can be involved.

Parten (1932) divides play into the following six stages:

- Unoccupied behaviour points to how children play passively by watching or conversing with other children engaged in play activities.

- Solitary play is dominant in infancy (2 to 2½ years). This involves a child playing on his or her own with objects. Other children playing nearby go unnoticed.
- Onlooker behaviour is when the child watches others at play but does not engage in it. The child may engage in forms of social interaction, such as conversation over play, without joining in the activity.
- Parallel play is typical of toddlers (2½ to 3½ years) who play in the same area or even share toys but remain playing individually. Interpersonal interaction is limited, although they are aware of and pleased by company.
- Associative play is seen in most pre-school-age children (3½ to 4½ years). Although they play as groups in the same area, cooperation and negotiation are rare.
- Cooperative play, the most social form of play, is a characteristic of older pre-school and kindergarten or primary-school-age children. They cooperate to sustain play with themes, and they plan, negotiate, and share responsibilities and leadership while taking on different roles.

3.2.2 Johan Huizinga

Huizinga (as cited by Van Oers, 2013b) views play as a cultural-historical activity that focuses specifically on the role of play and argues that culture emerges within playful established human activities. Huizinga (as cited by Van Oers, 2013b, p. 231) defines play as "voluntary activity accomplished within specific temporal and spatial boundaries, according to voluntary accepted but stringent rules and characterised by an intrinsic goal, accompanied by feelings of suspense and pleasure, and by an awareness of being different of ordinary life".

Two other important theories of play that deal with cognitive development and link play as an act have been proposed by Piaget and Vygotsky. Zigler and Bishop-Josef (2006) point out that both of these scholars view play as being important in cognitive development, although they differ on how play influences cognitive development.

3.2.3 Jean Piaget

Piaget (1962) describes play as a particular type of activity and defines play as assimilation or the child's effort to make environmental stimuli match his or her own concepts. Piaget (as cited by Gould & Howson, 2019) defines play in terms of the relationship between mental processes (perception, memory, attitude, and decision making) and social behaviour. In other words, Piaget's approach focuses on emphasising children's abilities to make sense of their immediate, everyday surroundings in selecting and interpreting sensory information. Piaget (1962) theorises that play in and of itself does not necessarily result in the formation of new cognitive structures.

3.2.4 Lev Vygotsky

3.2.4.1 Vygotsky's play theories

Vygotsky (1967) proposes the idea that play that contributes to learning falls in the realm of dramatic or make-believe play. He delineates make-belief play into three components, namely children (i) create an imaginary situation, (ii) take on and act out roles, and (iii) follow a set of rules determined by specific roles. Bodrova et al. (2019) mention that these three components play an important role in the formation of the child's mind, in the development of abstract thinking, and in the development of conscious and voluntary behaviours, which are critical neoformation of early childhood.

Vygotsky (1967, p. 10) emphasises the centrality of rules when playing by saying that "[w]henever there is an imaginary situation in play, there are rules – not rules that are formulated in advance and change during the course of the game, but rules stemming from the imaginary situation". Vygotsky (1933/1967) further extends his view on how play influences the formation of the child's mind by stating that it happens through the development of conscious and voluntary behaviours.

El'Koninova and Grigoryev (2017) highlight three central points of Vygotsky's cultural-historic theory in terms of mental development in play. Firstly, mental development is achievable only through inculcation of the cultural experiences of humans as experienced in their cultural ideal forms. Secondly, the mediation of development is constructed as a transition from an inter-psychic form to an intra-psychic one. Thirdly, mental development involves a qualitative leap, implying a transition from the natural form of mental functions to their cultural form, that is, higher mental functions. In other words, it is through the use of and exposure to cultural media that children gain control of their behaviour. This implies that their actions then become more self-aware in the process of learning.

Even though all the above-mentioned researchers have made major contributions to the role of play in the development of the young child, it is the impact of Vygotsky and his followers that warrants further exposition in this study.

3.2.4.2 Extensions on Vygotsky's play theories

3.2.4.2.1 Leontiev

Leontiev (2009) applied the major concepts of Vygotsky's theory, namely motive, action, and operation, to analyse children's play (Bodrova & Leong, 2015). He analysed the motive of play and concluded that the motive of play lay in the process of play. Leontiev views the imaginary situation because of the difference between the actions the child wishes to engage in and the actions with toys and other props (Bodrova & Leong, 2015). For example, the child cannot drive a car but can, in play, pretend that a chair is a car and pretend to drive a car using hand movements.

3.2.4.2.2 El'konin

Daniel El'konin worked closely with Leontiev in developing and extending the idea of mature play as a leading activity. El'konin (2005a) extended the Vygotskian-based theory of child development. Bodrova et al. (2019) point out that El'konin uniquely emphasises the importance of play for children's mastery of social interaction, cognitive development, and development of self-regulation. Furthermore, El'konin, like Vygotsky, is specific about the idea that only mature play qualifies to be a leading activity, while other play-like behaviours are assigned secondary important roles.

El'konin (2005a) has introduced the idea of mature play, which, according to him, is the only kind of play that can be the source of development in childhood. He defines mature play as a "unique form of children's activity, the subject of which is the adult, his work and the systems of his relationships with others" (El'konin, 2005a, p. 19). In other words, El'konin (as cited by Bodrova et al., 2019) distinguishes the following components of mature play: object substitution, specific role, integrated themes, time spent, ability to follow rules, extended planning, and rudimentary acting out.

El'konin (2005a) further separates play into four distinct levels from least to most mature play.

Level 1

On Level 1, the main content of play consists of actions with everyday objects or toys (e.g. "feeding" or dressing dolls). At this level, only realistic toys are used, with no expression of imagination or creative play on the side of the players (Smirnova & Gudareva, 2015). In other words, objects and toys are used according to their social status following the cues from adults or more able children (Karpov, 2003).

Roles are determined by objects or the nature of actions (Smirnova & Gudareva, 2015). In other words, children do not attempt to name the roles they take on or to assign the names of people whose roles they are playing. Bodrova & Leong (2015) also point out that actions are original and uniform and consist of a series of repeating operations. So, in playing the role of "teacher" or "mother", the child focuses on the action of "serving lunch to someone". The order in which the lunch is served and the kind of food served by the "teacher" or "mother" are not important (Bodrova et al., 2019). What is important is the actions that are performed in a particular sequence (Smirnova & Gudareva, 2015). There seems to be no logical order in how the actions are performed – a baby can be dressed first and towelled later (Bodrova & Leong, 2015). If a child acts inconsistently with how this script unfolds in real life (e.g. when a child gives a "baby" a bath while keeping its clothes on), other children do not object (Bodrova & Leong, 2015; Bodrova et al., 2019). Initially, children concentrate only on playing out the role, while exploring the rules and expectations associated with the role in society (Fleer, 2011a).

Level 2

On Level 2, actions with objects remain the main content of play. However, Bodrova et al. (2019), Bodrova and Leong (2015), and Smirnova and Gudareva (2015) point out that it is different from Level 1 in the sense that the play actions accurately reflect the structure and sequence of actions as they unfold in real life. Moreover, Bodrova and Leong (2006) draw attention to the fact that the conventional use of objects will start to make place for the use of objects in a pretend way.

For a child, to play a role means to perform actions associated with this role; on Level 2, this scope of actions is expanded compared to Level 1 (Bodrova & Leong, 2019). The same game is repeated multiple times (Bodrova & Leong, 2015; Smirnova & Gudareva, 2015). Putting on an apron makes one “Mommy”, but the role is not elaborated by speed and action; the apron is enough (Bodrova & Leong, 2006). Toddlers are in the process of mastering language, and they begin to use it to label what they are doing (Bodrova & Leong, 2006). They name and label the roles they play, but only after they have started to play (Bodrova et al., 2019; Bodrova & Leong, 2015; Smirnova & Gudareva, 2015). In the process of play, children sometimes call themselves or their playmate by the play name (“I am mama”, “You are the driver”). However, there is no vocal interaction in the roles, although specific phrases related to the role do appear (Smirnova & Gudareva, 2015). No explicit rule emerges yet; the first interaction occurs between the participants regarding the use of a common toy or the nature of an action. Groupings of children are short-lived and small (two or three children each). Toys are not selected in advance, but children use the same ones more often (Smirnova & Gudareva, 2015).

The structure and sequence of play actions are determined by how these actions unfold in real life (Bodrova & Leong, 2015; Smirnova & Gudareva, 2015). The variety of actions increases and goes beyond the limits of any single type, for example not only “feeding” but also preparing dinner, putting to sleep, dressing, and so forth. When one of the players does not follow the real-life sequence of the actions, for example “mommy” deserves dessert before serving the main dish or the “doctor” first puts the “patient’s” arm in a cast and then takes an X-ray, the other players do not accept these actions, but neither do they argue with them, protest, or explain what was done wrong (Bodrova et al., 2019; Bodrova & Leong, 2015; Smirnova & Gudareva, 2015).

Level 3

On Level 3, the main content of play is now the performance of a role and the actions arising from it. Smirnova & Gudareva (2015) explain that roles are clearly designated and named before play begins, while Bodrova & Leong (2015) and Bodrova et al. (2019) point out that children will name the roles they will play before the play starts. These roles are now distinct and well defined, and actions become more varied and logical and are determined by the role the child plays (Bodrova et al., 2019; Bodrova & Leong, 2015; Smirnova & Gudareva, 2015). Bodrova et al. (2019) demonstrate this with an example of the way a playmate is addressed in a way that is determined by the role, such as the “customer” asks the “waiter” to bring a “kiddies” meal for her baby. The roles determine and direct the children’s behaviour and are distinct and defined (Bodrova & Leong, 2015; Smirnova & Gudareva, 2015). Special actions signal the relationships between the players. For example, a child addresses another child in a way that is determined by the role the child is playing (Bodrova et al., 2019; Smirnova & Gudareva, 2015). The relationships among the players are reflected in special actions.

In their play, children are re-enacting social roles (Van Oers, 2013a). The nature and the logic of actions are determined by the role the child plays. The actions become more varied. For example, the “nurse” does not just give the “patient” a shot but also takes his or her blood pressure or changes bandages. The “mother” not only puts her “baby” to bed but also gives it a bath, reads a bedtime story, and so forth (Bodrova et al., 2019).

The duration of play increases, and the narratives become more varied (Smirnova & Gudareva, 2015). At this stage, children reflect the everyday life, work, and relationships of adults. The logic, nature, and orientation of actions are determined by the role that is taken up by the child (Smirnova & Gudareva, 2015). Toys and objects are selected in accordance with the role of the children. Play proceeds more often as a joint activity, although interaction alternates with actions by the game partners that are unrelated to one another but correspond to the roles.

Rules of behaviour emerge, and the defined rules govern the players' actions (Bodrova et al., 2019). Children subordinate their actions to these rules; although the rules do not yet completely determine behaviour, they may sometimes override a spontaneous desire that arises (Smirnova & Gudareva, 2015). A breach of the rules is better noticed by playmates, as they are usually better at monitoring their friends' compliance with the rules than their own (Bodrova et al., 2019; Smirnova & Gudareva, 2015).

If a child acts in a way that is inconsistent with the real-life logic of actions, other children will object by saying something like "you are not supposed to do that", "that doesn't happen", "mothers don't run", "police officers don't yell", and so forth (Bodrova et al., 2019; Smirnova & Gudareva, 2015). When corrected, children treat their mistakes seriously and try to fix them and to explain why they have broken the rule (Bodrova et al., 2019).

Level 4

On Level 4, the highest level of play development (mature play) is reached in the middle and later pre-school years (El'konin, 2005a; Smirnova & Gudareva, 2015; Vygotsky, 1967). Play is determined by the roles children play and the actions associated with these roles (Bodrova and Leong, 2015; Bodrova et al., 2019; Smirnova & Gudareva, 2015). For example, the relationship between a "father" and a "child" is associated with the "father" being in charge, which is manifested in the way he addresses the "child"; for example "you have to eat your vegetables or you will get no dessert" or "one more time I see you teasing your sister and you will go to your room". On the other hand, the relationship between the "doctor" and the "nurse" is one of collaboration.

Smirnova and Gudareva (2015), Bodrova and Leong (2015), and Bodrova et al. (2019) point out another difference to previous levels in that children identify and define roles before they start to play and these are maintained throughout the duration of the playing. Smirnova and Gudareva (2015) explain that the functions of the role are interconnected, and speech is related to the roles. Bodrova and Leong (2015) and Bodrova et al. (2019) add that "role-related speech" is consistent with the role played by the child who uses it as well as the child to whom this speech is addressed.

The actions in the game are varied and accurately represent the variety of actions of the person whose role the child is playing (Bodrova et al., 2019). A sequence of real-life relations is recreated (Smirnova & Gudareva, 2015). Play is emotionally coloured, captivating, and draws children into the game. Their words and actions contain elements of creativity (Smirnova & Gudareva, 2015), while the sequence of play actions is well defined and consistent with the logic of these actions in real life (Bodrova et al., 2019; Bodrova & Leong, 2015).

The rules followed in playing are well defined, with children using real-life rules as their reference. Actions directed at different players are well defined and distinct (Bodrova et al., 2019). Children object when someone does not follow the logic of actions or breaks the rule. They go beyond stating "you are not supposed to do that" by referring to the reason for the existence of this rule in real life (Bodrova & Leong, 2015; Bodrova et al., 2019). Any breach of the logic of actions is rejected. During play, the child follows strict rules that determine his or her behaviour (Smirnova & Gudareva, 2015).

A group of children playing together is stable, and the construction of the group is based on the children's interest in the same games or on personal fondness and attachment. In the game, a preparatory stage often emerges, during which the distribution of roles and the selection of play material are made. The number of children taking part in games increases to five or six (Smirnova & Gudareva, 2015).

In Table 3.1 below, El'konin's four levels of play discussed above are summarised.

Table 3.1: Levels of play activity according to El'konin (adopted from Bodrova & Leong, 2015; Smirnova & Gudareva, 2015)

	Level 1 (2-3 years old)	Level 2	Level 3	Level 4 (6-7 years)
Main content	Actions of objects are directed at play partner.	Children perform actions with objects.	Role and actions determined by this role; special actions determine by this role; special actions emerge that signal the relationships among the players.	Carrying out actions associated with the relationships among the characters played by the children, e.g. mother and son, "mother" is in charge.
Roles	Roles exist, determined by the nature of actions. Children neither name the roles they take on nor do they assign themselves the names of people whose roles they are playing.	Children perform actions associated with this role. They can name the roles they play, but only after they have started to play.	Roles are distinct and well defined. They name roles before they play them. Roles determine and direct the children's behaviour. Special kind of "role speech", using vocabulary, intonation, and register in accordance with the specific roles they play.	Well-defined roles; child acts consistent with a role throughout the entire duration of play.
Play action	E.g. when playing "family" children follow the same routine – feed the baby, give the baby a bath, and put the baby to sleep; no logic order in actions.	Accurately reflects the action in real life. Sequence is determined by how these actions unfold in real life. Other players will not accept the wrong sequence but do not argue or explain what is wrong.	Special actions that signal the relationships between the players are more varied; e.g. "nurse" gives injections, takes blood pressure, and changes bandages. The child will be corrected by other children if he or she is acting inconsistently with the role; the child will try to fix the mistake and explain why he or she has broken the rule.	

3.3 The influence of play on the overall development of the pre-schooler

According to Bodrova and Leong (1998, 2007a), Vygotskians focus on the idea that play influences development in several ways, with the main effect being that of creating a zone of proximal development. They also emphasise the separation of thought from actions and objects while facilitating the development of self-regulation that has an impact on motivation and facilitates decentration. In other words, play as the leading activity for the pre-schooler will promote development in pre-school by influencing the zone of proximal development, separating thought from actions and objects, and facilitating the development of self-regulation, motivation, cognitive decentring, imagined situation, and language development.

3.3.1 Creating the zone of proximal development

For Vygotsky, play establishes a zone of proximal development for a child by providing support for skills that are on the edge of emergence. In playing, children act more socially mature and show better cognitive skills, higher levels of self-regulation, and a better ability to attend to purpose and remember deliberately.

> In play the child is always behaving beyond his age, above his usual everyday behaviour; in play he is, as it were, a head above himself. Play contains in a concentrated form, as in the focus of a magnifying glass, all developmental tendencies; it is as if the child tries to jump above his usual level. The relationship of play to development should be compared to the relationship between instruction and development … Play is a source of development and creates the zone of proximal development. (Vygotsky, 1978, p. 74)

Bodrova and Leong (2007a) use the above quotation from Vygotsky to motivate their statement that new developmental accomplishments become noticeable in play much earlier than they do in other activities, especially in more academic learning activities. At the age of four, children reach higher levels of attention, symbolising, and problem solving in play than in other situations. Developing a zone of proximal development through play will also create a zone of proximal development for scientific reflection, as play develops creative thinking in a social environment.

3.3.2 Facilitating the separation of thought from actions and objects

Vygotsky (2016) identifies the separation of thought from objects and actions as one of the important functions of play during the pre-school phase of development. The symbolic nature of role playing is pointed out by El'konin (1967) as being the centre of make-believe play. In make-believe play, children act in accordance with internal ideas rather than external reality. The child acts differently in relation to what he or she sees (Bodrova & Leong, 2007a).

Toddlers become capable of imaginative play, transferring meaning from one object to another (El'konin, 2005b). In other words, the objects a child uses in playing lose their natural signification and acquire a new, pretend significance according to what the child names it and the actions he or she performs with it. For example, a stick becomes a horse – the child can ride it, water it, and feed it. Karpov (2003) elaborates on this by saying that symbolic thought is achieved when one object "stands in" for another. This means that it is a unique moment when the stick becomes a horse; it also becomes a pivot for severing the meaning of "horse" from a real horse. Vygotsky (2016) views this action as radically altering the basic psychological structures determining the child's relationship to reality. This means that the child cannot yet split thought from object and needs another object to act as a pivot. To think of a horse and to define his or her action in using the horse, the child needs the stick as a pivot. The child's relationship to reality is radically changed because the perceptual structure changes. Actions according to rules begin to be determined by thought, not by objects themselves.

Vygotsky (2016) draws attention to the fact that the properties of the object that is serving as a pivot are important; for example, while a stick can be a horse, a postcard can never be a horse. Play is not symbolism; therefore, the stick is not a sign of the horse. In play, the meaning of the word or object will determine children's behaviour.

Vygotsky (1967, p. 17) points out the importance of children's actions in development as follows:

> A child learns to consciously recognise his own actions and becomes aware that every object has a meaning. From the point of view of development, the fact of creating an imaginary situation can be regarded as a means of developing abstract thought.

Meaning is transferred by naming the stick a “horse”. According to Vygotsky (2016), the transfer of meaning is facilitated by the fact that for the child, the word “horse” applied to the stick means “There is a horse here”; in other words, mentally, the child sees the object standing behind the word. When the child pretends to ride a horse, he or she needs a pivot to replace the real action.

Separation of meaning from objects in the forming of abstract ideas and thinking is important (Bodrova & Leong, 2007b). In abstract thinking, ideas are evaluated, manipulated, and monitored without reference to the real world. Separation of objects and ideas can also be preparation for transition to writing. Written words do not match the images they represent. When behaviour is no longer defined by objects, a toy block can represent a telephone, which the child can use to “order pizza”. The child is fully aware that the block is a pretend phone. By using the block in this way, the child imposes another meaning on the object of his or her actions. The role and the rules associated with it also create a situation where children need to suppress their impulses and self-regulate their behaviour to continue taking part in the game.

3.3.3 Facilitating the development of self-regulation

Vygotsky (1967, p. 10) made the following important observation:

> At every step, the child is faced with a conflict between the rule of the game and what he would do if he could suddenly act spontaneously. In the game he acts counter to what he wants … [achieving] the maximum display of willpower in the sense of renunciation of an immediate attraction in the game in the form of candy, which by the rules of the game the children are not allowed to eat because it represents something inedible. Ordinary a child experiences subordination to a rule in the renunciation of something he wants, but here subordination to a rule and renunciation of acting on immediate impulse are the means to maximum pleasure.

From Vygotsky’s statement, it can be deducted that in play, children are not free (El’konin, 2005a; Vygotsky, 1978) that is, playing is the first activity not driven by instant gratification but by a need to suppress immediate impulse (Bodrova, Germeroth & Leong, 2013; Karpov, 2003). In other words, when playing, the child acts opposite to what he or she really wants and, by doing so, achieves the maximum display of willpower. Bodrova and Leong (2007a) explain that play enables children to self-regulate, as they need to follow rules to play a role. The following of rules is enforced by play partners, as the only way to be part of the play scenario is to self-regulate and adhere to the rules for that specific role.

Acting out a role also implies the child's regulating his or her actions while pretending to be somebody else. For example, the child stops crying when the pretend character stops crying. Bodrova and Leong (1998) view this as practising other-regulation as well as self-regulation. The roles pre-schoolers play is mostly roles of adults, such as doctors or chefs, and are engaged in socially desired behaviour. Bodrova and Leong (2003) theorise that through imitating adults' behaviour in play, children learn to adjust their actions to meet the norms associated with the behaviour of role models, practising the planning, self-monitoring, and reflection essential for intentional behaviour. Moreover, self-regulation develops mental processes such as memory and attention (Bodrova & Leong, 2007a). The child's desire to play a role will also serve as motivation to think creatively and experiment with possible outcomes for the professional whose role the child is playing.

3.3.4 The child's motivation

In play, children develop a complex hierarchical system of immediate and long-term goals where immediate goals can occasionally be forgone to reach long-term goals. Bodrova and Leong (2007a) point out that through the process of coordinating short- and long-term goals, children become aware of their actions, which make it possible to move from reactive to intentional behaviour. For example, to play airplane, children first have to make tickets and passports and set up security. In other words, they must postpone their play to make props and set up the environment. In this way, children are developing creatively thinking of what is necessary to achieve an outcome and, in this way, improve scientific reflection.

3.3.5 Facilitating cognitive “decentring”

Bodrova and Leong (2007a) state that the ability to take other people’s perspective is critical for coordinating multiple roles and negotiating play scenarios. Put differently, children learn to look at objects through the ideas of play partners – a form of cognitive decentring. Thus, the child must understand and comprehend what another player means by his or her actions, for example reacting like a “patient”, and understand the “doctor’s” meaning. In the same way, scientific reflections require making sense of and understanding the thinking of other scientists.

3.3.6 Play as imagined situation

Vygotsky (1933/1967) describes imagination as teaching the child to guide his or her behaviour not only by the immediate perception of objects or the situation immediately affecting the child but also by the meaning of this situation. Imagination is, therefore, identified by Vygotsky (2016) as the psychological basis for the origin of play, while play is also a transitional stage in the development of imagination. Vygotsky (1978) theorises that in play, the child creates an imaginary situation; therefore, play is the highest level of pre-school development. Play is activity in an imaginary field; it is a creation of voluntary intentions and the genesis of real-life plans and voluntary motives. In make-believe play, children act in accordance with internal ideas rather than with external reality (Bodrova et al., 2019) and begin to act independently of what they see in a situation that is not seen but only conceived in an imaginary state.

In socio-dramatic play, children transfer meaning from one object to another (Bodrova et al., 2019; El’konin, 2005b). In the process, an object can take the meaning of another. Bodrova et al. (2019) use the example of children using a block as a phone; the idea of the phone is separated from an actual phone. If the block is to act like a phone, it can stand for the phone. Role playing in an imaginary situation requires children to carry out two types of actions simultaneously – external and internal. Although internal actions utilise meaning, they are still dependent on the external functioning of the objects. The emergence of internal actions is also the start of a transformation from sensory-motor and visual representations to more advanced abstract thought. In this way, make-believe play lays the foundation for two higher mental functions, namely symbolic thinking and imagination.

Bodrova and Leong (2015) point out that imagination will only develop once the child has become independent of his or her own perception and can substitute one object for another, in the process separating the meaning or idea from the object itself. Vygotsky (1978), Bodrova and Leong (2006), and Karpov (2003) identify the ability to depart from reality and function in a world of imagination and symbols as the first step towards the development of abstract symbolic thought. Fleer (2011a) describes imagination as the bridge between play as the leading activity of pre-schoolers and learning as the leading activity of Foundation Phase children. Imagination is also the bridge to scientific reflection and understanding of scientific concepts such as molecule structures or DNA.

3.3.7 Language development in play

Vygotsky (1997b, 2016) identifies language as essential for children to take part in make-believe play. Bodrova and Leong (2006, p. 168) extend this idea by remarking that activities such as trying on hats will remain the exploring of material unless the child verbally declares, “I am playing hat store, and I am going to buy myself a nice hat to go to a party.” In make-believe play, the child’s range of roles will increase and, with it, vocabulary and the learning of grammar. By the age of four or five years, children use language to allocate meaning to toys, props, and their own actions. Language also regulates play behaviour and is necessary for the negotiation of the roles and rules in imaginary situations. According to Vygotsky (1997d), a rich oral connection interprets, explains, and conveys meaning to objects and performances of play activities.

Leong and Bodrova (2003) highlight that through playing the role of an adult, such as a teacher, children master the vocabulary associated with that role. Children are not able to learn new words if not in relevant context. Play props are multifunctional, and by assigning them a name, they are used in a new function. In this way, children are mastering the symbolic nature of words. For scientific reflection, the child is also required to be able to use language to reflect on phenomena observed in the environment.

3.4 Importance of collaboration

Vygotsky, El'konin, Leontiev, and Zaporozhets all emphasise the crucial importance of joint activities with adults and peers in each period of development of higher mental functions. Adults and peers supply the psychological tools and mediate the mental processes that serve these activities (Karpov, 2003). Polivanova (2015) adds that adults have an intermediary role between the child and the world of higher, ideal, cultural forms, for example modelling the use of a spoon.

El'konin (2005a, p. 18) states that, "play on the threshold of preschool years does not develop spontaneously, but forms under the influence of child-rearing". Bodrova et al. (2019) describe make-believe play as the result of interaction between the young child, adults, and peers. In the case of the absence of interaction or a lack of quality interaction, children may not reach mature levels of play. For make-believe play to become mature play (and the leading activity for the pre-schoolers), there is a need for engagement in specific interaction with adults who lead children in their leading activity.

Based on El'konin's (1999) periodisation, Zuckerman (2016) identifies the most common forms of collaboration (see Table 3.2). At every age period, there is a foreseeable change in the formation of the main mental neoformation. Every leading activity has a specific form of cooperation between the child and adults; that is, the nature of joint actions and the type of collaboration are specific to each leading activity and can be viewed as a leading form of interaction. Each new mental formation is influenced by the neoformations from the previous stages and will influence the next stage. The collaboration in each stage equips children with new techniques for communication. Scientific reflection takes place in the social environment of the young child's home, day care centre, or other social situations.

Table 3.2: Leading forms of collaboration between a child and an adult (adopted from Zuckerman, 2016)

Age period	Leading forms of collaboration between a child and an adult
Infancy	Immediate emotional communication between the child and a loving adult as a universal source of warmth, care, understanding, protection, and acceptance of the child
Toddlerhood (early childhood)	Object-manipulation collaboration between the child and a skilled, active adult as the conveyer of models of concrete, practical action
Pre-school and kindergarten	Play collaboration of groups of children with an ideal adult as a conveyer of norms of social relationships
Elementary grades (young school age)	Collaborative learning by a group of children with an ideal adult as the conveyer of norms of thinking and activity

Zuckerman (2016) draws attention to the fact that the young school child will assimilate the principles of science into systems of theoretical concepts. Theoretical thinking and reflection are the leading activities of school children. For the young school child to achieve quality learning demands qualitative new forms of assimilation. Child-adult learning collaboration is necessary for the assimilation of new theoretical knowledge by the young school child (age 6-7 years). Collaboration between the child and the teacher is necessary for the development of scientific reflection.

3.5 Changes in quality of play

3.5.1 Observed changes in play

Bodrova (2008) refers to studies conducted in the 1940s and the 2000s. In the 1940 Russian study, researchers found that play as super self-regulation was a common characteristic of past generations. Pre-schoolers followed directions better in play situations than in non-play settings. The ability to follow directions at all ages and in all conditions had generally declined compared to the pre-schoolers in the 1940s. This has implications for scientific reflection in that the child is not able to follow directions for problem solving. The quality and quantity of play and self-regulation have declined from the 1940s to the 2000s.

In addition, the ability to follow directions at all ages and in all conditions has generally declined too: seven-year-olds at the beginning of the 21st century have self-regulation levels more like those of pre-school children of the mid-20th century. The researchers attribute it to the decline in both quantity and quality of play in pre-school and kindergarten. Only 10% of the six-year-olds studied demonstrated a mature level of play, and 48% of the five-year-olds demonstrated the lowest (toddler) level of play (Bodrova, 2008; Bodrova et al., 2019).

Similar findings were obtained in another study in the United States of America, where the correlation between play and self-regulation for children playing at a higher level was explored. These researchers agree that the make-believe play of today's children is not only different from the play of the past but has declined in quality and quantity as well. The decline in the self-regulation of young children puts them at risk for later cognitive and social-emotional problems (Bodrova, 2008; Bodrova et al., 2019). Leong and Bodrova (2003) state that, by age four, children should be capable of engaging in mature play, but many modern pre-schoolers still play at the toddler level, staying in the same roles and repeating the same actions. Children who play at a lower level are not likely to use play opportunities to expand their language skills or to engage in pretend reading and writing. If the quality of language is negatively influenced by low quality of play, it will also negatively influence the quality of science learning and reflection.

The play that exists in many modern early childhood classrooms across the world does not always fit the definition of mature play. Even five- and six-year-olds, who should be at the peak of their play performance, often display signs of immature play – playing only with realistic props, enacting play scenarios that are stereotypical and primitive, and displaying a repertoire of themes and roles that is rather limited (Bodrova, 2008; Bodrova et al., 2019). Children who came to pre-school with some play skills often have not acquired new skills by the end of the year or even regress to less mature play (Bodrova et al., 2019).

Immature play or the underdevelopment of imaginary situations and the roles and rules of this immature play cannot serve as a source of child development or create a zone of proximal development (Bodrova, 2008; Bodrova et al., 2019). In their research, Kravtsov and Kravtsova (2010) have found that at the end of the pre-school age, many children have not developed mature play. The quality of imagination in play will influence the understanding and the quality of scientific reflection, especially in topics such as electricity where imagination is necessary for understanding.

Smirnova and Gudareva (2017) examined the connection between the levels of development of play and voluntariness among pre-schoolers. They were interested in a broad and generalised picture of what today's pre-schoolers play and how, and what the narratives and content of their games are. They concluded that changes in play had an impact on children's play activity and specific features of children's development. Social transformations are disrupting the psychological-pedagogical conditions of play activity and, consequently, are causing a decrease in the level of development of narrative role playing. They further concluded that if narrative role playing contributed to the formation of need-orientated and motivational sphere and voluntariness, it could be assumed that a reduction in this activity led to aberrations in the development of these important aspects of the child's personality (Smirnova & Gudareva, 2017).

In their research, Smirnova and Gudareva (2017) observed that during free activity, 46% of the pre-schoolers they studied did not play narrative role-playing games in their free time. Some were engaged in specific object-related activities, such as riding miniature cars or throwing balls, looking at books, drawing, or building a Lego set. When they were instructed to play, many children took educational games from the shelf and were not involved in any form of role play. This lack of development of role play will also negatively influence the development of scientific reflection.

Furthermore, Smirnova and Gudareva (2017) found that 54% of the pre-schoolers demonstrated various forms of role playing. Traditional domestic narratives of playing "family" turned out to be the most popular – feeding, putting someone to bed, taking a walk, and so forth. "Barbie Doll's family" was also put in this group. Narratives related to television programmes and cartoons, such as Spiderman, robots, and Ninja Turtles, occurred in about 25% of the cases. About half of these consisted of aggressive narratives related to defence and attack, such as "Cops and Robbers" or "Ghost Busters", played more often by boys. Occupational narratives turned up in only 8% of the cases, in games of “restaurant”, “café”, “hospital”, “haircutter”, and so forth. Other narratives in individual cases widely varied in nature, such as playing circus, traffic officer, airplane, flying to the moon, dances, and so forth. In 10% of the cases, children assumed the role of cats and dogs and their masters and played out the relationship between them – feeding, taking walks, medical treatment, and so forth.

Smirnova and Gudareva (2017) compare the result of their research with the generally accepted principles of pre-school education. It is customary, when considering the narratives of children’s games, to focus on domestic, occupational, and social-political games. Despite the repetition of the same narratives at various ages, their overall trend in the pre-school years is from domestic narratives (typical of younger children) to occupational and then to social-political ones. In comparing data with these principles, it can be seen that among today’s children, even in pre-schoolers, domestic narratives are clearly dominant, while occupational and social-political ones are being displaced by television-related narratives. Smirnova and Gudareva (2017) view this to be reflecting the gap between the lives of today’s children and adults. The lack of relevant experience and of the concepts derived from it is an obstacle in the development of occupational and social narratives related to the lives of adults. The real-life experience of children is confined, on the one hand, to everyday life and, on the other, to narratives about films and virtual characters that come from the television screen.

Scientific reflection develops through experiences in a social environment. When these experiences become limited, it will also limit science reflection. Considering the above, if play is viewed as a cultural-historical phenomenon, it can be concluded that today’s social situation almost guarantees that children will not develop mature play unless adult mediation is restored. The changes in the social context of young children’s development do not mean that make-believe play is destined to disappear for good. These changes also create new opportunities, such as the availability of high-quality pre-school programmes for scaffolding make-believe play. However, the mechanisms for play scaffolding need to be designed to fit the new social context (Bodrova, 2008; Bodrova et al., 2019).

Kravtsov & Kravtsova (2010) are of the opinion that when children do not develop a full activity of play by the end of the pre-school age, it leads to a low level of psychological preparedness for learning in school settings. Children's lack of play prevents them from developing within educational settings. The lack of physical conditions allowing for the development of play can later lead to situations where children play in school instead of study. Quality play is necessary not only for the development of learning in educational settings but also the development of scientific reflection. To ensure high-quality play, teachers need to scaffold make-believe play.

3.5.2 Reasons for changes in play styles

Smirnova and Gudareva (2017) identify different possible reasons for the changes in play styles today. One of the reasons is the changes in society and the fact that parents are less involved in their children's upbringing, which results in alienation between children and adults. According to Smirnova and Gudareva (2017), children exhibit a clear lack of emotional control, basic relationships with parents and positive contact with their peers. A second possible reason for the changes in children's play involves the new professions of parents, such as programmers, managers, and designers (Smirnova & Gudareva, 2017). The nature of adult behaviour in these professions cannot be modelled by children in play. In this way, the world of adults has become more closed to children's understanding, and the domain of children's possible participation in adults' work has become even narrower. As a result, the potential for representing an ideal image of adulthood is being lost, and living with a grownup does not provide content for children's play activity.

The changes in social conditions result in children having less opportunity to join activities and have interaction with older children (Smirnova & Gudareva, 2017). Children are spending more time in pre-school centres where they are restricted to contact with children of the same age. In pretend play, younger children learn from older, more experienced children (Bodrova & Leong, 2015). Longer periods of time in pre-school centres reduce the time young children can play with older children in the neighbourhood or with older siblings. In other words, their play experience will not prepare them for mature play.

Baumer (2013) identifies the segregation on different levels of the child's life as a possible reason for changes in play. If parents and teachers reason that play is important for development but, at the same time, they also believe that play should be free from adults' guidance and influence, children are left on their own in nursery rooms, playgrounds, and theme parks. These parents and teachers assume that play- and child-dedicated spaces will ensure that children's play is nurtured and protected and their development is optimised. However, in the absence of parents and educators, children's play spaces have become depleted of cultural resources.

Both Vygotsky and El'konin view play as the result of specific interaction young children have with older peers and adults (Bodrova et al., 2019). For most pre-schoolers, pre-school centres may be the only place where they can learn how to play. However, learning to play in the classroom is not the same as learning to play within informal peer groups. Many of the play skills that in the past were observed and imitated now have to be modelled by teachers. In classrooms, playtime is limited; consequently, play scaffolding in classrooms needs to be designed (Bodrova & Leong, 2015).

When these interactions are absent or lacking in quality, even older pre-schoolers may not rise to the level of mature play but continue to engage in immature play like that of toddlers. Unlike the unstructured play of the past that often lasted for hours or days, playtime in today's early childhood classroom is limited and rarely exceeds one or two hours. To achieve rapid progress in the quality of play, play scaffolding in the classroom needs to be designed to strategically target its most critical components (Bodrova et al., 2019).

In recent decades, technology has also influenced the quality of play, resulting in imagination disappearing from the lives of children (Hakkarainen, Milda Brėdikytė, Jakkula, & Munter, 2013). Mature play is replaced by commercial toys and games (Baumer, 2013; Bodrova, 2008; Hakkarainen et al., 2013). As new information technologies are actively being introduced into modern childhood, play is supplanted by watching television, while the introduction of information technologies into the daily lives of children and adults brings about an increase in the value of intellect from an early age (Smirnova & Gudareva, 2017). Parents expect children to begin learning at the earliest age (Smirnova & Gudareva, 2017). The demands of parents and governments for early learning and the demands on pre-school education put pressure on institutions to replace play with learning (see Chapter 5).

Role play is important for development in pre-school years and will influence scientific reflection through the development of language and imagination.

3.6 Play as foundation for school learning

Even before school, children can realise the necessity of reading and writing through play (Leong & Bodrova, 2003). For example, a doctor will mix up X-ray films if the patient's name is not written on it, and firefighters would not find a house on fire if they cannot read a map.

Bodrova and Leong (2003) identify different important developments that are the result of make-believe play and are important for school learning. Play promotes executive functioning skills with emotional regulation, planning, and memory and prepares the foundation of two higher mental functions, namely symbolic thinking and imagination. Play affects discrete skills, promotes the restructuring of the child's psychological processes, and is the source of systemic change in mental development. Make-believe play reflects the universal path of cognitive development from concrete, object-orientated thinking, and action to abstract mental action (Bodrova et al., 2019).

Bodrova (2008) points out that make-believe play equips children with the beginnings of symbol-mediated, intentional, internalised behaviour. The use of symbolism in make-believe play is identified as helping to develop language (Leong & Bodrova, 2003) and is the genesis of written language as well (Bodrova, 2008). Bodrova and Leong (2007a) identify written speech as necessary for the development of abstract reflective thinking resulting in the mastery of subjects such as science and mathematics.

3.7 Summary

While most scholars agree that play is an important mediator of emergent competence in early childhood there is still disagreement on how to define children's play theories. Vygotskians focus on the idea that play influences development, they view play as the leading activity for the pre-schooler will promote development in preschool. According to Vygotsky play establish a ZPD for a child by providing support for skills that are on the edge of emergence. In play children act more socially mature, show better cognitive skills, higher levels of self-regulation, and better ability to attend on purpose and remember deliberately. An important function of play is the separation of thought from objects and actions. Through play the children develop self-regulation when playing the child acts opposite to what s/he really wants and by doing so achieving the maximum display of willpower. The development of ZPD through play will also create a ZPD for scientific reflection as play develops creative thinking in a social environment.

If pre-schoolers do not reach mature levels of play it could result in low levels of psychological preparedness for all learning in formal school settings. This creates new challenges for the use of play as one of the pedagogies in early child teaching and learning.

The next chapters deal with the issue of considering relevant and appropriate teaching methodologies (pedagogies), including play, while considering the pertinence of age phases and the related development milestones thereof in supporting the scientific-reflective teaching of the young child.

CHAPTER 4: TEACHING METHODOLOGIES FOR SCIENCE TEACHING OF YOUNG CHILDREN

4.1 Introduction

Children in the 21st century are growing up in a world facing complex global issues, great scientific discoveries, and revolutionary technological advances. Léna (2014) emphasises the fact that these children will have to deal with complex future situations, such as climate change, artificial intelligence, and many more. Therefore, one of the main goals of contemporary science education would be to produce scientifically literate adults, implying that they should acquire and, finally, possess the required skills and tools to reason about scientific concepts (Zimmerman, 2005). Moreover, this implies that specific appropriate teaching methodologies are required to develop the skills related to science domains. These teaching methodologies should be suitable for the age and phase of the child, considering the physical, cognitive, social, and emotional development of the child at specific times in their development (Harlen, 2010). This leaves us with two more critical questions: What should be the nature of the methodologies that are required for teaching science-related content? What specific type of content should be dealt with in order for the very young of today to become scientifically literate adults in the 21st century? This chapter will focus on the first question, dealing with the methodology for teaching and learning between the ages of zero and nine years.

4.2 Early proponents of pedagogies for teaching young children

Historically, three of the earlier most prominent scholars that are worth taking note of related to specific pedagogy that is required for teaching and learning of the young are Jean-Jacques Rousseau, John Dewey, and Friedrich Froebel. The consensual view held by most scholars at the turn of the last century is the importance of play as a dominant feature of early childhood development in general (Pramling et al., 2019). Contemporary scholars, such as Fleer (2015) and Adbo and Carulla (2020), echo the views of these earlier scholars by pointing out that play-based learning turns the everyday social practices of children into conscious realisation of science concepts.

4.2.1 Rousseau (1712-1778)

Rousseau ascribed to the idea that the young child is innocent and therefore needs protection from adults by allowing them to play and interact in a spontaneous way, allowing for natural learning. This idea forms the underpinning of the phenomenon of child-centredness, supported by a play pedagogy that is still a hallmark of most pre-school practices in the world today (Pramling et al., 2019).

4.2.2 John Dewey (1859-1952)

Dewey stated that the teacher should plan and connect the subject matter to the learners, keeping into consideration the needs, desires, interests, and cognitive development of the learners. Learning should be hands-on, collaborative learning experiences that help them to fully learn new skills and knowledge. To take advantage of their curious nature, social behaviour teachers should plan positive, constructive environments through partnerships between teachers and learners (Sikander, 2015). So, Dewey's focus is on the importance of collaboration between teacher and learner, while also considering the children's level of development, related to the socio-economic context in which they have operated at a specific junction in time.

4.2.3 Froebel (1782-1852)

Froebel proposed a way of thinking about childhood that was evolving before him in the work of Rousseau and Pestalozzi and continued to evolve after him through the efforts of Dewey and others (Strauch-Nelson, 2012). Froebel (1885, 1896) is most well-known for his creation of the "kindergarten", which encapsulates several of these key ideas about the importance of children's self-directed activity and play, respecting children and the centrality of nature and community. Smedley and Hoskins (2020) mention that Froebel had the view that children must develop a fundamental relationship with nature through understanding the unity and interconnection of all things. In other words, Froebel wanted to free children from rote learning and allow for a more self-directed way of learning. So, Froebel placed great emphasis on children's self-directed play, accompanied by their imagination and allowing for an expression of their creativity. He was also of the opinion that symbolic activities, such as art, language, music, and dance, all contributed to nourishing the child's inner life and provided a means to express and transform understanding. One of Froebel's major contributions, apart from also emphasising play as pedagogy, was his emphasis on the appropriate use of materials in developing different scientific and mathematical concepts.

4.3 Recent proponents of pedagogies for teaching young children

Van Dijk and Steenbeek (2018) identify the accelerated rate of language and cognitive development between ages three and seven as enabling young children to understand scientific phenomena. These children are curious about science and scientific subjects, ask questions, and spontaneously manipulate objects. Kolokouri and Plakitsi (2016) describe the young child as ready and excited to develop skills and understanding of science.

Thinking skills used in scientific inquiry can be related to other formal and informal thinking skills (Zimmerman, 2005). Zimmerman (2005) explains that science involves the skills implicated in generating, testing, and revising theories, and in the case of fully developed skills, reflecting on the processes of knowledge acquisition and change.

Siraj-Blatchord and MacLeod-Brudenell (2005) identify reasoning as one of the most important scientific skills. Morris, Croker, et al., (2012) define scientific reasoning as a type of intentional information seeking, which encompasses the reasoning and problem-solving skills involved in generating, testing, and revising hypotheses or theories. Fully developed scientific reasoning skills reflect on the process of knowledge acquisition and this knowledge. Scientific reasoning requires both deductive and inductive skills. Individuals should understand how to assess what is currently known or believed, develop testable questions, test hypotheses, and draw appropriate conclusions by coordinating empirical evidence and theory. Such reasoning also requires the ability to systematically attend to information and draw reasonable inferences from patterns that are observed (Morris et al., 2012).

According to Zimmerman (2000), scientific reasoning focuses on the acquisition and development of two types of knowledge, namely domain-specific knowledge and domain-general strategies. Zimmerman (2000) describes domain-specific or conceptual knowledge of science as typical scientific reasoning tasks consisting of questions or problems that require participants to use their conceptual knowledge of a scientific phenomenon. Domain-specific learning is what children know about a concept, while domain-general knowledge is the cognitive skills needed to understand how the domain-specific knowledge describes, for example, process skills or scientific thinking. Domain-specific science learning can be studied in relation with a range of science concepts, such as astronomy, electricity, and force (Fleer, 2017), as well as physics and biology (Hong, Torquati, & Molfese, 2013).

Zimmerman (2000) describes domain-general reasoning and problem-solving strategies as being involved in the discovery and modification of theories about categorical or causal relationships. These strategies include the general skills implicated in experimental design and evidence evaluation, where the focus is on the cognitive skills and strategies that transcend the content domain to which they are being applied.

Domain-general knowledge is more focused on determining children's abilities in how things function and work as models of supporting everyday life (Fleer, 2017). These studies point to the general ability of pre-school children to engage in scientific reasoning or thinking skills but do not give insight into what might be a model of science teaching for play-based settings where science through experiments and the visualisation of science through play are used to support the learning of science concepts.

Young children have an aptitude for learning, and their abilities include both domain-general learning mechanisms and limited domain-specific knowledge (Hong et al., 2013). Children experience the urge to explore and explain the world around them. The young child's orientating response, representational capacity, and memory enable their investigation of phenomena in the environment, as well as storing and retrieving information. The young child's limited domain-specific knowledge includes knowledge of the living or non-living distinction, physics, and biology. Children use this knowledge and learning processes with the support of older children and adults to extend their scientific knowledge.

Vygotsky (1987a) has made a particularly important contribution with his delineation of thinking by children into everyday concepts or spontaneous concepts and scientific concepts. While spontaneous concepts are formed through interaction with the physical and social world, scientific concepts are introduced through formal schooling. A dialectic relationship exists between the formation of everyday concepts and the formation of scientific concepts. Karpov (2003) draws attention to the fact that spontaneous concepts, although “unscientific” in nature, play an important role in children’s learning as a foundation for the acquisition of scientific concepts. Fleer and Robbins (2003) add that spontaneous concepts influence how children interpret the scientific experiences that are organised by the teacher. Their mini (naïve) theories about their environment are based on their own cultural or everyday experiences. Children’s existing ideas may or may not match those of school science, but they make sense of scientific ideas or lessons in relation to the existing ideas they hold. Children younger than eight years already have a range of views about scientific concepts.

Sikder and Fleer (2014) propose that concept development is an act of generalised and direct instruction that will not lead to concept formation. The role of the teacher is pointed out by Fleer, Tonyan, Mantilla, and Patricia Rivalland (2009) as organising the classroom and connecting with the learner’s real-world life. Teachers need to acknowledge the child’s personal everyday cognition as a valuable source of knowledge to be built on and developed.

Using the child’s everyday cognition is in line with Harlen’s (2001) notion of “small” ideas. Harlen also emphasises the initial use of familiar objects and events. Through development, the “small” ideas will become more applicable scientific ideas or “big” ideas. Big ideas will enable children to link ideas from related but different events. The big ideas explain more events and are interlinked to form broad theories or principles. For example, if children, through investigation and observation, have developed an understanding that there is interdependence among plants and animals in their own environment, they will eventually understand the reasons for protecting rain forests (Harlen, 2001).

Harlen (2010) highlights the fact that children should develop ideas of science as well as ideas about science. Through interaction with teachers, learners should recognise the need for evidence to support ideas and claims. Learners should also develop an understanding that findings may be changed or refined with new evidence.

In this study, three teaching pedagogies that utilise the contributions of the mentioned philosophers will be investigated by looking at the importance of play in teaching and learning the sciences, the development of scientific playworlds, and the utilisation of an inquiry-based approach to the education of the sciences.

4.4 Analysis of recent pedagogies for teaching young children

The following three pedagogies are currently standing out in the domain of teaching young children the sciences, namely play, playworlds and IBSE.

4.4.1 Play

In the industrial world, play was traditionally the leading pedagogical practice and an essential part of pre-school education (Fleer, 2011b; Hakkarainen et al., 2013). Pramling, Samuelsson, and Johansson (2006) add that in most pre-school programmes since Froebel, play has been an important aspect in the work with children. The work of Pramling et al. (2019) shows that play has been viewed as children's work and their natural way of acting in the surrounding world. In other words, the importance of children's play has rarely been questioned and has always been recognised as an important mediator of emerging capabilities in the young child.

Baumer and Radcliff (2009) have observed a change over the previous 20 years, namely that there has been an increasing emphasis on instructional academic activities to prepare young children for school. This phenomenon has also been observed by Fleer (2020), who calls it the marginalising of play in the pre-school curriculum of many pre-schools. Several scholars, for example Pramling, Samuelsson, and Carlsson (2008) and Fleer (2018), point out that this is a universal trend. They mention that there seems to be an intentional attempt by governments to increasingly put pressure on pre-schools to treat play instrumentally, as something that can be leveraged in the service of producing greater learning or academic and cognitive outcomes in early childhood education.

Pyle and Daniels (2017) argue that because of this pressure from governments, pedagogy has become heavily focused on teaching academic skills as early as possible to maximise children's future academic success. This focus on academic learning puts in question the educational and developmental value of play. Many current standards are focusing on academic skills at a young age, resulting in an increase in teacher-directed academic instruction. Thus, children are taking on the role of passive recipients of knowledge, while the length of time many pre-schoolers spend in play is decreasing.

This teaching methodology has serious practical implications, as indicated by Zigler and Bishop-Josef (2006). In other words, children are sitting at tables, engaged in whole-class activities, instead of activities such as making play-dough gifts, with the teacher engaging the children in conversations about their work. For Pramling et al. (2019), this situation risks resulting in a curriculum for modern pre-school where the educational practice may be reduced to premature adjustment to and training for formal schooling. Nilsson, Ferholt, and Lecusay (2018) point out that traditionally, learning and play were viewed as separate from each other. While play was viewed as happening outside the classroom, teaching and learning took place in the classroom.

Pramling et al. (2006) explain that "real" learning has traditionally been considered to take place in special activities and special moments, often organised and led by the teacher. Nilsson et al. (2018) point out that play should be protected, free, joyful, and carefree. Pramling et al. (2006) describe play as an activity for children, and teachers should not disturb them, as it is valued as important in pre-school as learning is in school.

The focus on cognitive development via formal teaching causes challenges for educational systems all over the world in terms of the pedagogy of play (Hakkarainen et al., 2013). Fleer (2011b) recommends that if teachers are required to deliver increased cognitive outcomes, they need pedagogical support to deal with the new goals for teaching the young child.

Pramling et al. (2006) contest the traditional view that play and learning are separated and argue that they are intertwined. Pramling et al. (2006) identify the following characteristics of learning:

- Learning can be viewed as characterised by seeing, perceiving, experiencing, distinguishing, or understanding something in a new and qualitatively different way, by relating to the surrounding world in light of this experience.
- Learning is dependent on a child's social-cultural experiences – the child's whole lifeworld. Then a child's experiencing and understanding become the foundation for new experiences and ways of creating meaning. From this point of view, children are expected to be involved in their own learning.
- Learning takes place in communication between teachers and children, as well as among children. Learning becomes a collective and social activity. Characteristics of learning are joy and involvement. Defined in this way, the world of play becomes a source of learning.

With the change in perspective to play and learning, these are now looked upon as two interrelated phenomena, while play is viewed as an important part of the learning process (Pramling et al., 2006). In other words, play and learning are flip sides of the same coin, can stimulate each other, and can be seen an indivisible entirety that is part of children's experiencing which helps them to create an understanding of their surrounding world in a lifelong process.

Nilsson et al. (2018) argue for a reorientation back to an understanding of play as learning, where learning is not just understood in the narrow cognitive sense described above but understood more broadly as transformations driven by different kinds of experiences that lead to sustaining change. This reorientation is motivated by an understanding that in early childhood, children's engagement with the world is predominantly focused on play and exploration, not instructional adult-child interactions.

In early childhood, both pretend play and exploration are necessary for developmental change (Nilsson et al., 2018). This means that in exploration, children are creators of knowledge who advance theories and hypotheses that can be investigated collaboratively in collective, exploratory projects using a variety of expressive modes.

Nilsson et al. (2018) explain that learning is an essential part of both play and exploration (see Figure 4.1), implying that learning in pre-school is not led by participation in academically orientated schooling. In play, meaning is made by attributing meaning to objects and actions, and in exploration, meaning is made by formulating, debating, and testing hypotheses and theories. Therefore, learning is the outcome of meaning-making processes in both play and exploration, leading to human development.

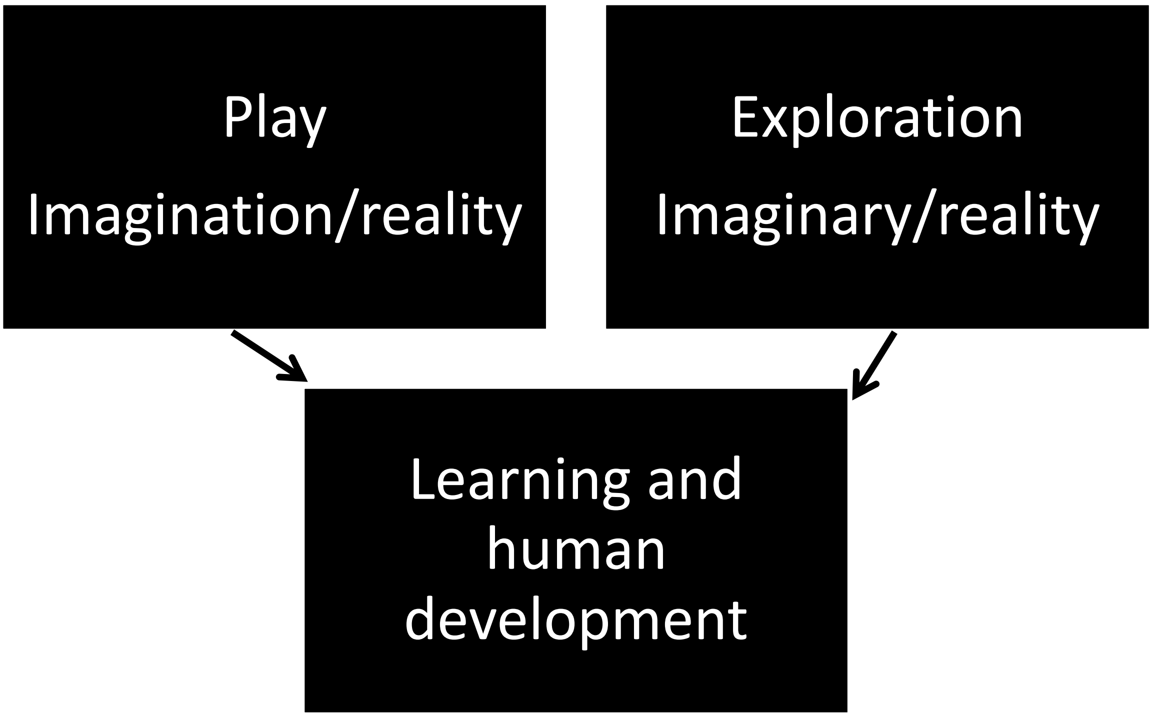

Figure 4.1: Play, exploration, and learning (Nilsson et al., 2018)

Fleer (2011a) identifies play-based programmes as having the potential to turn everyday practices into the conscious realisation of concepts. The concepts developed through role playing make it easier to engage with academic concepts. While imagination and consciousness are important components of a child's learning and development, play-based programmes supporting imagination improve cognitive tasks, while thinking consciously of concepts enables children to interact in new ways in their everyday world.

Although play is a vital activity in early childhood and at the core of pre-school and early elementary school curricula, it has been established that it is disappearing from children's lives (Bodrova, 2008; Bodrova et al., 2019; Fleer et al., 2019; Kravtsov & Kravtsova, 2010; Smirnova & Gudareva, 2017). An important question that arises is what the role of adults should be in children's play activities (Hakkarainen et al., 2013). Vygotsky's (1987b) theory of development emphasises education and the role of teachers as adults in learning and development. So, teachers will need new practice models that recognise play as the leading activity of the child but in ways that orientate children to learning (Fleer, 2018). Goswami and Bryant (2007) raise the concern that undirected play may not be beneficial for learning and that thinking, reasoning, and understanding can be enhanced by imaginative or pretend play, although scaffolding by an adult is required if these are to be effective for learning (see also quality of play in Chapter 3).

To address the issue of the role of teachers or adults in the play activity of children, Bodrova and Leong (2012) identify several critical elements of children's play that can be assessed and scaffolded by adults, namely planning, rules and roles, props, extended time frame, language, and the scenario.

- Scaffolding planning

  The planning of roles and rules is scaffolded when the teacher directs children's attention to the specifics of their roles and the existence of rules associated with them. It can prevent arguments over roles and props as children solve possible conflict. Bodrova and Leong (2012) suggest that the teacher scaffolds planning by drawing or writing. By drawing, children are focused for longer, thinking over more details of the pretend scenario. It also provides them with a tangible reminder to regulate their own and the play partners' behaviour.

- Scaffolding roles and rules

  The focus of mature play is the social roles of and relationships among people (Bodrova & Leong, 2012). This cannot be learnt by simply observing the behaviour. To scaffold the roles, and therefore the rules too, the teacher can explain that a customer cannot just go to the kitchen to get a pizza but needs to give the order to the waiter. The waiter will then take the order to the chef and the waiter will serve the pizza. Bodrova and Leong (2012) emphasise that the rules that hold make-believe play together are not arbitrary but are based on the logic of real-life situations. If children do not know how the scripts should unfold, they are not able to follow the rules.

- Scaffolding the use of props in a symbolic way

  Bodrova and Leong (2012) blame the availability of realistic toys for children's inability to use open-ended material. It is necessary for the teacher to scaffold the use of these materials. Children can also be assisted in making their own props. Moreover, the teacher can scaffold the use of existing props for different purposes.

- Scaffolding the use of language in play

  Bodrova and Leong (2012) suggest that language be scaffolded by naming props for children to understand the functions thereof. Assigning new names to props as they are used in new functions helps children master the symbolic nature of words, leading to children realising the unique relationship between words and the objects indicated. Bodrova and Leong (2012) also highlight the function of "role speech" to scaffold and model vocabulary, sentence structure, and intonation that fit a specific role. During field trips or the reading of stories, teachers can draw attention to the way different characters with different jobs use language. Teachers can also temporarily assume a secondary role to prompt the use of correct vocabulary.

- Scaffolding development of extended play scenarios

  Teachers need to scaffold the development of consistent and extended play scenarios. Children often lack background knowledge to build their scenarios, even to play “house”, “hospital”, “family dinner”, or “grocery store” (Bodrova & Leong, 2012; Bodrova et al., 2019). Although children are expected to be familiar with these scenarios, they lack knowledge of the settings, roles, and actions associated with these scenarios. Bodrova and Leong (2012) suggest that scenarios can be extended by questions such as the following: What happens when you go to the doctor’s office? Your baby might be sick, or you might have a broken leg; what will you say to the doctor? What will he or she do to help you?

Background knowledge about less familiar topics or scenarios can also be improved by using field trips, guest speakers, books, and videos (Bodrova, 2008; Bodrova & Leong, 2012; Bodrova et al., 2019). To promote mature play, the choice of places for field trips, books, and videos needs to be guided by how well these activities and tools will help children to learn about people and their activities (Bodrova & Leong, 2012). For children to benefit from these activities that clearly and understandably describe people, their activities, and how they interact, they should cause children to want to produce the content in play (Bodrova & Leong, 2019).

4.4.1.1 The role of imagination and creativity in learning science

Fleer and Pramling (2014) investigated how Vygotsky’s (2004) laws of imagination (see Chapter 2) can inform the science learning of the young child. Imagination is acquired through cultural and social interactions within the concrete and social world. It is an important basis for all creative activity and an important component of all aspects of cultural life, enabling artistic, scientific, and technical creations.

According to Vygotsky’s (2004) first law, previous experience provides the material for fantasy and the richer the experience, the richer the act of experience. Fleer and Pramling (2014) theorise that a child’s experience of waiting for food to cool down is a real need and gives a reason why the three bears were waiting for their porridge to cool. It also creates the opportunity to learn about heating and cooling. The implication is that the richer the experience, the richer the possibilities for imaginative and creative thought and action.

Vygotsky’s (2004) second law of imagination states that a person can imagine a phenomenon from somebody else’s experience. Fleer and Pramling (2014) reason that children can imagine a range of security systems and locks to keep Goldilocks from entering the bears’ house from looking at books or other children’s explanations of how their houses are secured. Vygotsky’s view (2004) is that in this sense, imagination has an important function in human behaviour and learning, as experience is extended by means of imagination. Fleer and Pramling (2014) refer to different scientific concepts in science such as the molecular movement of atoms during the cooling process that is not directly observed but imagined in the way the bears’ porridge cools down.

The third law of imagination described by Vygotsky (2004) is emotion. There is a double and mutual dependence between imagination and emotional experience. Imagination is based on experience, and experience is based on imagination. Every experience has an image associated with it. An image also has a corresponding feeling – an emotional quality. For a child to wait for porridge to cool, it will depend on whether the child likes or dislikes porridge.

4.4.1.2 Affective imagination in science learning

Fleer (2013) used Vygotsky’s (1999) explanation of the relations between cognition and emotions to research the affective imagination in science learning of young children. From a cultural-historic perspective, science learning can be examined in relation to how everyday situations create scientific encounters that are emotionally charged and socially mediated in actions and activities within the pre-school setting. Fleer (2013) identifies the main concepts that contribute to the formation of collective constructed imaginary scientific situations. These main concepts are collective investigations and narratives, affective imagination, and flickering.

4.4.1.2.1 Collective investigations and narratives

As indicated in Table 4.1, there is a collective relation between emotion and cognition. Fleer (2013) views the group setting of pre-school as ideal for the emotional framing of scientific learning and refers to Vygotsky’s (1999) statement that in drama, a form of social consciousness is created. It is common practice in early childhood education to tell fairy tales and to role-play and dramatise them. Fleer and Pramling (2014) also refer to the use of language from fairy tales that leads to the use of rudimentary science language, such as the concept of hot porridge making the child conscious of the concept of “heating and cooling”. In the same fashion as three- and four-year-old children imagine “hot food”, they will later need to imagine molecular movement to understand scientific explanations of heating and cooling.

Apart from the use of a fairy tales, other cultural devices, such as software programmes and iPads, can be utilised to enable children to create photographic images with self-generated narration to explain science concepts of the story created. This process enables children to consider concepts more consciously, while fairy tales make emotions and cognition more visible (Fleer, 2013; Fleer & Pramling, 2014). Other cultural objects, such as bowls, bears, beds, and so forth, enable children to tell and re-tell the fairy tale. In their study, Fleer and Pramling (2014) reported that the pictures of the bears cooking and eating porridge resulted in the participating children designing and building a “cooling-down machine” to help the three bears to cool their porridge so that they would not need to leave their house. In the telling of the fairy tale, the children identified with the bears; they sought to assist the bears and wanted to help them cool their porridge.

Table 4.1: Concepts informing collectively constructed imaginary scientific situations (Fleer, 2013)

Concept	Emotionality in fairy tales	Emotionality in scientific and technological learning
Collective investigation and narratives	Children want to identify with the hero of the story, wishing to assist the hero, and through this, together they re-enact the ideal moral response to the given situation, along with all the associated risks, in reaching the final victory. Children imagine the feeling state of fairy tale characters, and empathise with and want to help the characters to solve the collective problem.	Collective scientific investigation – children collectively develop a consciousness of scientific and technological concepts and emotionality by working together with other children to solve the problem. In a scientific narrative, children empathise with and want to help the characters to solve the collective scientific and technological problem.
Affective imagination or emotional imagination Zaporozhets (2002c, p. 58) demonstrates that through emotional and cognitive participation in fairy tales, children reach "the ideal plane of emotional imagination"	Through the re-enactment of fairy tales, children gain a sense of the main character's action in role play, while clarifying their own feeling state because the story plot is mirrored in the acted-out actions of the children. Children are not "enacting the story but really live in it" (El'Koninova, 2002, p. 45).	Through role playing scientific narratives and learning, children collectively begin to anticipate the results of one another's actions in the play. They also begin to anticipate their own actions, including image-bearing dramatisation, verbal descriptions, prop use, transformation, and, importantly, the scientific solutions created through the support of the teacher.
Flickering *Children flicker between real and imaginary worlds* *Imagination, thinking, and emotions in play*	In fairy tales, children begin to separate the imaginary world from the real world and find themselves in the borderline between these worlds. Children give new meanings to objects and actions in play, e.g. when a stick becomes	It is the border of the imaginary world and the real world that creates a dialectical relation and emotional tension that promotes scientific conceptual development, which helps children imagine scientific explanations not easily observable. Children give new meanings to objects and actions to everyday situations when learning

Concept	Emotionality in fairy tales	Emotionality in scientific and technological learning
	a hobbyhorse and the child a rider, creating a new sense of the situation.	science, creating a new scientific sense of the situation.
Dual role of emotions in thinking	Children must be inside of the plot, living the story, and outside of the plot as a real person. El'Koninova (2002, p. 41) argues that a child must "gropingly look for a territory where this is possible".	Children feel happy enacting or exploring a science narrative with others, but also feel excited or curious, learning new things and solving scientific and technologic problems to scientifically help the characters in the narrative.
Emotional anticipation 1. Fairy tales provide children with the possibilities for emotional tension, engagement, and self-awareness *2. Emotional filtering* 3. Situation "where kindergarten teachers attribute emotional significance to events" (Iakovela, 2003, p. 93)	Feeling happy in role play, but also feeling frightened when pretending to be Goldilocks seeing the three bears. In fairy tales, emotional anticipation of what is to unfold develops. Children begin to think consciously about the present and future situations and build emotional anticipation. Teachers emotionally charge events, actions, and objects that focus the children's attention, thinking, and feeling state.	In scientific investigations, children's feelings are connected with the learning as they anticipate finding a solution. Through consciously considering feelings in science, emotions become intellectualised, generalised, and anticipatory, while cognitive processes acquire an affective dimension, performing a special role in the discrimination and formation of meaning. Teachers help children to know what is noteworthy to pay attention to in science learning, and what they should notice or look for. The gesturing of teachers is usually accompanied by expressive sounds and facial expressions of surprise or interest.

4.4.1.2.2 Affective imagination

Affective imagination is used when the child imagines the feeling state of the characters in, for example, a fairy tale (see Table 4.1). Fleer and Pramling (2014) refer to Zaporozhets's (2002c) theory that children sympathise with and want to help story characters to solve the collective problem. Fairy tales provide emotional tension, engagement, and self-awareness. Through the telling and re-telling of fairy tales, the characters of the plot are acted out.

Science learning for young children can also be an emotional experience for them when they use science to help recreate the narrative of the fairy tale and together engage in scientific experiences to support the story plot. As with fairy tale narratives, a scientific narrative gives purpose and develops a motive for engagement in thinking and acting scientifically. Through the re-enactment of fairy tales, over and over again, children test out "the sense of the main character's actions but also clarified their own internal world of feeling" and distinguishing a real action "from its function in a role" (El'Koninova, 2002, p. 47). Through the repetition of telling, re-telling and re-enacting fairy tales, children come to understand the difference between real actions and role actions (Fleer & Pramling, 2014).

Fleer (2013) points out that five- to six-year-old children's everyday life is full of abstract events, but still events children wish to imaginatively develop or scientifically understand, such as rainbows, which are abstract, complex phenomena to try to reproduce in the classroom. Children between the ages of three and six years regularly feature real and imaginary situations in their discourse and play. Fleer (2013) refers to El'Koninova's (2002) suggestion that when children begin to separate the imaginary world from the real world, they found themselves on the border of these two worlds.

In an imaginary situation, children change the meaning of objects; for example, straw becomes porridge for the bears. In other words, they change the meaning of objects from what they see to what they imagine it to represent in their play. The objects used in their play act as pivots; groups of children must negotiate the meaning of these objects in their collective imaginary situations. For play to continue, it is essential that all the children in the group imagine the object in the same way and attribute the same meaning to it. Objects get new meaning, and children act according to their role in the imaginary situation. In playing Goldilocks and the Three Bears, children become the bears cooking porridge. Through the cooking of porridge, the emotional anticipation of hot porridge is created. The emotional anticipation of actions is represented through imagination when the imaginary situation is created and the imagined events are anticipated as affective imagination. Thus, through recreating the story, the children can anticipate the problem of hot porridge that needs to cool down (Fleer, 2013).

Through verbal descriptions and eloquent authentic depictions created by teachers telling and children re-telling and role playing, the emotional expectation of "hot porridge" was created and played out by the children. In the imaginative situation, the children used the concept of "cooling" at an everyday level. The expectation of "hot porridge" and the necessity for "cooling the porridge" created an emotional tension in the story, which built an affective scientific imaginary situation. Imagination supports scientific thinking in play. Fleer (2013) describes how the process of the distribution of heat through the cooling process can be played when small cut-up straws are used to represent porridge. Fleer and Pramling (2014) explain how the anticipation of eating the porridge and wishing for the porridge to cool faster led to the children attempting to help the bears cool down their porridge inventing a "cooling-down machine". These children also needed to imagine heat transfer and the cooling process they could use to cool down the porridge.

Imagining such scientific processes is easier for young children in playful events that they can come back to again and again in play. Role playing the bears gives the space and opportunity for imagination where scientific concepts can be played out as a form of scientific imagination at the everyday level. Changing the meaning of objects in play is important for being able to imagine new possibilities. Many scientific concepts are imaginary constructions rather than the consequence of direct observation (Fleer, 2013).

4.4.1.2.3 Being in and out of imaginary situations – flickering

As indicated in Table 4.1, when children are listening to a fairy tale, they are both inside the plot living the story and outside the plot as a real person (Fleer, 2013).

Moving in and out of imaginary situations also happens when children play; in fact, it is necessary for the participants to move in and out of imaginary situations. When play does not progress as expected, participants need to direct play from the outside. Being in both the imaginary situation and the real world helps children interrogate the concepts as they play, allowing for a more conscious response to the play or learning situation. Through play, the children are inside of the situation, for example feeling the heating and cooling in their play when they are playing Goldilocks and the Three Bears (Fleer & Pramling, 2014).

Furthermore, Fleer and Pramling (2014) identify moving in and out of imaginary situations as an important aspect of the formation of everyday scientific concepts. A conscious exploration of a concept allows children to build a deeper understanding of science. In role playing heating or cooling, children must exaggerate or explicitly show the concepts concretely or symbolically in their play for other children to understand and engage in the imaginary situation. In doing so, children make the concepts conscious and thereby consciously explore the concept. Flickering between the real and imaginary situations can also assist children to think in situated and imaginary ways that enable them to imagine scientific explanations that are often not apparent, such as the earth circling the sun (Fleer, 2013).

4.4.2 Playworlds

In the search for a curriculum that would support science learning, Fleer (2018) makes four assumptions about play, namely that play is a leading activity, play is dramatic, play is a source of child development, and play matures through the dynamic relationship between the reproductive and productive nature of play activity. Fleer (2018) found some promising properties in a pedagogy originally developed by Lindqvist in 1996 and coined the term “playworlds”.

To comprehend the importance of the influence of Lindqvist’s work on Fleer’s ideas, a short overview of this is provided below.

4.4.2.1 The work of Lindqvist

Lindqvist (as cited by Fleer, 2020) has developed this aesthetic play pedagogy to capture the dynamic relationship between the productive and reproductive nature of children's play to study how play acts as a source of children's development. Lindqvist also investigates the nature of the connections between play and the aesthetic activities that can influence children's play. Fleer (2020) points out that Lindqvist's work is based on Vygotsky's theory. Lindqvist's original theoretical writing and model of "an aesthetic pedagogy in preschools" are based on Vygotsky's cultural-historical concepts of development (1987, 1998), dialectics (1997) and imagination, emotions, and creativity (2004). In Lindqvist's later work, she also used Vygotsky's (1987a) notion of relations between everyday and scientific concepts to discuss problems with abstract learning. These Vygotskian concepts came together with drama pedagogy. Lindqvist's central point in introducing the notion of the aesthetics of play in common playworlds was that Vygotsky's conception of play needed a new interpretation because it was viewed as not focusing enough on the aesthetics of children's play.

Playworlds are described by Lindqvist (as cited by Fleer, 2020) as making use of stories and dramatisation of stories. To develop play means finding a theme, the content, which children can relate to and take interest in. Stories have traces of basic conflict situations, and children often relate to their surroundings in a dramatic way. Play is a dynamic meeting between the child's internal activities (emotions and thoughts) and external ones.

According to Lindqvist (as cited by Fleer, 2020), the ability to play is a process that starts as a vague whole and develops into a differentiated approach to form and content. It takes the child from a one-dimensional reproduction of characters towards the ability to produce nuanced interpretations of different roles. In play, the child creates meaning and also an aesthetic form that gives life an outline at the same time as it provides a specific amount of distance and an awareness of what the thinking process and cultural, aesthetic forms look like; for example, something that provides a base for both abstract thinking and artistic, creative ability. A multi-layered text is essential for developing children's play, and adults also need to be able to dramatise characters and actions in play. The best way of achieving this is through dialogue between children and adults. Children of different ages have interpreted and dramatised the theme together with adults, producing multidimensional play, each with its own text in a universal context. This is possible because children can move between internal and external levels in fiction. While being part of the universal context, they are, at the same time, creating their own text. The younger children are responsible for creating the underlying atmosphere and keeping it alive, while the older children make numerous interpretations and the transformation into new words. At the same time, as they take part in the universal story, they also play their own games, in the shape of either a pattern of actions or a story. The experience is enhanced by the fact that the children are not all from the same age group.

Several other researchers have built on and extended Lindqvist's (1996) theory of playworlds in countries such as Austria (Fleer, 2017), China (Fleer, 2018), Finland (Hakkarainen, 2010), Italy (Talamo, Pozzi, & Mellini, 2010), Japan (Marjanovic-Shane, et al. 2011), Lithuania (Hakkarainen, Milda Brėdikytė, Jakkula, & Munter, 2013), Serbia (Marjanovic-Shane et al., 2011), Sweden (Nilsson et al., 2018), and the United States of America (Ferholt & Lecusay, 2010). Baumer (2013) identifies the following differences in how playworlds are explored in different countries.

In Finland, researchers explore playworlds as the intersection between play, narrative learning, and school learning. Finnish researchers view a playworld as an "intermediate" form of activity, where the interaction occurring between children and adults promotes the development of narrative cognition that serves as an important resource when these children enter school.

In the United States, researchers have focused on examining the impact of playworld activity on the development of children and adults. Evidence has been found that children's participation in playworld activity leads to higher levels of narrative competence (Baumer, 2013).

The main purpose of the Japanese playworld project has been to challenge the recent tendency of Japanese educational policy that marginalises play. Teachers' deep emotional engagement has resulted in art pieces and play that were collaboratively produced by children and adults and were reflective of their diverse points of view (Baumer, 2013).

Hakkarainen and Bredikyte (2020) describe playworlds as a pedagogical methodology in which adults actively design, organise, and collaboratively carry out social, pretend role play with children. Fleer (2017) points out that teachers are included in the children's play, and it foregrounds a problem scenario as part of building a play narrative. What is unique about playworlds is that they give a pedagogical role to the adult, which actively supports imagination and which, in turn, has been shown to develop children's imaginative play. The conceptual framework is based on the cultural-historic theory of play and how it can be used to theorise how children change the meaning of actions and objects in their play to take on a scientific meaning.

Ferholt, Lecusay, and Nilsson (2019) view playworlds as designed to enable adults and children to engage in joint pretence as a means of promoting the emotional, cognitive, and social development of both children and adults. A playworld can be described as a combination of the adult form of creative imagination (which requires extensive experience, e.g. art and science) and children's forms of creative imagination (e.g. play, which requires the embodiment of ideas and emotions in the material world). Playworlds allow children as well as adults to take the position of an expert, as indicated in Diagram 4.1.

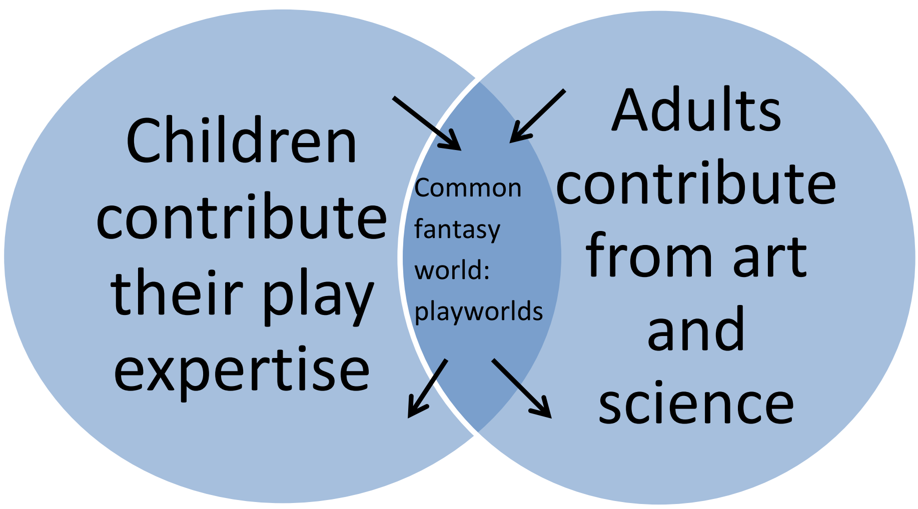

Diagram 4.1: Schematic representation of a playworld (Ferholt et al., 2019)

Ferholt et al. (2019) explain that a playworld is created through the activity of bringing the actions and characters in a literary text to life through drama. The pedagogy of playworlds is framed through the telling or reading of a story. The children and the teacher worked together to create playworlds and play narratives. Reading and role playing stories from children's literature, folk tales, and fairy tales help children re-live and develop the dramatic moments through play.

Hakkarainen et al. (2013) identify the main components of the fictitious world created by adults and children in playworlds as an exciting or meaningful theme, a dramatic plot (story, narrative), and an enactment or dramatisation of the plot. Fleer, Veresov, Harrison, and Walker (2017) point out that play can be evolved through the introduction of new elements where the teacher and children elaborate on the basic theme or plot, constructing scenes and enacting specific roles where they agree jointly to imagine particular settings and props. The unique feature of playworlds is that realistic problems can be embedded into a storyline.

Ferholt, Lecusay and Nilsson (2017) have found that playworlds deepens teachers' listening to children. Baumer, Ferholt, & Lecusay (2005) have observed that adults promote the narrative competence in terms of narrative length, coherence, and the comprehension developed in five- to seven-year-olds. By staying in character, the teacher can use the role relation and storyline to engage an ambivalent child.

Fleer (2018) describes the role of the adult as acting as a partner with children, going on adventures, co-developing the play scripts, and dramatising the fiction and play plots over extended periods of time. By doing this, the teacher actively enters into the fantasy play of young children, and the teacher as well as the children enters into an imaginary physical playworld space, such as a hot air balloon.

4.4.2.2 The work of Fleer culminating in the ideas of scientific playworlds

With concern for a more playful curriculum in some countries, Fleer (2020) suggests that now the time is right for a reanalysis of the reach of Lindqvist's original work. Specifically, her work can offer a new way forward in resolving the "academisation" in countries where a formal curriculum is being demanded, and it can contribute to finding solutions for making and learning concepts more playful.

The focus of Fleer's (2018) studies is slightly different from that of Lindqvist's. Although there is vast evidence showing the contribution play makes to childhood learning and development, Fleer (2017) is concerned about models for pre-school science teaching tending to concentrate on setting up resource-rich environments and promoting discovery learning. In this teaching model, opportunities to teach science in play-based settings are lost. Vygotsky's conception of play alone does not theoretically explain what the force of development of scientific thinking might be in imagination and dealing with contradictions. Other concepts are needed for understanding the scientific play of children. The goal of Fleer's study was to understand the pedagogical practices in the play-based settings that supported the scientific engagement of children and teachers and the development of scientific thinking within imaginative play.

There is a variety of models of play in the literature, with different concepts of play across cultures and different definitions of what play is and what it is not. However, Fleer (2017) finds it problematic that none of these models have been specifically developed to support science learning. For Fleer, the playworlds idea is the closest possible approach to be used for science learning. In playworlds, Fleer (2017) has found some promising properties for the development of a model specifically for science teaching using play-based settings that feature teacher strengths in the pedagogy of play.

Cultural-historical concepts were used as a framework for Fleer's (2017) study to investigate the process of the development of scientific thinking. For this model, the concepts of drama and dual position were used. A cultural-historical view of role play was psychologically connected to Vygotsky's (1997b) conception of drama. Children engage in drama on an inter-psychological and intra-psychological level. Through drama, children develop and gain different standpoints. Play as a form of drama enables a collective consciousness about everyday life events, for example pretending to ride a horse.

In the two-positional perspective described by Kravtsov & Kravtsova (2010) and used by Fleer (2017), play from the dual-position perspective allows the child to better understand him- or herself, as well as the surrounding world. While the child is inside the play, acting out what he or she has experienced, observed, read, or viewed in everyday life, the child is also able to step out of the play, directing how the play should take place. This two-positional perspective supports the analysis of children's modelling in play and science through analysing when children visualise, model, or imagine scientific concepts during play. As indicated in Table 4.2, in play, children use meta-communicative language, such as "pretend I am inside the drop of water", and a sing-song cadence at the end of the sentence to signal that they are inside the imaginary situation. Analysing meta-communicative language from two-positional perspectives gives more confidence in research about when children are in the imaginary situation and when they are not. Meta-communicative language also has the potential to signal in the analysis particular modelling and potential thought experiments being tested in their play, for example "wriggling worms" exploring how a worm moves without legs. Teachers can use and model meta-communicative language specific to pre-school science, such as "I wonder if …". This has the potential for better understanding how play pedagogy could consciously and systematically, over time, support science learning in play-based settings. Fleer (2017) uses cultural-historical concepts for the framework of her study, seeking to capture the process of the development of children's scientific thinking.

Fleer (2017, 2020) has identified three key features of playworlds based on Lindqvist's (1995, 2003) theory. The first key feature of playworlds is crossing a border. When entering playworlds, where new rules and roles are interacted and where dramatic events are experimented, children must cross a border of some kind to signal they are collectively in the imaginary situation (Lindqvist, 2003). Lindqvist (1995) gives the example of entering a basket and riding in a hot air balloon into other lands, to go on a journey.

The second key feature of playworlds is that they are collectively created imaginary situations where the teacher takes on the role of a character in play (Lindqvist, 1995). Lindqvist (1995) states that adults needed to dramatise the action to provide play with meaning. Hakkarainen et al. (2013) add that in playworlds, teachers work with young children to support the development of ongoing play and to present and model higher forms of play. Teachers, who are inside the imaginary situation in play with children, can sensitively expand the play, pose new problems, support the development of solutions, and generate new adventures.

The third distinguishing characteristic of playworlds identified by Lindqvist (1995) is the need for dramatic events – ones that are exciting and motivating for children. In playworlds, dramatic collisions refer to exciting, engaging, or contradicting moments in imaginary situations in which both children and teachers are emotionally involved. Drama creates conditions that can activate children into action as well as into imagining solutions to pending problems and creating collective moments of reflection in the play.

Moreover, drama can create conditions to support the development of playworlds, which, in turn, has been shown to support children's development (Fleer, Veresov, & Walker, 2020). The cultural-historical concept of drama may be a powerful tool for theorising the development conditions for executive functioning in playworlds for two reasons. First, dramatic events and dramatisation are distinguishing characteristics of playworlds where adults play a key role.

> … the adults needed to dramatize the action to provide play with meaning. The characters played by the pedagogues were of importance in bringing play to life because they created a dialogue between the adults and the children which opened the door to factious world. The pedagogues become mediators." (Lindqvist, 1995, p. 10)

> To make playworlds successful, adults need to take on and play a role, dramatize, and create a dialogue. It does not mean the adult's role is a leading role. Children are active creators and participators in imaginary situations and may take on leading roles. Drama, therefore, is not only a necessary component of playworlds but can be regarded as a fundamental condition for the existence and development of the playworld itself (Fleer et al., 2020).

The second reason for the concept of drama being a powerful analytical tool comes from the theoretical domain. In the cultural-historical theory, the concept of drama contains two theoretical aspects. The first is that the drama begins with a collision, a conflict, a critical moment that happens in the form of an event; participants remain personally and emotionally involved in drama until the collision is resolved. These aspects of dramatic events in playworlds was theorised by Hakkarainen (2010) in relation to the development of reflection in children.

Fleer (2020) has analysed the theoretical concepts that bind the systems of pedagogical practices of Lindqvist (1995, 1999) and identified the following six assumptions about Lindqvist's theory:

(i) There is a notable difference between a playworld concept of play and the general literature on play. General literature about children's play does not contain a scripted plot but rather is centred on action and dialogue only. In drama, everyone must be part of common fiction. Consequently, a child's activity in a playworld is different from free play, because it has a plot and dramatic narrative in which all the children participate.

(ii) Although Vygotsky does not refer to adult-child play as such, a central assumption underpinning an aesthetic pedagogy of play is that the teacher has an active role in children's play (Fleer et al., 2020). The central assumption underpinning an aesthetic pedagogy of play is that the teacher takes on an active role in children's play (Lindqvist, 1995). This is challenging, as traditionally, adults are not role players.

(iii) "The theories of drama pedagogy show how children and adults can serve to develop a dynamic relationship to reality, and such a working method can provide new angles of approach to preschool pedagogy" (Lindqvist, 1995 p. 38). Therefore, Lindqvist developed aesthetic play pedagogy.

(iv) "Consciousness is the key concept and the principle of individual development, and to children play is the activity through which they become conscious of the world" (Lindqvist, p. 4). Play is viewed as the cultural source of a child's development. Lindqvist's (1995) work advocates for a cultural perspective of play, uniting art, cultural, and social processes. Cultural development reveals itself in children's play action. The assumption is that play action acts as the window into a child's imagination, and this gives insight into the cultural development of children as they become conscious of their world.

(v) In play as a cultural process, the assumption is that a unity of emotions and cognition exists through imagination. Play arises through the interplay between emotion and intellect that imagination in play brings about. An emotional gap exists between children and adults, and unimaginative environments are created. Lindqvist agrees that emotions and thoughts, as presented by Vygotsky (1971) in the psychology of art, are united. In a common playworld, the unity of emotion, thought, and will is foregrounded as part of children's and teachers' collective cultural practices. In the drama of the playworld, the unity of emotion and intellect opens the development of the child's imagination and vice versa. Lindqvist refers to Vygotsky's conception of the unity of emotion and intellect (see 4.4.2.3).

(vi) In playworlds, the dialectics between the world of the child and the world of adults creates a contradiction, and this contradiction also acts as a productive force for development. For instance, children are seeking to reproduce in play the reality they experience, while at the same time producing their own play scripts during the process of coming to understand the roles and rules of the society in which they live. In play, "children are expressing their feeling and asserting themselves in relation to adults, while the adult senses that children also wish to move closer to adult world, this is dialectics" (Lindqvist, 1995, p. 50).

The child's capacity to separate meaning from the visual field of the concrete object gives new possibilities in play, in language, in thought, and in the self-regulation of emotions and will. Lindqvist (1995, p. 49) uses Vygotsky's concept of imagination and creativity in saying "the interplay between emotions and intellect gives rise to the development of imagination in play". Children can imagine new actions and possible play scripts. There is a meaning of inner ideas and external actions that play makes the child conscious of. Actions can now arise from ideas, not just concrete objects (Fleer, 2020).

In line with Vygotsky's theory, Lindqvist (1995) states that children make meaning of their world by producing for themselves their own production of reality in their play. Imagination is both emotional and intellectual and develops creativity.

4.4.2.3 Perezhivanie in playworlds

In children's emotional participation in playworlds, another important concept emerges as defined by Vygotsky (1994). Vygotsky (1994, pp. 340-341) called it "perezhivanie", which he defined as "how a child becomes aware of, interprets, and emotionally relates to a certain event". Fleer et al. (2020) identify playworld settings as situations in which children's emotional reactions and responses are easy to observe. In other words, their view is that perezhivanie as a phenomenon is more than an emotional reaction – it is an integral complex network of various psychological functions such as perception, memory, thinking, volition, and imagination.

Fleer (2020) identifies perezhivanie as a theoretical concept that acts as an analytical tool that allows one to study the role and influence of the environment on the psychological developmental conditions of playworlds that support executive functioning. There are two ways in which perezhivanie supports executive functioning. Firstly, it highlights the active role of the child who, being a participant in an imaginary situation in a playworld, perceives, interprets, understands, and reacts in an individual and unique way (Fleer et al., 2020). The transition and transformation of a psychological function from the "inter-psychological" plane to the "intra-psychological" plane are not a direct transition but a complex process of internalisation that goes through perezhivanie as a refracting prism. Secondly, the concept of perezhivanie allows one to advance one's understanding of opportunities and developmental conditions. They are potential opportunities until the child refracts them through perezhivanie. Dramatic perezhivanie creates the opportunity to theorise the developmental conditions of dramatic social situations. Because of the dramatic nature of playworlds, the concept of dramatic perezhivanie is regarded as an appropriate theoretical instrument (Fleer et al., 2020).

4.4.2.3.1 Executive functioning

There is growing evidence that the development of executive functioning is an important aspect of early childhood education. "Executive functioning" is a collective term for a set of cognitive processes or abilities – the ability to hold memory information, to inhibit an immediate response, to shift between different sets of rules, and is a reaction to a novel or difficult situation (Fleer, Veresov, & Walker, 2017a; Fleer et al., 2020). Therefore, executive functioning can be conceptualised as a social practice crucial to the success of the 21st-century learner, as it includes creativity, flexibility, self-control, and discipline (Fleer et al., 2017a). These abilities make it possible to mentally play with ideas, quickly and flexibly adapt to changed circumstances, take time to consider what to do next, resist temptation, stay focused, and meet novel, unanticipated challenges (Fleer et al., 2017).

Executive functioning is also foundational for complex cognitive processes, such as abstract thought. Studies show a direct relation between training in executive functioning in pre-school and positive cognitive social outcomes in school (Fleer, Veresov, Harrison, & Walker, 2017; Fleer, Veresov, & Walker, 2017). Three of these abilities (elements) are working memory, inhibition, and cognitive flexibility.

Working memory can be described as the ability to store, update, and retrieve information while simultaneously doing other things, for example playing cards and the need to store and retrieve information while socialising at the same time (Fleer, Veresov, Harrison, & Walker, 2017; Fleer, Veresov & Walker, 2017; Fleer et al., 2020). Playworlds support working memory, because children have to recall play narratives and be in character when responding to problem situations such as solving a problem from the perspective of the wolf when playing the fairy tale of the Three Little Pigs (Fleer et al., 2020).

Inhibitory control is the ability to self-regulate and not respond immediately but withhold a response in favour of another action, for example playing the game Simon Says (Fleer, Veresov, Harrison & Walker, 2017; Fleer, Veresov, & Walker, 2017). Playworlds promote inhibition because children are required, on entering into the playworld, to follow specific rules that are counterintuitive, such as asking children to do things back to front (Hakkarainen, 2006), or “up being down” and “down being up” (Fleer et al., 2020).

Shifting or cognitive flexibility supports children’s ability to manage and control thoughts and behaviours. With this ability, children think or plan before they act, remember rules and events, and are focused and less likely to be distracted by irrelevant or extraneous factors (Fleer, Veresov, Harrison & Walker, 2017; Fleer et al., 2020). Cognitive flexibility is the ability to maintain competing sets of rules or instructions and shift among them, for instance when a criterion suddenly changes during a sorting game (Fleer, Veresov & Walker, 2017).

The exhibition of these three elements of executive functioning has been found to predict both early and long-term academic success. Early childhood is a crucial time for laying the foundation of executive functioning. Between the ages of two and six, typically developing children make impressive strides in focusing attention, inhibiting inappropriate responses, planning sequences of actions, and thinking flexibly. These skills increase their ability to solve problems, make decisions, persist at tasks, recognise and correct mistakes, control impulsive behaviour, and set goals and work towards them. These abilities help children to meet challenges at school. Make-believe play is a potentially important causal factor in the development of executive functioning (Fleer et al., 2020).

Because of the unique features of playworlds, they are described by Fleer et al. (2020) as ideal settings to create specific conditions for the development of executive functioning. A variety of executive functioning tasks could be successfully embedded by teachers into playworlds they collectively create. Playworlds are an ideal vehicle for the development of executive functioning because teachers can support shifting by creating new rules in the playworld, such as children walking backwards or inviting children to devise new passwords and then changing these.

4.4.2.3.2 Imagination in scientific playworlds

According to Fleer (2017), there seems to be a link between imagination in science and imagination in play. The building of a collective scientific narrative alongside the discourse of wondering is a key determinant of science learning in play-based settings. Specifically, the following are key determinants of science learning in play-based settings: the pedagogical principles of using a cultural device that mirrors the science experiences; creating imaginary scientific situations; collectively building scientific problem situations; and imagining the relations between observable contexts and non-observable concepts that change everyday practices into a scientific narrative alongside discourses of wondering.

In their respective studies, Fleer (2017) and Hakkarainen (2010) identified three different ways of building collective scientific imaginary situations. Firstly, the participating teachers drew upon their practice of reading stories to create a collective imaginary situation with the children at group time. In Hakkarainen's (2010) research, the story of *The Wishing Chair* was used to build an imaginary situation. The story created the conditions for children to imagine flying to faraway lands to explore. The story invited the children to jointly create imaginary situations based on stories, serving as the basis of adult-child joint playworlds and child-initiated play (Hakkarainen, 2010).

Secondly, teachers used a psychological tool to support the children's collective imagining of going on adventures. Hakkarainen (2010) refers to the story of the Wishing Chair, with a chair that was placed in the space where the children sat for group time. Fleer (2017) refers to a tunnel and bubble. All these psychological tools act as a placeholder. The psychological tool is used in the transition from the classroom to the imaginary playworlds. According to Vygotsky (2005), initially objects, then actions and later words act as placeholders in the development of complex play. Although it did not result in a scientific imaginary play situation being developed, Fleer is convinced that a scientific playworld can be created (see Table 4.2).

The third key dimension of building a mutual scientific imaginary situation identified by Fleer (2017) is the use of a range of cultural devices that more intricately link to the science that the teacher is supporting the children to learn. For example, for the exploration of microbes in the environment, a microscope and hand lenses are used to study the content of the compost bin and samples of pond water. Magnification was also a new concept that has to be explicitly introduced for children to engage with the concept of microbes. In Fleer's (2017) research, the children also used iPads for magnification. The digital devices available to the children supported their exploration of the environment; they could zoom into exceedingly small organisms to see them clearly and document their findings as photographs or video clips to share with one another afterwards. However, these experiences do not necessarily result in the imagining of scientific concepts. There is also a need for teachers to build a narrative that would allow children to role-play being microscopic, so that they can consciously think and embody what they are experiencing.

Table 4.2: Pedagogical characteristics of scientific playworlds (adapted from Fleer, 2017)

Pedagogic practices unique to playworlds	Pedagogic principles to support scientific playworlds	Examples from the data set	Theoretical concept
A story with a structure that allows children to collectively go on adventures		Children imagine going on adventures inspired by Enid Blyton's *The Wishing Chair.*	Playworlds (Lindqvist, 1996)
Psychological tool to support the transition from the pre-school to the imaginary situation	Cultural device that closely mirrors what the children are scientifically experiencing	Fabric tunnel was used for simulating science experiences and a plastic bubble for imagining being inside a drop of pond water.	Playworlds (Lindqvist, 1996)
Being inside the imaginary play, taking a role	Creates an imaginary scientific situation (adult/child)	The teacher or a child changes the meaning of an object, e.g. when using the fabric tunnel for imagining being a worm – it could be a "worm skin, a worm sack".	Cultural-historical conception of play (Vygotsky, 1966)
Being deliberately in frame, setting problems up inside the imaginary play; inviting children to imagine together	Collectively building scientific narratives, scenarios, or problem situations	Play is jointly created and later independently enacted as the social becomes the child's personal understanding. Alex, in an excited tone, says, "I can see slime coming out of him!" The teacher thoughtfully asks, "Oh, is that his slime? Gosh, imagine if you had slime that came out of your feet, or out of your fingers, everywhere you went." Contradictions and dramatic events create the conditions for children's development.	Inter-psychological and intra-psychological functioning (Vygotsky, 1997)
	Consciously considers scientific concepts	Signals they are in the imaginary situation through words, actions, or objects – "imagine how big you would be if you wore this shoe". Offers solutions to the problem situation inside/outside the imaginary situation, such as telling the children it is size 55 and then inviting the children to look at their shoe size,	Play from the "dual-positional perspective" (Kravtsov & Kravtsova, 2010)

Pedagogic practices unique to playworlds	Pedagogic principles to support scientific playworlds	Examples from the data set	Theoretical concept
		noting many are size 3. Harriette then concludes, “So if you were big enough to fit into this shoe, I think you would be a giant.”	
	Imagining the relations between the observable contexts and the non-observable concepts	Child creates scientific models in play to show ideas, e.g. when role playing, using physical materials to make something, drawing upon symbols, using digital animation, etc. “That slug, it got longer.” The teacher asks, “How did it get longer?” Mitchell responds, “Because it is stretching. Arrrr.” Harriette wonders, “Do you get longer when you stretch?” Mitchell moves his arms up and out away from his body, as Harriette says, “Wow. Looks like you are right.” “Watch this,” says Alex as he also stretches out. “Wow,” says Harriette. Alex says, “I am so long.”	Play from the “dual-positional perspective” (Kravtsov & Kravtsova, 2010)
	Wondering: widening the scope of the imaginary situations Wonder: “I wonder what might happen if …?”; Doing: What would you do if ...?” Evaluate: “Do you think they really are ...”	Underscores actions or words through the use of high inflexion at the end of the sentence or emotionally charged language. You are inside the drop of water. What might you do? The teacher asks, “How did it get longer?” Mitchell responds, “Because it is stretching. Arrrr.” Harriette wonders, “Do you get longer when you stretch?”	Meta-communicative language (Bretherton, 1984) in collective play (Fleer, 2011)
Dramatic concepts; creating dramatic moments and tension	Emotionally charged situations help focus scientific attention and engagement	Engaging in theoretical contradictions, e.g. magnification process – shrinking down into a drop of water; being big in a microscopic world and, at the same time, small in an adult world.	Cultural-historical conception of imagination in science (Vygotsky, 2004)

4.4.2.3.3 A scientific playworlds model

A second model of playworlds is “scientific playworlds”, coined by Fleer. In Figure 4.2 below, Fleer (2017) represents the findings of her study and theorises them into a model of teaching science for play-based settings. According to Fleer’s (2017) scientific playworlds model, it begins with the collective scientific imaginary situation, which draws upon a cultural device that is related to the science being learnt and which requests children to go on scientific journeys to produce dynamic imaginary scientific context. These findings are theorised and shown in the top half of Figure 4.2.

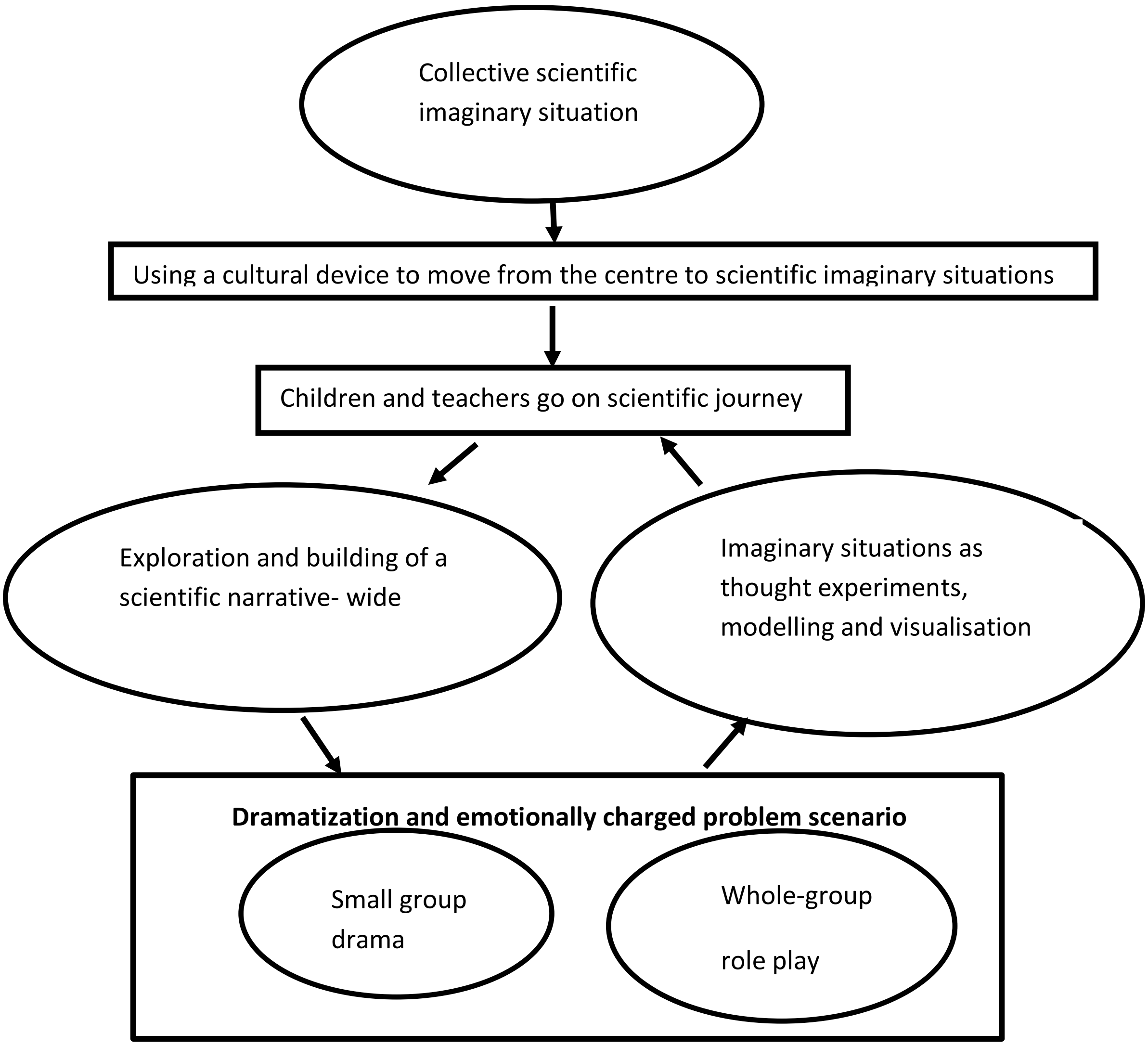

Figure 4.2: Scientific playworlds for teaching science in play-based settings (Fleer, 2017)

The bottom half of the model in Figure 4.2 theorises the iterative process of building the scientific narrative where a scientific problem needs to be solved. This tension creates the driving force for ongoing and imaginary situations that the study found deepened the scientific imagining and conceptual understandings. Based on the results of her research, Fleer (2017) concludes that imaginary play is the context, the motive, and the narrative. It also binds together science learning for children; it is a continuous activity binding children's attention and desire for the continuation of the scientific journey.

4.4.3 Inquiry-based science education

The third pedagogy considered for science teaching of the young child is inquiry-based science education (IBSE). Inquiry can be defined as a set of cognitive processes for understanding phenomena, based on evidence, variable incidence, and casual relationships (Montes, Van Dijk, Punche ,& Van Geert, 2017).

IBSE is described by Zimmerman (2007) as a common instructional method to increase scientific thinking to have children gain knowledge about scientific domains via scientific inquiry. It is a more learner-centred approach than traditional science teaching, as it means the gathering of evidence and considering possible explanations, and is about performing experiments and making observations (Harlen, 2012a; Zuckerman, Chudinova, & Khavkin, 1998).

Harlen (2012a) explains that scientific inquiry leads to knowledge and understanding of the natural and manmade world. An original question or problem will lead to the formulation of a hypothesis leading to predictions and investigations. The prediction is tested by comparing some theory or model with what has been found or observed. It often involves experimenting but may also involve collecting data by observation. Data are collected and analysed to provide evidence in relation to the questions raised and hypotheses being tested. Conclusions can be drawn. Throughout the process, scientists keep records, consult others' work, and present and discuss their ideas and procedures with one another.

Scientific inquiry for the young child builds on children's natural desire to discover new knowledge about their surroundings. Worth (2010) explains that children's natural curiosity creates a need to make sense of the world. In this way, curiosity becomes the foundation for the use of skills of inquiry. To explore basic phenomena and materials of the world surrounding children, they need appropriate adult guidance. However, Zuckerman, Chudinova, and Khavkin (1998) warn that curiosity alone is not enough as a foundation for inquiry. Only in scientific reasoning is curiosity sated by deliberate data collection and formal analysis of evidence (Morris, Croker, Masnick, & Zimmerman, 2012).

Constantinou, Tsivitanidou, and Rybska (2018) point out that when children take part in scientific inquiry and are engaged in meaningful scientifically orientated questions, they will give priority to evidence, which allows them to develop and evaluate ideas that address scientific questions. They will formulate knowledge claims and arguments from evidence to settle scientific questions; they will be evaluating their explanations considering alternative explanations, in particular those reflecting scientific understanding; they will communicate and justify their proposed explanations. In the process, they will learn how to do science, acquire relevant skills and abilities, and develop an understanding of the inquiry.

4.4.3.1 Aim of inquiry-based science education

Harlen (2012b) identifies the aim of IBSE as for students to become more independent learners. Inquiry-based teaching approaches rely on the assumption that students will benefit if they try to find solutions to scientific problems encountered in everyday life (Ergazaki & Zogza, 2013). Scientific inquiry encourages children to (i) ask questions, (ii) conduct investigations, (iii) conduct explorations, and (iv) form inferences like scientists (Albert Shanker Institute, 2009; Ergazaki & Zogza, 2013; Moonaw, 2013).

(i) Questions

The Albert Shanker Institute (2009) describes the teacher's role as guiding children, as they determine an interesting science question and suggest possible methods to find an answer or explanation. The children participate in observing and experimenting to determine the answer to their question.

Zuckerman et al. (1998) identify the kind of answers provided by teachers as enhancing and perpetuating for children's systematic questioning. The teacher's answers must stimulate further questions for understanding. Teachers should refrain from coming up with ready answers but change towards a scientific problem that can be solved experimentally. The child's request for information is changed into a request for the method to gain the information, for example "What is it?" is changed to "How can we find out?" This transformation elicits a switch from everyday to theoretical knowledge requiring metacognition.

Teachers' questions are important in using inquiry in science teaching because good questions advance the inquiry process (Harlen, 2012a). It will stimulate further questions and involve children in closer examination or experiment. Productive questions encourage learners to start thinking about their own questions and how to find answers. It may move a group of learners to a deeper level of work and reasoning.

(ii) Investigations

Through active participation, children learn the steps scientists use to investigate and solve problems (Albert Shanker Institute, 2009). Teachers guide children through participation. The implication is that learners grow in both their ability to participate in the cycle of scientific inquiry and in their knowledge of science concepts. The investigating activities also build background knowledge and vocabulary that are essential for future science learning as well as for reading comprehension in the elementary years. Through participation, they gain in-depth knowledge of science content. While children's preconceptions about the world can be resistant to change, active participation in hands-on science experiments is more likely to advance their ideas than simply being told new information.

(iii) Exploration

Initial exploration reveals features that recall previous ideas leading to possible explanations – “I think it might be …”, “I’ve seen something like this when …”, or “it’s a bit like …” Harlen (2012a) explains that there may be several ideas from previous experiences that could be relevant, and through discussion, one of these is chosen as giving the possible explanation of the hypothesis to be tried. Learning through scientific inquiry is a process of building understanding through collecting evidence to test possible explanations and the ideas behind them in a scientific manner. Modelling the building of understanding in this way offers a view of how smaller ideas, applying to observations or experiences, are progressively developed into big ideas that apply to a range of related objects or phenomena (Harlen, 2012a).

(iv) Inferences

Harlen (2012a) explains that children evaluate how useful an existing idea is by making predictions based on their hypothesis. Children test the prediction using new data about the phenomenon that are gathered and analysed. The outcome is then used as evidence to compare with the predicted result. From these results, a tentative conclusion can be drawn about the initial idea. If it gives a good explanation, then the existing idea is not only confirmed but becomes more powerful and “bigger”, because then it explains a wider range of phenomena. If necessary, an alternative idea needs to be explored, and the idea may need to clarify an idea, so knowing that the existing idea does not fit is useful too.

4.4.3.2 Inquiry-based science education and young children

One of the challenges of using IBSE as a teaching method for younger children is their limited experience of the world, making it hard to ask questions about something they have not had a chance to experience (Chalufour & Worth, 2006). Fleer (2017) points out that as a result of this, pre-school children do not readily ask questions that can be used as a basis of inquiry.

Scholars such as Samarapungavan, Patrick, and Mantzicopoulos (2011) and Worth and Grollman (2003) are of a slightly different opinion, namely that children of kindergarten age (5-year-olds) can take part in inquiry-orientated science learning. Samarapungavan et al. (2011) found evidence that participation in inquiry-orientated, literacy-rich science learning activities, which facilitate kindergartners' learning and interest in science, is possible at a relatively young age. These children can ask meaningful questions, make predictions about outcomes, observe and record evidence, revise and represent their knowledge, and communicate their findings. Chalufour and Worth (2006) is more sceptical though and warns that most five-year-olds at kindergarten level will only be able of asking questions and not demonstrate the other aspects of inquiry, namely revision and representation of their thinking.

According to both Samarapungavan et al. (2011) and Worth and Grollman (2003), five-year-olds need instructional scaffolding to engage in productive scientific investigations that, at least partially, simulate authentic scientific inquiry about objects and events around them. In this age group, children will explore materials, objects, and events by acting upon them and noticing what happens (Worth & Grollman, 2003).

Samarapungavan, Mantzicopoulos, & Patrick (2008) and Ergazaki and Zogza (2013) agree that five-year-olds are able of inquiry into biological concepts. Ergazaki and Zogza (2013) are of the opinion that IBSE can be implemented in kindergarten classes to help young children reach a better understanding of entities and phenomena of the biological world, as they demonstrate a functional understanding of the science inquiry processes and important life science concepts. They can engage in the process of making and recording simple observations (Samarapungavan et al., 2011) by using their senses, enabling them to describe, compare, sort, classify, and order the observable characteristics and properties (Worth & Grollman, 2003). In addition, they can use a variety of simple tools, such as hand lenses and measuring tools, to extend their observation (Worth & Grollman, 2003). Samarapungavan et al. (2011) and Worth and Grollman (2003) describe five-year-olds as collaborative with others and able to share and discuss ideas and listen to new perspectives from others. They also communicate the result of their investigations, observations, and ideas through multiple forms of representation, including drawings, simple graphs, writing, or posters.

Van der Graaf, Segers, and Verhoeven (2018) point out that recent research has found that learners between four and six years old can design unconfounded experiments with multiple variables and are able to evaluate various types of evidence. Individual differences, executive differences, and linguistic differences appear to predict experimentation and evidence evaluation in kindergarten.

So, it seems that most scholars agree that although pre-schoolers can participate in some form of inquiry, the extent of it is limited and only possible when dealing with specific science content in a specific way. This is most extensively discussed by Chaillé and Britain (2003) in their seminal work *The young child as scientist: a constructivist approach to early childhood science education*. In this work, they highlight the fact that care should be taken when dealing with a diversity of science content.

Chaillé and Britain (2003) believe that children construct their own knowledge through a dynamic interactive process. Children are continuously engaged in building theories about science. In the construction of concepts about the physical world, Chaillé and Britain (2003) refer to the work of Kamii and De Vries (1978) and Forman & Kushner (1983), who used the Piaget concept of physical knowledge to describe and explain the young child's science learning and understanding of physics concepts. Kamii and De Vries (1978) point out that physical knowledge is constructed through the child's action on an object and observation of the object's reaction. Four criteria are identified in maximising the child's ability to observe change: the child must be able to move the object by his or her own actions; the child must be able to vary his or her own actions; the reaction of the object must be observable; and the reaction of the object must be immediate.

According to Forman and Kushner (1983), major intellectual developments all involve the understanding of transformation. Children's physical knowledge develops through learning how objects move, how they change position and shape, and how they change in relation to themselves and other objects. The focus in early childhood education should be on the facilitation of transformational thinking. A key to such a focus is the child's representation of transformation.

Chaillé and Britain (2003) describe transformation in chemistry as play activities, for example the push and pound of playdough, stacking blocks, and painting a box to pretend it is a playhouse. These activities can be divided into two distinct categories of reconstruction and combination.

- The rearrangement of parts and structures (reconstruction), for example building with wooden blocks.
- Changes in substance and consistency (combination), for example mixing water, sand, or paint. The children are changing things and observe the results of their actions. Growth, decomposition, and the creation of habitat are transformations too.

Chaillé and Britain (2003) identify transformation as a major focus in the natural world, like birth, growth, death, decay, and composition are changes in substances over time. Not all topics in the natural world lend themselves to active experimentation by children. Some of the most interesting transformations occur over a long period. In other words, it is less immediate and less visible to young children, and so, the teacher needs to plan for children to observe the change process.

From the above-mentioned information, it emerges that there seems to be a definite place for IBSE when dealing with the teaching and learning of the pre-schooler and the early school child. However, care should be taken in selecting appropriate methodology and content for teaching science to young children.

4.4.3.3 Inquiry-based science education model

Constantinou et al. (2018) describe the IBSE model as an intentional process of diagnosing situations, formulating problems, critiquing experiments, and distinguishing alternatives. IBSE involves two major actors – the teacher and the learner(s). It involves two processes, namely teaching and learning. The educational process has a cognitive as well as a cultural facet, applied through communication among the different actors. Inquiring learning refers to the active learning processes in which learners are inevitably engaged.

4.4.3.4 Key elements of the inquiry-based science education model

Ergazaki and Zogza (2013) identify the following as key elements of the IBSE model: (i) experience as a key element for learning scientific concepts; (ii) the development of reasoning or argumentation; (iii) understanding; (iv) the development of basic science skills, such as “observation”; and (v) the promotion of collaboration.

(i) Young children develop science skills and knowledge over time by engaging in experimental learning (McClure, et al., 2017; Wood & Hedges, 2016). Through their participation in simple hands-on investigations, they can test, observe, discuss, draw conclusions, and generalise their understanding (Albert Shanker Institute, 2009). Children have many ideas about the phenomena they encounter in their day-to-day lives (everyday knowledge), although these ideas are often incomplete or contradicting scientific explanations of the phenomena. These naïve conceptions are based on limited experience (Harlen, 2012a).

Scientific ideas become modified as learners use them to try to explain new experiences. Harlen (2012b) elucidates that an idea can then be used to make predictions and then be tested by seeing if the evidence from the new experience agrees with what has been predicted. Then the idea becomes “bigger” because it explains a wider range of phenomena. If it does not work, an alternative idea has to be tried; the experience helps to refine the idea. This process results in quantitative change in terms of the range of events and phenomena that can be understood, and a qualitative change in the nature and scope of ideas. Scientific ideas that are widely applicable are necessarily context-independent, for example the idea of what makes things float can be used for all objects and all fluids.

To move from the idea of why an object floats in water to the big idea of floating is a large step that involves making connections between observations in quite different situations. A conceptual step may also force children to deconstruct and then reconstruct new and more encompassing ideas. Ideas developed in this way are only understood if they make sense to the child as a product of his or her own thinking. Learners need experiences that enable them to make sense of different aspects of the world. First-hand experiences are important for younger children in particular, but all children need to develop the skills used in testing ideas, questioning, predicting, observing, interpreting, communicating, and reflecting (Harlen, 2012b).

(ii) Reasoning develops through the mastery of objects as the child acquires the ability to transfer functions from one object to another. Reasoning first happens in play activity that results in changes in the nature of the child's thinking. Initially, the child's reasoning can be faulty due to a lack of relevant information. Children's reasoning depends on their general development, the broadening of their experience, and the development of their practical and play activities (Zaporozhets, 2002d). Reasoning skills develop when children are engaged in investigations and by formulating and evaluating explanations (Ergazaki & Zogza, 2013).

Young children are sensitive to contradictions and will try to modify former reasoning when confronted with new facts, resulting in changes in their reasoning process (Zaporozhets & Lukov, 2002). Harlen (2012a) states that young children's existing ideas (theories) may influence what is "observed" through focusing on specific observations that confirm their ideas, leaving out of account those that may challenge them. They sometimes make "predictions" that they already know to be true, and so these are not true tests of an idea.

In Soviet experiments, described by Zaporozhets and Lukov (2002), the development of reasoning about floating and sinking by children between three and seven years of age was observed. At age three, children already have their own ways of linking judgements together. Several judgements were made based on everyday experience. At first, it seemed that the children based their generalisation on one criterion, for example the size of the object, which led to mistakes. It seemed that when a series of floating objects was observed, the child would assume that all the objects would float, and the same when a series of sinking objects was observed (Zaporozhets & Lukov, 2002).

In those experiments, after a four-year-old had observed a series of wooden objects that floated, he predicted that a metal object would also float, but as soon as he saw the metal object sank, he corrected his answer. The Soviet researchers concluded that children could engage in self-observation, analysing their thinking, but would solve such problems in their normal daily experiences. Three- and four-year-old children can make judgements about objects, where the judgements are based on the properties of the objects. Although children use predictions, it is only possible with links between judgements and the reasoning process having connections with the object the judgements are about. They can link past and present judgements about the same object. Their judgement comes about through generalising several facts that characterise an object. In that research, the children were also making judgements about objects based on reasoning about a series of objects presented as a series. Such judgements could influence the judgement about one object because of the judgements about several objects (Zaporozhets & Lukov, 2002).

In the five- to seven-year-old group, the children's everyday experience expanded, the conditions of their activity became more complicated and richer, leading to changes in the reasoning process. From this, Zaporozhets and Lukov (2002) identify the main reason for the changes in the child's thinking as the nature of the child's activity and the orientation towards the surrounding reality. First, children perform acts with particular objects, without distinguishing the object from the action. After having mastered the acts, they can be carried out with different objects. The child's more relative independence leads to independence in reasoning.

At this stage of development, reasoning depends on the sequence in which objects are handled and how the objects perform during the acts. Experiments on floating and sinking in the age group of five to seven years showed that what the children did with objects and how they did it were important (Zaporozhets & Lukov, 2002). After a floating spoon collected water and sink,[1] a child explained that it had sunk because of the way it was put in the water and tried to sink floating objects by the way they were put in the water.[2] The children justified their reasoning using practical experiences from their own lives; for example, a toy duck would float because a child had seen ducks floating on a dam. Their reasoning was intricately linked with their activity; so,

[1] After putting an aluminium spoon in the water, which floated, a child put a spoon in the water, which collected water and sank. The child did the same with a metal box lid, explaining that it sank because of the way it was put in the water. The child tried to repeat it by putting a wooden block vertically in the water.

[2] A child replied that a wooden locomotive would not float as it had wheels and needed rails, while another replied that a toy duck would float as the child had seen ducks floating on the water. Another suggested sinking a wooden pencil box by putting bricks in at, as the child had observed before.

they would first do the activity with the object before giving an opinion whether an object would sink or float (Zaporozhets & Lukov, 2002).

The children began to sense the contradictions and inadequacy of their judgements, forecasting and confirming judgement. They would manipulate the objects to confirm their judgements; for example, if a child had predicted that an object would sink, he or she would try anything to sink it, for example plunging it or throwing it in so that it would collect water.[3] A child's conclusions and generalisations influence later judgements. Participants would turn away from the container if their prediction was proven wrong to reconcile their forecasting judgement with their confirming judgement. It proved that the children sensed contradiction in their judgement[4] (Zaporozhets & Lukov, 2002).

(iv) By encouraging peer learning, the power structure in the classroom is changed; the children understand that their answers do not come from authoritative sources but from their own reasoning and problem solving. Through discussion, reasoning helps children understand their own thought process – an important step towards metacognition and self-regulation of learning. Understanding that a person's knowledge is built from the person's own cognitive activity promotes intellectual autonomy. It is important to respect children's ideas to understand their reasoning processes and support their development of intellectual autonomy and self-regulated learning (Hong, Torquati, & Molfese, 2013).

Children are curious about science and scientific subjects, ask questions, and spontaneously manipulate objects (Van Dijk & Steenbeek, 2018). They are ready and excited to develop skills and an understanding of science (Kolokouri & Plakitsi, 2016). Harlen (2012b) values dialogue in the classroom and indicates that it contributes to the development of understanding. The accelerated rate of language and cognitive development between ages three and seven enables the young child to understand scientific phenomena (Van Dijk & Steenbeek, 2018).

[3] A participant said that iron would sink because it expanded in water; she even put her hand in the water and straightened out the wire to prove that it expanded.

[4] A participant was convinced that any object made of iron would sink and predicted that a tin box would sink because it was made of iron. When it floated, the child insisted that it would sink. When confronted with the facts, he replied that he had guessed that it would sink.

Harlen (2012b) suggests that children should have the chance to express themselves by using their own words and writing their own opinions (understanding), hypotheses, and conclusions through a free and collaborative process that will increase their self-confidence. Hong et al. (2013) draw attention to the fact that children learn from one another when they explain their reasoning processes. Metacognition and taking perspective are supported by children in explaining their thinking to others. Children need to use inhibitory control, a key component of executive functioning, to suppress their own perspective and expression while considering the perspectives of others.

It is important for children to pose a plan, predict outcomes of experiments, observe to test ideas, and use their senses to make observations. Tools such as magnifying lenses, eyedroppers and cameras can be used to improve observation (Albert Shanker Institute, 2009). Bybee (2011) finds it important that teachers help children understand the importance of accurate observations and measurement and help them to increase their accuracy. Children must use their observations to formulate answers to their scientific questions. The ability to use evidence as the basis for an explanation is vital to science.

Depending on children's age, the teacher may need to help them make connections between observations and the evidence. Moonaw (2013) regards the role of the teacher as important through the questions they pose and the conversations they have with children. Their interaction with materials can expand children's use of scientific inquiry, increase their thinking skills, and provoke deeper investigations (Bybee, 2011).

(v) Collaboration by peers and teachers is important to improve children's learning of science. Harlen (2012a) views it as important for groups of children to have space to work together (collaboration) and access materials. Together they should systematically compile, classify, and order collected information and make predictions based on previous experience and background knowledge.

Although children can test their theories on their own, Hong et al. (2013) express the opinion that they often need an adult who is attuned to their theories and can provide opportunities to test these. Creating a scientific ethos within early childhood classrooms is necessary for fostering science process skills. Science is a social enterprise, and norms, values, and meanings related to science learning are mediated through interactions. A classroom environment that values scepticism, open-mindedness, the examination of evidence, and listening to multiple perspectives can help children develop important scientific habits of mind.

It is unlikely that such habits of mind would develop in an environment where children worry about having the correct answer or where the interaction among children is not respectful. Children need a classroom culture in which all learners feel comfortable and everyone can participate in all aspects – hands-on, thinking, talking, and writing (Harlen, 2012a). In other words, children use different methods to collect information.

4.4.4 The South African curriculum

The South African CAPS document (Department of Basic Education, 2011) makes no mention of the methodology to be used for the teaching of the science section of life skills as part of Beginning Knowledge. The only reference to methodology is the following two descriptive comments under the heading “Explaining the life skills study area”: scientific process skills include the process of inquiry which involves observing, comparing, classifying, measuring, experimenting, and communicating; while technological process skills include investigating, designing, making, evaluating, and communicating.

No specific reference is made to how teachers should teach these skills or how children should learn the science content in the Beginning Knowledge in the South African curriculum. There is also no reference to IBSE, play, or playworlds as a methodology for the science learning of the young child.

4.4.5 International curricula

The following curriculum documents of various countries have been scrutinised to see how they reflect the specific methodologies that are required when teaching specific content: the Australian curriculum, Next Generation Science Standards, La main à la pâte, Creative Little Scientist, and Curious Minds (TalentenKracht).

4.4.5.1 The Australian curriculum for children years K to 2 (2016)

The Australian curriculum for children years K to 2 (5 to 8 years of age) states that in this age group, children are curious about their immediate world and have a desire to explore and investigate things around them, asking questions that lead to speculation and the testing of ideas. Exploratory, purposeful play is a central feature of their investigation. In this age group, observations utilising their senses are important.

According to the Australian curriculum, unifying ideas for learners in this age range are as follows:

- Exploration, which includes investigation of objects and things around them as a precursor to more direct inquiry in later years.
- Observation through the senses to observe and gather information about the environment, looking for what is the same and what is different.
- Observing similarities and differences, and comparing, sorting, and classifying to create an order that is more meaningful.
- Many changes occur in the world, for example in materials, the position of objects, and the growth cycles of plants and animals. Some of these changes are reversible, but many are not. These changes vary in rate and scale.
- Questions and ideas about the world become increasingly purposeful; explanatory ideas are developed and tested through further exploration.

This Australian curriculum only addresses IBSE, with no reference to play or playworlds. The curriculum only recommends observation as a thinking skill, but as indicated by Chaillé and Britain (2003), the most interesting changes occur over longer periods and are less visible to young children.

4.4.4.2 Next Generation Science Standards (2017)

In the United States of America, the Next Generation Science Standards (2017) are a curriculum for children from kindergarten (5-6 years old) to Grade 5. This curriculum is an inquiry-based model, stating that in kindergarten, children are expected to demonstrate grade-appropriate proficiency in asking questions, developing and using models, planning and carrying out investigations, analysing and interpreting data, designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. They are expected to use these practices to demonstrate understanding of the core ideas.

Although the Next Generation Science Standards suggest IBSE, there is no mention of play or playworlds as alternative methodologies. According to Chaillé and Britain (2003), the curriculum points to the idea of children being able to experience chemistry transformations through play activities, for example playing with clay, stacking blocks, or mixing different materials, such as water and paint.

4.4.4.3 La main à la pâte

The French foundation La main à la pâte aims at improving the quality of science and technology teaching in primary and middle schools. It is a foundation for scientific cooperation founded in 2011 by the Académie des Sciences, the École Normale Supérieure in Paris, and the École Normale Supérieure in Lyon. The activities of the foundation are carried out both within France and internationally, aiding in and providing professional development to teachers. Programmes are designed to help them implement inquiry-based learning that stimulates a scientific spirit in learners, understanding of the world, and capacities for expression (Fondation La main à la pâte, n.d.).

Léna (2002) describes the general idea of La main à la pâte, which means "hands-on", as to involve children and get them to participate in the discovery of natural objects and phenomena. Children should be brought into contact with phenomena in their reality (outside of virtual reconstructions), directly through observation and experimentation to stimulate their imagination, to broaden their mind, and to improve their command of the language.

The La main à la pâte classroom is a learning space where learners' questions are referred to the other learners in the classroom (Léna, 2002). The learners are asked for their opinion, and they need to formulate a hypothesis. In this way, their imagination is stimulated. This is followed by a simple experiment observation, manipulation, and measurement. The learners need to compare their results to the initial hypotheses, which gives rise to the dialectic of reasoning and experiment that lies at the heart of research work. Lastly, the learners have to express their thoughts in statements, enriching their vocabulary and refining their logic. In investigations with living creatures, the learners cannot use experimentation but only their senses.

The La main à la pâte approach focuses its entire methodology on IBSE. Again, there is no mention of the idea of play or playworlds in its curriculum.

4.4.4.4 Creative Little Scientist

Creative Little Scientist was a 30-month comparative study funded by the European Union and working across nine participating countries – Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania, and the countries of the United Kingdom. The Creative Little Scientist project sought to build a picture of policy and practice in science and mathematics education for children aged three to eight years and their potential to foster creativity and inquiry-based learning and teaching (Stylianidou, 2014).

The recommendation of the Creative Little Scientist project is that curriculum and policy guidance should emphasise the important roles of play-based approaches, child-initiated activity, and practical investigation in both pre-school and primary school. The conceptual framework of Creative Little Scientist considers playful experimentation and exploration to be inherent in all young children’s activity. Such exploration is at the core of IBSE and creative approaches in early-years settings. Policy in most partner countries promotes playful exploration in pre-school considerably more than primary education, with guidance that suggests the recognition of its value in promoting creative skills and dispositions. Greater importance is afforded to investigation and problem solving in primary education (Stylianidou, 2014).

Curious Little Scientist considers playful experimentation and exploration to be the genesis of IBSE but does not regard play and playworlds as pedagogy for science learning. Chaillé & Britain (2003) point out that not all topics in the natural world do lend themselves to active experimentation by children. Some of the most interesting transformations occur over a long period and are difficult for children to observe.

4.4.4.5 Curious minds (TalentenKracht)

TalentenKracht is a Dutch scientific research programme conducted by seven universities in the Netherlands, investigating the talent and development in terms of science and technology of children between the age of three and 14 (Swaab, Noordam, Munk, Van Dongen, & Sjoer, 2012). In “TalentenKracht” talent stands not for “excellent” but for “competent”. In other words, talent is not only for achievers but for all children (Menninga & Van Dijk, 2016). Munk (2012) explains that several variables are contemplated within the area of talents, such as curiosity, enthusiasm, concentration, willingness to explore, task persistence, reflection, processing information, and verbalising, enabling children to look for solutions and optimal strategies. The child’s natural curiosity must be used to stimulate investigation.

TalentenKracht (2008) suggests an empirical process for the teaching of science and technology. The programme for toddlers and pre-schoolers is based on the properties of young children, namely logical reasoning, recognising of patterns, and finding their way around and at construction. Children of this age are amazed by the world around them; therefore, they ask questions, theorise, experiment, reason, and solve problems during their play. The aim of the programme is finding ways to map, preserve, and develop these talents.

Swaab and Noordam (2012) describe children as developing scientists, whose sense of wondering motivates them to want to know more and understand what they observe and experience with their senses. Experimenting follows the handling of objects in a quest to understand scientific phenomena. Experience leads to knowledge and skills – a schema, which is a representation of the memory of an experience. A schema can be a piece of knowledge, a pattern of behaviour, or a motor operation. The schema is activated in a situation where it is applicable. So, attention can be drawn to new parts of the situation. Schemas are used to give meaning and inform behaviour before the next phase of exploration.

TalentenKracht describes the development of new schemas as being developed either through instruction, exploration, or a combination of instruction and exploration (Swaab & Noordam, 2012). Self-discovery via exploration is a powerful learning mechanism and an important mechanism for establishing knowledge and skills. Not only knowledge is developed but also the skill to develop knowledge, that is, a process making knowledge possible.

TalentenKracht does not consider play or playworlds as methodologies for teaching science. According to Chaillé and Britain (2003), the basis of chemistry learning takes place through reconstruction and combination in play activities. In other words, not all play activities and the basics of dividing and construction will be learnt through play.

4.5 Summary

Due to technological changes science literacy becomes a necessity for the future grown-up. Young children are curious about scientific subjects, they about science by manipulating objects in their environment forming “small” scientific ideas. These ideas should develop into “big” ideas, by linking “small” ideas. Big ideas will enable children to link ideas from related but different events. The big ideas explain more events and are interlinked to form broad theories or principles.

Three teaching pedagogies was investigated namely play, playworlds and inquiry-based science education. Play helps children create an understanding of their surroundings world. The Scientific Playworlds model draws upon a cultural device that is related to the science being learned, and which request children to go on scientific journeys, together produce the dynamic imaginary scientific context. Inquiry Based Science Education approaches rely on the assumption that students will benefit if they try to find solutions to scientific problems encountered in everyday life, by asking questions, thinking of possible explanations, conducting investigations, and drawing conclusions.

The next chapters deal with the issues of considering relevant and appropriate content that young children need to be exposed to when considering developing their overall scientific-reflective capacities. The next chapter should be read while considering the importance of age phases in child development coupled with the possibility of utilising at least three different teaching methodologies.

CHAPTER 5: THE CONTENT OF THE SCIENCE CURRICULUM OF THE EARLY YEARS

5.1 Introduction

The young child of the 21st century is growing up in a world filled with smart devices (Bers González-González & Armas-Torres, 2019). Consequently, young children have access to the internet, digital clocks and bathroom scales, video machines, and computers that allow them to scan, take and store photographs and desktop publish (Feasey and Still, 2006). Shute, Sun, & Asbell-Clarke (2017) are of the opinion that because of this new world, it is essential that children, in general, become digitally literate. One of the main aspects of this is the fact that this technologically changed world will also influence and change the content and outcomes of education in general and science education specifically.

Currently, there is a debate among educators of science about the incorporation of the arts into STEAM education (Psycharis, 2018). The incorporation of the arts into the sciences will lead to a transdisciplinary approach that will support the development of children's inquiry skills and creative thinking skills. In other words, STEAM can be viewed as an educational teaching and learning vehicle that covers a broader spectrum of skills development. Although the current study concentrates on the learning and teaching of science content, scholars such as McClure, et al. (2017) are also of the opinion that just as the industrial revolution made it necessary for children to learn to read, the technology revolution has made it critical for all children to develop the necessary scientific habits of mind associated with high-quality science, technology, engineering, and mathematics (STEM) exposure. These scientific habits of mind are defined by Butler (2017) as a pattern of thinking characterised by the developing from critical reasoning, examining quantitative and qualitative information, and the capacity to place things into larger contexts and recognising connections.

McClure et al. (2017) provide some examples where the young child is learning these subjects through their daily activities, which include gardening, fort building, block stacking, playing at the water table, or lining up by height in the classroom. These high-quality early STEM or STEAM experiences can support children's growth across areas as diverse as executive functioning and literacy development. McClure et al. (2017) mention that children's earliest experiences with STEM or STEAM will map out the way for later success, while mediocre STEM or STEAM teaching can result in children losing confidence in their ability to do STEM or STEAM subjects.

Other phenomena present in the digital 21st century is the prevalence of ICT in the form of all kinds of digital technology, such as mobile phones, tablets, and many more. Yelland (2005) feels so strongly about it as to state that ICT has become an important civic requirement for interaction and participation in society, including education. Apart from the practical value thereof in everyday communication, ICT can support the development of higher order thinking skills, such as being able to think creatively and in divergent ways, analysing contexts and making plans to solve problems, posing problems, collaborating effectively in teams, monitoring progress, responding to feedback, synthesising ideas, and re-evaluating new plans where necessary.

Another way to introduce very young children to ICT can be through computer games. Mertala (2018) explains that ICT supports the interactional skills of children, as well as the development of writing and reading skills. In other words, ICT can be integrated into early childhood education to meet the changing educational needs of a digitised society.

In the 21st century, as technology has progressively become part of the workplace, there is a bigger need to use technology to support thinking. Moore et al. (2020) point out that young children adapt swiftly to digital and mechanical technology, such as computers, mobile devices, and building kits. Computational thinking is described by Lee, Grover, Martin, Pillai, & Malyn-Smith (2020) as the connective material that connects computer science to other disciplines such as STEM.

The value of computational thinking in STEM education is identified by Moore et al. (2020) as the involvement of problem-solving skills associated with using technology. Wing (2008) identifies ways computational thinking influences each of the STEM subjects. Computational thinking is a kind of analytic thinking, it shares with mathematical thinking the common method in which problems might be solved. It shares with engineering thinking the common ways in which the workings of complex systems are evaluated. Computational thinking shares with scientific thinking the general ways in which understanding computability, intelligence, the mind, and human behaviour can be approached.

In other words, the development of science content for the early years would have to consider not only the topics and domains that traditionally were part of the science curricula of the past, but also the contribution of technology and its accompanying domains.

5.2 The content of science for the young child

The learning of science for the young child should form the basis for the understanding of the natural and technological world around them (Harlen, 2001). In a rapidly changing technological world, it is important that everybody becomes "scientifically literate". Harlen (2001) defines scientific literacy as a broad basic understanding and competency in science and being at ease with key scientific ideas and skills. Harlen (2010) further explains that science education should enhance the young child's natural curiosity, their wondering about natural phenomena, and their questions about these. The teaching should build on children's natural inclination to seek meaning and understanding of the world. As children are constructing knowledge since birth, Harlen (2010) recommends that the selection of topics and activities for science teaching should progress from phenomena in their everyday lives towards key ideas empowering children to understand phenomena in the natural world and the relevance thereof to their daily lives.

Chaillé and Britain (2003) suggest four questions that can be used to identify possible content for science during the early years of development, namely: How do I make it move? – physics; How can I make it change? – chemistry; How does it live? – biology and ecology; How does it work? – planets, systems, and digit and electronic control.

These content areas are informative in the sense that they deal with the lacunae found in many of the science content curricula prescribed for the early years of development. A short summary of each of these content areas follows.

5.2.1 How do I make it move? (Intuitive physics)

Perceptual information forms the basis of what Goswami (2015) calls “naïve physics”. Chaillé and Britain (2003) identify the movement of objects through pushing, pulling, sliding, tilting, throwing, and so forth as one of the most immediate, visible, and comprehensible ways of experimenting with the physical world. Harlen and Léna (2011) point out that through the manipulation of objects, the very young child will come to understand the relationship between objects and the force acting on them.

Chaillé & Britain (2003) describe three categories of activities children can be engaged in when dealing with moving of objects, progressing from less to more complex. These categories are a logical progression in how children come to understand and increasingly conceptualise the movement of objects.

- In the first category, objects are to be moved and activities are designed to provide opportunities for action on objects that make them move, for example experimenting with the effect that changing the incline has on the movement of a ball.
- In the second category, the movement of object is more directed, with emphasis on movement towards something and the direction of movement, for example directing the movement of a boat with a stick.
- In the third category, the connection between the movement of objects and the actions of the child is the focus, and the representation of the object’s movement is of interest, for example visually following the movement of objects.

It is clear from the discussion above that although intuitive physics activities can be done, care should be taken when choosing specific content dealing with the intuitive development of movement in physics. The child needs to be exposed to specific activities to make sure there is a build-up in skills. This also implies that the age phase of the child plays a role in the choice of content.

5.2.2 How do I make it change? (Intuitive chemistry)

Chaillé and Britain (2003) define chemistry as involving the transformation of substances; therefore, they reason that transformations can be defined as early childhood chemistry. This beginner chemistry can be divided into reconstructions and combinations. Reconstruction involves the rearrangement of existing parts and structures to produce a new structure. It can be building or rebuilding with the same parts or construction by adding new parts, for example, construction with wooden blocks or more complex combinations of different types of construction materials that combine in different ways.

Combinations involve changes in substance and consistency, usually by combining materials, for example combining materials such as sand, water, and paint (Chaillé & Britain, 2003). Children enjoy pouring, mixing, stirring, and examining the different textures using their hands. In these cases, the focus should on the change from one consistency or substance to another – from powder to watery paint, or from white shaving cream to coloured shaving cream. When mixing paint, the focus should not be on the colour that will be created when two different colours are mixed, for example blue and red paint mixed will result in purple paint. In other words, what should be emphasised is when substances are combined, one of the properties that might change is the colour or shade.

This means care should be taken when introducing scenarios where there are several variables. Very young children cannot deal with many variables at once. This aligns with the work of Zaporozhets and Lukov (2002) on reasoning.

5.2.3 How does it live? (Intuitive biology and ecology)

Teachers place emphasis on plants, animals, and ecology as the most natural and appropriate way of teaching science (Chaillé & Britain, 2003). Ecological perspective taking means that the young child has developed a sense of wonder and respect for nature. Chaillé and Britain (2003) point out that the goal of teaching is gaining an understanding of the natural world with the goal of developing respect and understanding for living and non-living things – an ecological perspective.

In their first year already, children are able to make a distinction between living and non-living (Harlen, 2010). Worth and Grollman (2003) theorise that through their exposure to animals, such as pets, children develop the distinction between living and non-living. Goswami (2015) is of the opinion that when children observe objects changing speed and direction, they realise that objects that move on their own are alive and their movements are not predictable. According to Worth and Grollman (2003), this generalisation can also be the reason for misconceptions, for instance that wind-up cars are alive because they move on their own, or plants are dead because they do not move. Again this aligns with the findings of Zaporozhets (2002) as discussed in Chapter 2.

Worth and Grollman (2003) therefore explain that learning about living creatures should focus on the characteristics of organisms, which can be achieved by guiding children to compare what the living creatures look like, how they live, and how they change. This is achieved mainly by observation using perception, assisted with magnifiers and measuring tools while children record their findings. Through observation, they recognise the relationship between living organisms and their environment. They are also able to share their observations, reflect on what they see, arrange information, consider patterns, and generate questions.

The observation of the living world will also enable children to develop an appreciation for the diversity and variety of different living organisms (Worth & Grollman, 2003). It allows children to develop their ideas about the characteristics of living organisms, including their basic needs, life cycles, and dependence on one another and on the environment. Children should be motivated to treat all living creatures and their environment with respect.

Chaillé and Britain (2003) explain that when children observe a spider web, they must be aware of the spider as a living creature. While observing a spider weaving a spider web, they should connect the spider's weaving with their own creation of space. Through making the connection between the natural world, living and non-living, and themselves, the basis of their understanding of ecology is formed. In addition, Chaillé and Britain (2003) are of the opinion that teachers should point out the interdependence of plants and animals as well.

Worth and Grollman (2003) identify the understanding of children's thinking about living things and clear goals as necessary for creating experiences to guide children to a deeper awareness and understanding of the living world around them. By encouraging children to observe more closely and notice patterns in what they see, they can begin to refine their ideas, laying the foundation for more reasoned and evidence-based theories of life. Worth and Grollman (2003) also point out that the studying of living things is a lengthy process, for example watching a plant grows or observing and reflecting on the life cycle of an organism. The children's own documentation and recording, along with the teacher's documentation and ongoing classroom discussion, can provide a bridge from week to week and from month and month to observe these slow processes. This means that when dealing with the content of biology, where there are living systems involved, the content focus should be of such a nature that the children can interact with it, without damaging or destroying living things.

All of the above-mentioned content areas will also be accessible making use of the different modern-day technological tools. In the 21st century, it is important to also consider the integrated nature of the science curriculum with different aspects of science, including technology.

5.3 Teaching and learning in STEM or STEAM using digital technologies

Computer programming promotes computational thinking skills. Shute et al. (2017) identify the analysis of problems as a requirement for computer programming, breaking it down to its constituent processes and requiring abstraction and generalisation. Bers et al. (2019) and Sullivan, Kazakoff, and Bers (2013) have found that children from the age of four years can build and programming basic robots. According to Bers et al. (2019), children at a young age are capable of learning to code through fun, play, and creativity. The introduction of robotics into an early childhood context requires an appropriate developmental pedagogical approach and should engage children cognitively, socially, physically, emotionally, and creatively.

Sullivan et al. (2019) describe robotics as the early childhood manipulatives of the 21st century, and as new technology, it provides a variety of learning possibilities. Although research on robotics and computational thinking in childhood education is still in its early stages, Bers et al. (2019) point out that these studies have shown the potential of robotics education for the early years. The manipulation of robotic objects develops fine motor skills and hand-eye coordination (Bers et al., 2019; Sullivan et al., 2019). Another area of development through robotic toys identified by Shute et al. (2017) is the development of metacognitive skills. It provides a playful and developmentally appropriate learning experience, which includes problem solving, abstract thinking, and logical thinking. Sullivan et al. (2019) further identify opportunities for creativity, social interaction, and cognitive development through robotic toys, as robotics makes abstract ideas more concrete. Children can observe the result of programming, that is, abstract ideas made concrete, through robotic actions.

Bers et al. (2019) investigated the use of KIBO robotics to teach children programming and computational thinking skills in the context of an educational programme that uses robotics to support positive interpersonal behaviour. Bers et al. (2019) describe the positive technological development framework as the six C’s: communication, collaboration, community building, content creation, creativity, and choices of conduct. The intrapersonal domains are enhanced by content creation, creativity, and choices of conduct. The interpersonal domain and social aspects are addressed by communication, cooperation, and community building (see Figure 5.1).

Bers et al. (2019) use the positive technological development framework (Figure 5.1) for describing how technology can be designed and utilised to promote positive behaviour and how this behaviour can, in turn, yield developmental assets. This theoretical model involves three components, namely individual assets, technology-mediated behaviours or activities, and applied practice. Figure 5.1 shows how individual assets and technology-mediated behaviours, or activities are connected and provides examples of how they can be implemented in classroom settings. The positive technological development framework provides a method for supporting these positive behaviours using new technologies in different contexts. Positive technological development shows the importance of encouraging collaboration instead of competition, promoting shared resources and caring about one another. Collaboration is included in the whole learning process.

Figure 5.1: Coding as a playground – programming and computational thinking in early childhood classrooms (Bers et al., 2019)

Bers et al. (2019) are of the opinion that the positive technological development framework can be used for both the design of new educational technologies and technology-rich interventions, as well as their evaluation. Some activities could include the sharing of tools or materials, working on the same project, seeking the help of other children, making suggestions, and giving feedback. Bers et al. (2019) theorise that KIBO robotic kits can be used to foster and integrate science, technology, engineering, art, and mathematics (STEAM) integration, as it is possible to design curricula that integrate robotics with music, dance, and culture and with engineering and programming.

Despite the urgent need for STEM education for modern children, Harlen and Léna (2011) refer to recommendations of the European Commission (2011) mentioning that one of the possible reasons for children not being interested in studying science is the way it is taught, which greatly influences their attitude towards the subject. In other words, today's education should be adjusted to prepare tomorrow's citizens for the needs of a digitised world. Furthermore, it is not only the content that may be a hindrance in the choice of children being interested in the sciences but also, ultimately, the way the teachers teach the subject. So, an important question that can be asked is what the role of the teacher is in teaching science to the young child growing up in the 21st century. What knowledge and skills does the teacher need and how will the teacher's knowledge and skills influence teaching and learning?

5.4 The influence of the teacher on teaching and learning in the sciences

5.4.1 The role of the teacher

Yoon and Onchwari (2006) identify the creation of a rich environment for science learning as a crucial role for the teacher. While Kornelaki and Plakitsi (2018) describe the teacher as a catalyst in the teaching process, Karpov (2003) depicts the teacher as a mediator in the activities necessary for science learning. In other words, the quality teaching of science depends heavily on the teacher.

According to Harlen and Léna (2011), the role of the teacher is to enable the child to understand and enjoy finding out about the natural world (small ideas) to become big ideas through broad generalisation. The teacher should create a learning environment that will develop a deep understanding of science concepts. The learning environment should be created in such a way that a sense of awe and wonder is created, as the National Research Council (1998) views it as important for exploring and understanding the natural and technological world.

Vosniadou and Ioannides (1998) point out that children do not enter the pre-school or primary school science learning as a "tabula rasa" or blank slate, as they have already acquired rich knowledge about the physical world based on their everyday experiences. The responsibility of the teacher is to help children understand the relationship between new situations and familiar ones (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2020). The teacher should also focus children's attention, structure experiences, and organise the information children receive, while helping them develop strategies for intentional learning and problem solving.

An important factor in the effective teaching of science, as explained by Cho, Kim, and Choi (2003), is the teacher's attitude towards science teaching. The teacher's attitude towards science teaching influence their understanding of science and their thinking about classroom practices. Another important factor in the teaching of science in primary school is the motivation of the teacher. Barenthien et al. (2020) identify motivation as crucial for the implementation of science learning opportunities for children. Motivation can be divided into different dimensions, namely enthusiasm and self-efficacy beliefs. Enthusiasm and self-efficacy are predictive of their instructional quality. While enthusiasm describes the level of positive emotional experiences during teaching, self-efficacy refers to teachers' perception of their ability to successfully perform the task of teaching (Barenthien et al., 2020; Gerde et al., 2018). Barenthien et al. (2020) highlight science-specific motivation as especially important for pre-school teachers, as the curriculum is less structured, and teachers will only teach science content regularly when they are highly motivated.

Barenthien et al. (2020) and Gerde et al. (2018) emphasise the importance of self-efficacy to promote children's development and learning, as teachers' low self-efficacy will prevent them from teaching science, and therefore, there will be fewer learning opportunities. Teachers should believe that they do have the skills to promote children's development and learning (Gerde et al., 2018). In this way, teachers' sense of self-efficacy is related to success in children's learning. Teachers with high self-efficacy for teaching will have more positive expectations for learner achievement and better learner outcomes. High teacher self-efficacy predicts teachers' use of developmentally appropriate practices in pre-school and primary school. It implies that teachers' low self-efficacy can be a barrier to implement developmentally appropriate practices for children and can result in poorer outcomes. Teachers with domain-specific self-efficacy will feel confident in their own ability to teach specific content. Gerde et al. (2018) have found that in pre-school, teachers' self-efficacy is highest for literacy, lower for science, and lowest for mathematics.

The question that arises is what kind of knowledge is necessary for teachers to feel confident to teach science in such a way that will positively influence the science learning of the young child.

5.4.2 Teachers' own content knowledge

Neumann, Kind, and Harms (2019) point out that Lee Shulman played a crucial role in arguing for teaching as a profession. Shulman (1986) proposed a special domain of teacher knowledge, which he termed “pedagogic content knowledge”, that is, knowledge unique to teaching. Ball, Thames, and Phelps (2008) explain that this suggests that there is a kind of subject-matter-specific professional knowledge. This term has been interpreted differently by different researchers with variances in what the term includes. Moreover, there are differences in how researchers think it relates to content knowledge and the practice of teaching. A central contribution of Shulman and his colleagues was the re-examining of teacher knowledge in ways that address the role of content in teaching.

The second contribution of Shulman (1986) was to portray content understanding as a special kind of technical knowledge crucial for the profession of teaching. Schulman (1987) distinguishes the following categories of teacher knowledge:

- General pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organisation that appear to transcend subject matter.
- Knowledge of children and their characteristics.
- Knowledge of educational contexts, ranging from the workings of the group or classroom and the governance and financing of school districts to the character of communities and cultures.
- Knowledge of educational ends, purposes, and values, as well as their philosophical and historical grounds.
- Content knowledge.
- Curriculum knowledge, with a grasp of the materials and programmes that serve as the “tools of the trade” for teachers.
- Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers – their own special form of professional understanding.

Based on the work of Shulman (1986) and Ball et al. (2008), different domains of knowledge for teaching that is necessary for successful teaching can be identified. This knowledge falls into two main groups, namely subject matter knowledge and pedagogical knowledge. These domains of knowledge for teacher are illustrated in Figure 5.2.

SUBJECT MATTER KNOWLEDGE PEDAGOGIC CONTENT KNOWLEDGE

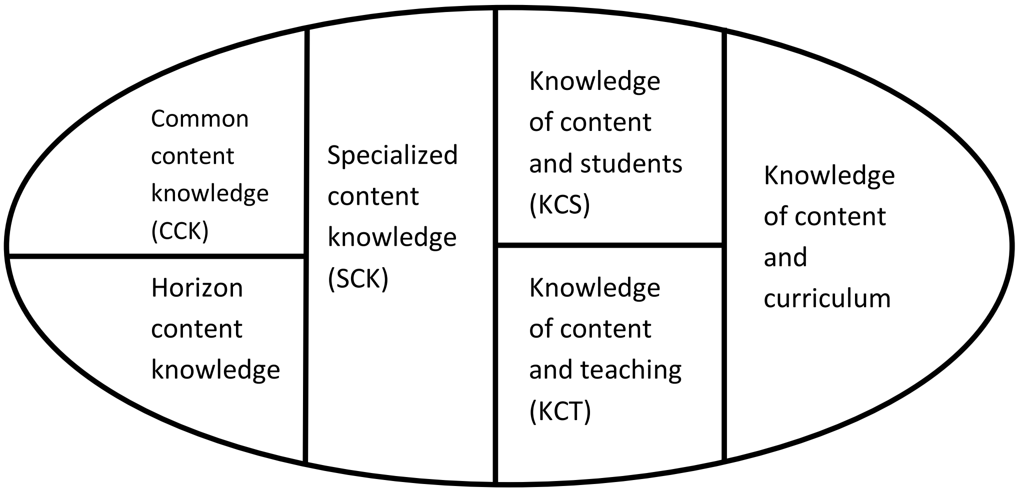

Figure 5.2: Domains of knowledge for teaching (Ball et al., 2008)

The first domain of knowledge identified by Ball et al. (2008) is common content knowledge (see Figure 5.2). They define it as the subject knowledge and skills used in a variety of settings other than teaching. If teachers have sufficient science knowledge, they would be able to identify mistakes in science textbooks and in the scientific reasoning of learners.

The second domain of knowledge identified by Ball et al. (2008) is specialised content knowledge, which is the subject knowledge and skills unique to teaching (see Figure 5.2). It is subject knowledge not typically needed for purposes other than teaching. Ball et al. (2008) point out that when the science teacher has the necessary specialised content knowledge, he or she will be able to set tasks that demand unique understanding and reasoning. Teaching requires knowledge beyond that being taught to learners. It includes responding to children's "why" questions, linking representations to underlying ideas or other representations, connecting topics from previous and future years of education, explaining goals and purposes, evaluating and adapting content in textbooks, evaluating the plausibility of learners' claims, and asking productive questions. Specialised content knowledge for the science teacher is, in the first place, knowledge of science but also knowledge of the curriculum and the children to be able to set tasks that will promote understanding and reasoning. The teacher's knowledge of science should also be sufficient to answer the learners' questions, but again on the age and development level of the learners.

Pedagogical content knowledge is described by Ball et al. (2008) as crucial knowledge for teachers and can be defined as the intersection of knowledge of the subject content, on the one hand, and knowledge of pedagogy, on the other. Pedagogical content knowledge is principal knowledge needed for teaching, as it implicates how teachers understand how to help the learners understand and how learners understand specific subject matter. The science teacher should have knowledge of how particular subject matter topics, problems, and issues can be organised, represented, and adapted to the diverse interests and abilities of the learners and then presented for instruction.

The third domain identified by Ball et al. (2008) is knowledge of content and students, combining knowing about students and knowing about the subject (see Figure 5.2). If the science teacher has the necessary knowledge of content and students, he or she will know what the students are likely to think and what they will find confusing. The teacher will be able to choose examples the students will find interesting and motivating and will know whether they will find it interesting and motivating. Teachers should also interpret emerging incomplete thinking, which requires interaction between specific subject understanding and familiarity with students and their thinking.

The last domain identified by Ball et al. (2008) is knowledge of content and teaching, combining subject knowledge with knowledge of teaching (see Figure 5.2). It requires subject knowledge of the design of instruction, such as the sequencing of content. Knowledge of content and curriculum is a combination of teachers' understanding of how children learn, teachers' pedagogic knowledge of the subject, comprehensive knowledge of the subject content, and knowledge of the content and the curriculum (see Figure 5.2). The science teacher's knowledge of content and teaching will be reflected in choosing the best instruction design, for example, inquiry-based teaching as well as the sequencing of the science content to improve science knowledge and scientific reasoning.

Bayram-Jacobs, et al. (2019) distinguish four pedagogical content knowledge components as depicted in Figure 5.3:

- Knowledge of goals (GO) refers to teachers' knowledge of the goals and objectives of the subjects they teach and knowledge of the vertical curriculum.

- Knowledge of students' understanding of science (SU) includes teachers' knowledge of the requirements for students to learn specific subjects and the skills, pre-knowledge, and abilities associated with these.
- Knowledge of instructional strategies (IS) addresses subject-specific and topic-specific strategies to teach science content.
- Knowledge of ways to assess students' understanding (AS) covers knowledge of dimensions of learning to assess and knowledge of assessment methods.

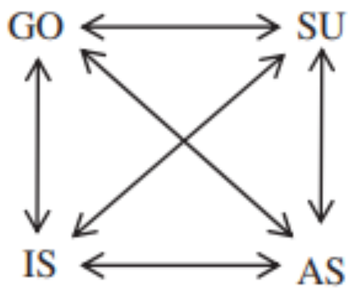

Figure 5.3: Pedagogical content knowledge components and their interconnections (Bayram-Jacobs et al., 2019)

Bayram-Jacobs et al. (2019) view the richness of the pedagogical content knowledge components and the interconnectedness of these components as an indication of the strength of teacher pedagogical content knowledge and, therefore, its transference to classroom practice. This implies that the science teacher's pedagogical content knowledge will influence what the teacher teaches or does not teach. When the teacher is not familiar with children's understanding of science, he or she will not be able to apply different teaching strategies according to topics and will not be able to apply assessment according to the dimensions of science learning or the assessment method according to the specific grade (age and development of the learners).

Classroom practice in the 21st century is also influenced by the progressive availability of digital and networked tools that have the potential to fundamentally transform the teaching and learning process. Koehler, Mishra, Kereluik, Shin, and Graham (2014) have found that teachers often lack the knowledge to successfully integrate technology in their teaching. Technology is used more as aids of efficiency and devices of extension rather than transforming tools. Researchers who try to understand better how teachers can better use technology in their classrooms also base it on the types of knowledge necessary for the teacher.

Mishra and Koehler (2006) extended Shulman's (1986) characterisation of teacher knowledge to contemplate how technology knowledge can improve effective teaching. Three knowledge components form the foundation of the TPACK framework, namely content knowledge, pedagogical knowledge, and technology knowledge (see Figure 5.4). Four components in the TPACK framework address how these different knowledges interact with, constrain, and facilitate (afford) one another, namely technological content knowledge, pedagogical content knowledge, and TPACK (Koehler et al., 2014).

Koehler et al. (2014) define technological content knowledge as knowledge of the reciprocal relationship between technology and content. Disciplinary knowledge is often defined and constrained by technologies and their representational and functional capabilities. Pedagogical content knowledge, according to Shulman's (1986) notion, is used to demonstrate how particular topics, problems, or issues are presented for instruction.

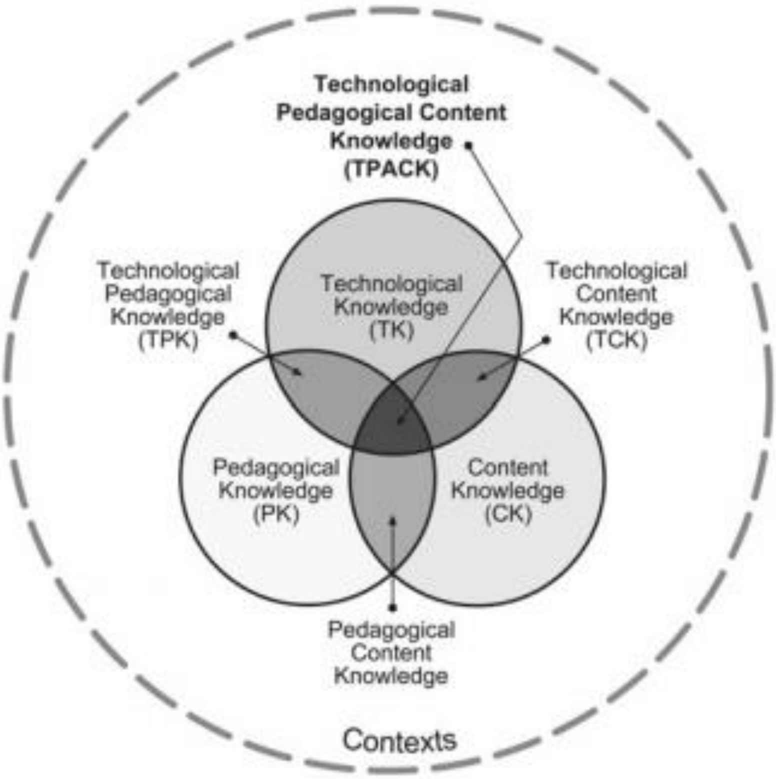

Figure 5.4: The TPACK framework (Koehler et al., 2014)

Technological content knowledge refers to an understanding of technology that can constrain and afford specific pedagogical practices (Koehler et al., 2014). TPACK is knowledge about the complex relations among technology, pedagogy, and content that enable learners to develop appropriate and context-specific teaching strategies.

The TPACK framework is not the only framework developed to understand and explain teachers' use of technology. Although there are different approaches, they all agree that the inclusion of new technologies in our daily lives requires teachers to possess knowledge that connects the affordances and constraints of these technologies to the transformation of content and pedagogy (Koehler et al., 2014). Once again, the science teacher's content knowledge of science and the pedagogic knowledge of what and how to teach will influence the quality of science teaching.

5.4.3 The influence of the lack of content knowledge on science teaching

Various scholars, for example Beni et al. (2012), Watters, Diezmann, Grieshaber, and Davis (2001), Rohaan & Van Keulen (2011), Appleton (2008), and Kallery and Psillos

(2001), have identified primary school science teachers' lack of content knowledge as having a negative effect on their teaching. Barenthien et al. (2020) view professional competence as a requirement for pre-school teachers to be able to provide pre-schoolers with science-specific learning opportunities. They have found that the science content knowledge of pre-school teachers is lower than that of primary school teachers. This results in teachers being unable to identify science-specific content in everyday situations, and in the process, opportunities to teach science are not utilised. The lack of content knowledge is also the reason teachers feel less confident and would rather not teach science.

The lack of content knowledge has the following negative effects on the teaching of science:

- It causes trepidation, insecurity, and uncertainty in teachers (Roth, Goulart, & Plakitsi, 2013).
- This uncertainty in teaching leads to a hesitancy to teach science (Appleton, 2008) and avoidance behaviour (Beni et al., 2012; Roehrig, Dubosarsky, Mason, Carlson, & Murphy, 2011; Rohaan & Van Keulen, 2011; Yilmaz-Tuzun, 2008).
- Teachers ask lower-level questions (Bustamante, Greenfield, & Nayfeld, 2018; Kallery & Psillos, 2001).
- Teachers will use lecturing instead of learner-centred teaching techniques that will result in science understanding (Beni et al., 2012; Yilmaz-Tuzun, 2008).
- The lack of subject knowledge and misconceptions will influence teachers' lesson planning, and their misconceptions will be embedded into their lesson plans and teaching and pass the misconceptions on to their learners. According to Kallery and Psillos (2001), some primary school teachers have alternative conceptions of current scientific ideas and have the same misconceptions as learners.

Yoon & Onchwari (2006) have found that pre-school and primary school teachers feel less prepared for science teaching, resulting in low confidence and a reluctance to teach science. The lack of confidence to teach science has also been identified by Appleton (2008), Fleer (2017), Gerde et al. (2018), Kallery and Psillos (2001), and Watters et al. (2001). Due to their lack of confidence, teachers downplay science

(Chaillé & Britain, 2003) or teach a version of science that more closely resembles subjects such as language or social studies (Beni et al., 2012), or they simply do not teach science at all (Barenthien et al., 2020).

Bustamante et al. (2018) describe teachers' preparation programmes as typically not preparing teachers to teach STEM content. Kornelaki and Plakitsi (2018) are of the opinion that meaningful teacher training should be a priority. Only teachers who feel confident and well-trained will be able to make science education sufficient and appealing to learners. Gelman and Brenneman (2012), Gerde, Pierce, Lee, and Van Egeren (2018), and Morris et al. (2012) all agree that children are unlikely to develop the necessary science knowledge and skills without effective science instruction and experience. Fitzgerald and Gunstone (2013) identify another negative influence of teachers' lack of confidence as teachers being unable to advance the development of a strong conceptual understanding of science in cases where lessons have stimulated their interest.

The lack of teachers' pedagogical content knowledge will influence the teaching of science in pre-school and primary school. Barenthien et al. (2020) have found a positive relation between learner achievement and teachers' pedagogical content knowledge. In primary school, the generalist character of the teaching of primary school teachers is identified by Timostsuk (2015) as being the reason for specific subject-related challenges. It has been found that primary school teachers have difficulty with implementing science inquiry teaching, problems in teaching school science as argumentation or in the adaptation of curriculum materials. They also experience difficulty with understanding the characteristics of learners' ideas. In other words, they experience problems with components of science pedagogical content knowledge.

Teachers' content knowledge influences different aspects of their pedagogical content knowledge. Kallery and Psillos (2001) point out that teachers' knowledge of the content influences the way they teach and represent content to the learners.

5.4.4 The status of science teaching in the Foundation Phase in South Africa

In her study on the historical development of life skills education in early childhood in South Africa, Du Preez (2016) has found that the subject matter knowledge and the pedagogical content knowledge of the teaching of Beginning Knowledge education in the Foundation Phase in South Africa are still facing challenges and are not yet on par with most recent findings and recommendations of international scholars on how to sufficiently teach this knowledge to the young child.

This is a confirmation of what Beni et al. (2012) has found in their study on South African Foundation Phase teachers' understanding of the natural science curriculum within the life skills learning programme. Beni et al. (2012) have found that Foundation Phase teachers have knowledge about children, teaching, learning, and the curriculum, but experience the teaching of science as exceptionally difficult because of their lack of the necessary background knowledge to integrate the content and pedagogy on their own. Some of the reasons Beni et al. (2012) have identified are the lack of a specific content in the curriculum for teachers to follow, teachers' lack of content knowledge, the unavailability of resources, large class sizes, insufficient teacher identity and teacher confidence, the background of teachers, and the fact that science is integrated into the life skills learning programme.

In their study, Beni et al. (2012) have found that teachers have limited experience of science, and their low level of the teachers' content knowledge of science effects science teaching in the following ways:

- A relationship exists between teachers' choice of content and their confidence to teach the content. Teachers feel more confident to teach biological-related topics, such as plants, nutrition, weather, water, and the human body systems. The teaching of these topics in the Foundation Phase may be easier because it seems natural and innate, as the natural environment can be used as a resource. Teachers are less confident to teach physical science-related topics, as they seem to teach only the content they feel confident to teach.
- Foundation Phase teachers are not science specialists; they do not have a broad spectrum of science content knowledge, and this influences their instructional practices. Although they see the value of science and know that

the inquiry-based approach should be promoted, they do not have the content knowledge to employ it.

- Their weak content knowledge restricts teachers' ability to implement innovative curriculum changes.

Du Preez (2016) found that subject matter knowledge and pedagogical content knowledge of the teaching of Beginning Knowledge education in the Foundation Phase in South Africa[5] were not on the same level with the latest findings and recommendations of international scholars of how to sufficiently teach science content to the young child. She found that the importance of and the need for sophisticated teaching of Beginning Knowledge education to promote scientific literacy, sensitivity and awareness of socio-scientific issues, and citizenship for the 21st century, were not optimally actualised and communicated in the South African curriculum.

An appropriate educational programme is crucial for spontaneous concepts to be transcending to scientific concepts. To achieve it, Vygotsky (1987a) reasons that a curriculum should be a learning programme that aids teachers to use it to purposefully plan content for children to make sense of their experiences.

Barenthien et al. (2020) draw attention to the fact that science has become an important domain in early childhood curricula, as studies have shown that early science knowledge and motivation may influence learners' performance in science later in school. An appropriate science teaching curriculum, according to Kolokouri and Plakitsi (2013), should promote understanding of natural concepts and develop scientific argumentation concerning various natural phenomena. An appropriate science curriculum will result in future citizens that will lead a life of responsibility and decision making in the contemporary society. Barenthien et al. (2020) identify the aim of early science education as the promotion of knowledge of science concepts, knowledge about scientific inquiry, and children's interest in science.

The curriculum for pre-schoolers and school-age children will differ based on the children's level of development. Chaillé and Britain (2003) view the purpose of the

[5] The content and concepts of Beginning Knowledge have been drawn from social sciences (history and geography), natural sciences, and technology.

curriculum for pre-schoolers as theory building, and the way pre-school children learn prevents the curriculum from being prescriptive and rigid. Instead, the curriculum should be responsive to the needs, interests, and capabilities of the learners.

Harlen (2010a) describes the value of a written curriculum as setting out goals of learning and the principles that should guide its implementation. The curriculum document should develop big ideas and not just be simply a series of facts or a collection of small ideas. The curriculum document should set out the progress towards big ideas in such a way that it clearly is a continuous process.

In the 21st century, ICT teaching requires a radical rethinking of the curriculum that encapsulates contemporary notions about creativity, imagination, and design that provide opportunities for children to explore and investigate in ways not possible before. Bers, et al., (2019) point out that in recent years, there has been a push to introduce coding and computational thinking in early childhood education, and robotics is an excellent tool to achieve this. However, the integration of these fundamental skills into formal and official curricula is still a challenge, and teachers need pedagogical perspectives to properly integrate robotics, coding, and computational thinking concepts into their classrooms.

Different levels of integration of ICT occur in different countries in the world. The Finnish curricula for early childhood education and pre-primary education include support for ICT competence in early childhood education (Mertala, 2018). Since 2016, all elementary learners in Finland must learn coding (Bers et al., 2019). In 16 European countries, coding has been included in their curricula, but with different approaches and at different levels. Estonia, Ireland, and Italy are actively modifying their curricula to include computing. The United Kingdom published a national curriculum in 2013 that incorporates computer science in the early years. In the United States of America, new initiatives suggest that programming and technological literacy skills are a priority for early childhood education. Singapore’s PlayMaker Programme has brought technology into early childhood education centres as part of a Smart Nation initiative (Bers et al., 2019).

5.5 Science curricula for the young child

5.5.1 Science curricula in South Africa

In South Africa, the NCF (Department of Basic Education, 2015) contains the curriculum for children from birth to four years of age, while the CAPS document (Department of Basic Education, 2011) contains the curriculum for children from pre-school to Grade 3.

5.5.1.1 NCF

In the NCF (Department of Basic Education, 2015), the science concepts are contained in Early Learning and Development Area Six, with the following three aims:

- Children explore and investigate their world
- Children explore, design, make items, and use technology
- Children explore and investigate time and place

The NCF does not specify content per se but assumes that the teacher would use the existing context of their everyday experiences.

5.5.1.2 CAPS

According to the CAPS document (Department of Basic Education, 2011), science teaching in the Foundation Phase should include topics from life and living (biology and ecology), energy and change (chemistry), matter and materials (physics), and planet earth and beyond (space and technology). Despite the fact that it is stated in the curriculum document that topics from life and living (biology and ecology), energy and change (chemistry), matter and materials (physics), and planet earth and beyond (space and technology) should be included, most topics come from life and living (biology and ecology).

Biology and ecology topics, such as seasons, weather, plants, and animals, are repeated in the different grades. These topics are also the ones teachers feel more confident teaching, according to Beni et al. (2012) (see Chapter 4). The only content that qualifies as energy and change (chemistry) is in Grade R – "mixing different things in water to change what it looks like".

The topics in the curriculum that qualify as planet earth and beyond (space and technology) are the following: in Grade 1, storing of food; in Grade 3, processing of food and of sand to make bricks; in Grade 1, moon and stars; and in Grade 3, planets, telescopes, and so forth.

The only content that may qualify as physics is in Grade R – objects that float and sink, what makes the sounds we hear. Considering the findings of Beni et al. (2012) and Du Preez (2016), it is doubtful that these will be dealt with as beginning physics.

5.5.2 International curricula

A collection of international curricula was used to compare the science curricula for pre-school and the Foundation Phase in other countries to the South African curriculum for children from birth to four years old (Department of Basic Education, 2015) and the early childhood (Grades R-3) science curriculum (Department of Basic Education, 2011).

5.5.2.1 New York State curriculum

For prekindergarten in the United States of America, the *New York State Prekindergarten Learning Standards* document (New York State Education Department, 2019) identifies physical sciences, life sciences, earth and space sciences, and engineering design as content for the very young child.

Physical science:

- Ask questions and use observation to test the claim that different kinds of matter exist either in solid or liquid form.
- Use tools and materials to design and build a device that causes an object to move faster with a push or a pull.
- Plan and conduct investigations to provide evidence that sound is produced by vibrating materials.

Life sciences:

- Observe familiar plants or animals (including humans) and describe what they need to survive.
- Plan and conduct investigations to determine how familiar plants use their external parts to help them survive in the environment.
- Develop a model to describe that some young plants and animals are similar to, but not exactly like, their parents.

Earth and space science:

- Observe and describe the apparent motions of the sun, moon, and stars to recognise predictable patterns.
- Ask questions, make observations, and collect and record data using simple instruments to recognise patterns about local weather conditions that change daily and seasonally.
- Plan and conduct an investigation to determine the effect of sunlight on the surface of the earth.

Engineering design:

- Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.
- Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
- Analyse data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

According to the South African NCF (Department of Basic Education, 2015), pre-Grade R learners should explore, investigate, and talk about objects and material in their environment they find interesting, and the teacher should help them to formulate questions. The only content mentioned is “discuss types of pets and pet care” and “talk about electronic items and their use, where available let children operate the items under adult supervision for example cell phones, electronic toys and computers, construction with cardboard and wooden blocks”.

The prekindergarten, according to the *New York State Prekindergarten Learning Standards* document (New York State Education Department, 2019), has specific content prescribed as content in physical science, life sciences, earth as space sciences, and engineering design. In other words, definite content is specified for the teacher to teach in the state of New York, while the South African teacher has no specific content to teach.

5.5.2.2 The Australian curriculum for children years K to 2

The Australian Curriculum (2016), as described by the Australian Curriculum Assessment and Reporting Authority, is divided into three strands of science understanding: science education, science as a human endeavour, and science inquiry skills. The three strands of the curriculum are interrelated, and their content is taught in an integrated way. The order and detail in which the content descriptions are organised into teaching and learning programmes are decisions to be made by the teacher.

The Australian Curriculum (2015) (see Table 5.1) identifies biological science, chemical sciences, earth and space sciences, and physical sciences in the curriculum. The development of content from one age group to the next in terms of topics covered is clear. For example, for foundation needs of living things for food and water: year 1 – features of living things and living places; year 2 – grow and change of living things; and year 3 – classification according to living and non-living.

The South African Curriculum (2011) lacks structure and progress of topics as compared to the Australian curriculum. For example, in Grade R, the curriculum requires learning about birds, reptiles, and wild animals in terms of the different types of animals that are represented in these groups and how they live. In Grade 1, animals kept as pets and how to look after pets are prescribed, which are the same as in the NCF (Department of Basic Education, 2015, p. 67) – "discuss types of pets and pet care". The only addition in Grade 1 is how animals are treated.

Table 5.1: Australian curriculum (2016)

Strand: science education				
Sub-strand	**Foundation**	**Year 1**	**Year 2**	**Year 3**
Biological science	Living things have basic needs, including food and water	Living things have a variety of external features Living things live in different places where their needs are met	Living things grow, change, and have offspring similar to themselves	Living things can be grouped on the basis of observable features and can be distinguished from non-living things
Chemical sciences	Objects are made of materials that have observable properties	Everyday materials can be physically changed in a variety of ways	Different materials can be combined for a particular purpose	A change of state between solid and liquid can be caused by adding or removing heat
Earth and space sciences	Daily and seasonal changes in our environment affect everyday life	Observable changes occur in the sky and landscape	Earth's resources are used in a variety of ways	Earth's rotation on its axis causes regular changes, including night and day
Physical sciences	The way objects move depends on a variety of factors, including their size and shape	Light and sound are produced by a range of sources and can be sensed	A push or a pull affects how an object moves or changes shape	Heat can be produced in many ways and can move from one object to another

Strand: science as a human endeavour			
Sub-strand	**Foundation**	**Year 1-2**	**Year 3-4**
Nature and development of science	Science involves observing, asking questions about, and describing changes in objects and events	Science involves observing, asking questions about, and describing changes in objects and events	Science involves making predictions and describing patterns and relationships

Strand: science as a human endeavour			
Use and influence of science		People use science in their daily lives, including when caring for their environment and living things	Science knowledge helps people to understand the effect of their actions

Strand: science inquiry skills			
Sub-strand	**Foundation**	**Year 1-2**	**Year 3-4**
Questioning and predicting	Pose and respond to questions about familiar objects and events	Pose and respond to questions and make predictions about familiar objects and events	With guidance, identify questions in familiar contexts that can be investigated scientifically and make predictions based on prior knowledge
Planning and conducting	Participate in guided investigations and make observations using the senses	Participate in guided investigations to explore and answered questions; use informal measurement to collect and record observations using digital technologies as appropriate	With guidance, plan and conduct scientific investigations to find answers to questions; consider safe use of appropriate materials and equipment
Processing and analysing of data and information	Engage in discussions about observations and represent ideas	Use a range of methods, including drawings, and provide tables; through discussion, compare observations to predictions	Use a range of methods, including tables and simple column graphs, to represent data and to identify patterns and trends; compare results with predictions; suggest possible reasons for the findings
Evaluating		Compare observations with those of others	Reflect on investigations, including whether a test was fair
Communicating	Share observation and ideas	Represent and communicate observations and ideas in a variety of ways	Represent and communicate observations, ideas, and findings using formal and informal representation

5.5.2.3 Next Generation Science Standards

Table 5.2: Next Generation Science Standards (2017)

Kindergarten	First grade	Second grade	Third grade
Motion and stability: forces and interactions	Waves and their applications in technologies for information transfer	Matter and its interactions	Motion and stability: forces and interactions
Energy	From molecules to organisms: structures and processes	Ecosystems: interactions, energy, and dynamics	From molecules to organisms: structures and processes
From molecules to organisms: structures and processes	Heredity: inheritance and variation of traits	Biological evolution: unity and diversity	Ecosystems: interactions, energy, and dynamics
Earth's systems	Earth's place in the universe	Earth's place in the universe	Heredity: inheritance and variation of traits
Earth and human activity		Earth's systems	Biological evolution: unity and diversity
		Engineering design	Earth's systems
			Earth and human activity

In the United States of America, the Next Generation Science Standards (2017) (see Table 5.2) for children from kindergarten (5-6 years old) to Grade 3, identify the following five disciplinary core ideas: Motion and stability: forces and interactions; Energy; From molecules to organisms: structures and processes; Earth's systems; and Earth and human activity.

In kindergarten, the American curriculum prescribes the following: Forces and interaction – push and pull; What happens if you push or pull an object harder?; Interdependent relationships in ecosystems: animals, plants, and their environment; Where do animals live and why do they live there?; Weather and climate: What are the weather like today and how it is different from yesterday? Learners are expected to develop an understanding of patterns and variations in local weather and the purpose of weather forecasting to prepare for and respond to severe weather. Children can apply an understanding of the effects of different strengths or different directions of pushes and pulls on the motion of an object to analyse a design.

The following content is covered in Grade R: Four seasons – weather for the season, how nature is affected, how animals and people are affected (what they eat, wear, games they play); Water – 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; Fruit and vegetables – different types, tastes, and textures, where it comes from; Birds, reptiles, dinosaurs – types, characteristics, food, and babies.

Although the CAPS document (Department of Basic Education, 2011) of South Africa states that science teaching in the Foundation Phase should include topics from life and living, energy and change, matter and materials, and planet earth and beyond, the majority of the topics described deal with content from live and living. Topics such as push and pull are not included in the South African curriculum (Department of Basic Education, 2011). While American pre-schoolers are expected to develop an understanding of weather patterns, variations in local weather, and the purpose of weather forecasting to prepare for and respond to severe weather, the South African Grade 1 child just needs to record daily weather observations on a weather chart.

In Grade 1, the American curriculum prescribes the following content: Waves, light, and sound; structures, function, and information processes; space systems: patterns and cycles. Wave properties: sound can make matter vibrate; vibrating makes a sound; electromagnetic radiation; objects can be seen if light is available to illuminate it or if it gives off light; object can let light through or block light and create a shadow; mirrors reflect. Information technology: devices to communicate over long distances. Animals' sensory perception and how it helps animals survive. The offspring of plants and animals look like parents. Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. Seasonal patterns of sunrise and sunset can be observed, described, and predicted.

The South African curriculum for Grade 1 prescribes a daily weather chart and regular observation of weather conditions – hot, cold, windy, cloudy, sunny, misty, rainy – symbols to describe conditions on weather chart. Use of plants, anatomy of plants, comparing plants, and comparing seeds. Growing plants from seeds. Food: sources of food; healthy and unhealthy foods; and storing food. Day and night, moon, and sun.

For American Grade 1 learners, in physics, topics such as different waves, like light and sound, are included, while their South African peers only deal with observing weather and learning about animals.

In Grade 2, the American curriculum prescribes the following: Phases of matter depend on temperature; matter can be described and classified by its observable properties; different properties are suited to different purposes. Objects are built up from a small set of pieces. Heating or cooling a substance may cause changes that can be observed; sometimes these changes are reversible, and sometimes they are not. Plants depend on water and light to grow; plants depend on animals for pollination or to move their seeds around. Different kinds of living things in water and on land. Where water can be found and states of water.

The South African curriculum only prescribes biology and ecology content: What we need to live – food, water, and sunlight. The influence of seasons on plants and animals. Farm animals and wild animals. Different types of soils, creatures that live in soil, and plants that grow in soil.

While the Grade 2 child in the United States of America learns about phases of matter, the South African child learns about types of soil and creatures that live in soil.

In Grade 3, the American curriculum prescribes forces and interactions, interdependent relationships in the ecosystem, inheritance and variation of traits, life cycles and traits, and weather and climate. The South African child is expected to learn about food groups, insects, life cycles, recycling, pollution, space, processing, disasters, and how animals help humans. The only technology content prescribed in the Foundation Phase in South Africa is in Grade 3 as the processing of sugar cane and clay.

5.5.2.4 La main à la pâte

La main à la pâte was invented to revitalise the teaching of the sciences in primary schools in France. The programme aims to establish science literacy through IBSE but does not recommend specific content for the early years (Lena, 2002).

5.5.2.5 Creative Little Scientist

Creative Little Scientist, in its *Recommendations to Policy Makers and Stakeholders* (2014), identifies the aims, objectives, and content of the science curriculum in partner countries as focusing more on the development of knowledge and understanding of scientific ideas and process skills associated with science inquiry than on social and affective factors of science learning. Stylianidou, Glauert, Rossis, and Havu-Nuutinen (2016) categorise the science content in the participating countries as either within a broad area of learning, such as “knowledge of the world” or “study of the environment”, or within a single subject.

5.5.2.6 TalentenKracht

TalentenKracht (2008) identifies topics children between the age of three and six years are very eager to learn and know more about. Scientific concepts and issues such as the moon, stars, planets, tides, volcanoes, dinosaurs, thunder and lightning, how planes fly and boats float, and so forth are proposed as topics for teaching.

The curriculum for South African children in this age group is limited to mainly topics of biology and ecology. Moreover, the content is of a lower conceptual level, for example in Grade R, the topic of objects that float and sink compares to how planes fly and boats float, suggested by TalentenKracht.

In the Grade 1 South African curriculum, indicating hot, cold, windy, cloudy, sunny, misty, and rainy conditions on a weather chart (Department of Basic Education, 2011) compares to thunder and lightning, suggested by TalentenKracht.

For Grade 3, the topics of what earth looks like from space, what are stars and planets, and the names of planets indicated in the South African curriculum (Department of Basic Education, 2011) compare to the moon, stars, planets, tides, and volcanoes, suggested by TalentenKracht.

Of all the topics suggested by TalentenKracht, only dinosaurs are included in the South African curriculum.

5.6 Summary

The technological change the children of the 21st century are growing up in requires that children become digital literate. This technologically changed world will influence and change the content and outcomes of education in general and science education specifically. In the modern world there is a need for scientific literacy, which can be understood as a broad basic understanding and competency in science. The teacher has an important role in creating a positive environment for the learning of science, the quality teaching of science depends heavily on the teacher. The teacher enables the child to find out about the natural world and become general concepts.

CHAPTER 6: SUMMARY, FRAMEWORK, CONCLUSION, AND FURTHER RESEARCH TOPICS

6.1 Summary

The aim of this research was to describe the potential teaching and learning capacity of young learners regarding their scientific-reflective capacity. This included the delineation of young learners' physical, emotional, mental, and social development as related to their capacity to engage in scientific reflection. It also involved the identification of appropriate science content and teaching methodologies suitable in different age phases of development. The acquired knowledge was utilised to develop a framework that could assist different practitioners in the field of science education for the young child.

During the first six years of a child's life, major development is taking place – physically, mentally, emotionally, and socially. At birth, infants are totally dependent on their caregivers, but during the first year, a spurt of physical and mental development is taking place while they are emotionally interacting with their caregivers. During the first year, the infant learns to walk and talk and develops affect and will. The toddler (age 1-3 years) learns the culturally determined use of objects through adult-mediated object-orientated activities. During the pre-school (age 3-7 years) period, make-believe play is responsible for the creation of the zone of proximal development, facilitates the separation of thought from actions and objects and the development of self-regulation, has an impact on the child's motivation, and facilitates cognitive decentring, the development of imagination, and the development of language. The school child needs to learn to be a student.

Therefore, it is clear that make-believe play is important for the development of the young child. Make-believe play is the leading activity of the pre-school (kindergarten) period. This type of play not only promotes the development of both mental and social abilities but also creates a zone of proximal development, which separates thought from actions and objects, while also developing self-regulation, imagination, and motivation.

This overall development of the child needs to be considered in the choice of the type of teaching methodologies (pedagogies) that needs to be employed at a particular age as well as the choice of possible scientific content to be taught to children in specific age phases. The fact that the young child is ever-evolving and constantly changing physically, socially, emotionally, and cognitively, necessitates a constant awareness of their changed potential to learn.

While most scholars agree that play is an important mediator of emergent competence in early childhood, there is still disagreement on how to define children's play theories. Vygotsky identifies dramatic or make-believe play as contributing to learning. He identifies three components of make-believe play, namely an imaginary situation, taking on and acting out roles, and following a set of rules determined by the role. An important prerequisite for successful make-believe play, as for scientific reflection, is creative thinking.

El'konin extended the Vygotskian-based theory of child development and introduced the idea of mature play as the only source of development in childhood. El'konin distinguishes the following components of mature play: object substitution, specific role, integrated themes, time spent, ability to follow rules, extended planning, and rudimentary acting out. El'konin identifies four levels of play from least to most mature play. As play, scientific reflection develops as the child's sensory experiences lead to thinking, assisted by the development of language.

Vygotskians focus on the idea that play influences development. They view play as the leading activity for the pre-schooler that will promote development in pre-school. According to Vygotsky, play establishes a zone of proximal development for the child by providing support for skills that are on the edge of emergence. In play, children act more socially mature and show better cognitive skills, higher levels of self-regulation, and a better ability to attend to purpose and remember deliberately. An important function of play is the separation of thought from objects and actions. Through play, children develop self-regulation, because when playing, they act opposite to what they really want, and by doing so, they achieve the maximum display of willpower. The development of a zone of proximal development through play will also create a zone of proximal development for scientific reflection, as play develops creative thinking in a social environment.

In play, children develop a complex hierarchical system of immediate and long-term goals, where immediate goals can occasionally be forgone to reach long term goals. Children learn to look at objects through the ideas of play partners, a form of cognitive decentring. Imagination is the psychological basis for the origin of play, while play is also a transitional stage in the development of imagination. Vygotsky identifies language as essential for children to take part in make-believe play. Scientific reflection also requires imagination and language for development in a social environment.

Scholars such as Vygotsky, El'konin, Leontiev, and Zaporozhets emphasise the crucial importance of joint activities of the young child with adults and peers in each period of development. These joint activities are important for the development of the higher mental functions needed for scientific reflection. In play, adults and peers supply the psychological tools to mediate the mental processes.

The quality of play has degraded over time since experiments done in 1940 in Russia. This problem is not restricted to Russia only but a worldwide phenomenon. This can be blamed on factors such as uninvolved parents and new professions of parents making it impossible for children to role-play. The degradation of play also has an impact on scientific reflection because of the child's weaker ability to think creatively and solve problems. Many studies have found that if pre-schoolers did not reach mature play, it could result in low levels of psychological preparedness for all learning in formal school settings, creating new challenges for the use of play as one of the pedagogies in the early child's teaching and learning.

Due to technological changes, science literacy has become a necessity for the adults of the future. The young child is curious about science and scientific subjects, asks questions, and spontaneously manipulates objects. Moreover, the young child is ready and excited to develop the necessary skills and understanding of science. Between the ages of three and seven, children can understand scientific phenomena because of their level of language proficiency and cognitive development.

Scientific inquiry requires skills for generating, testing, and revising theories, while scientific reasoning can be classified as an intentional information-seeking activity. In other words, scientific reasoning requires both deductive and inductive skills. The child first learns about science by manipulating objects in his or her environment, forming “small” scientific ideas. These ideas should develop into “big” ideas by linking “small” ideas. Big ideas will enable children to link ideas from related but different events. The big ideas explain more events and are interlinked to form broad theories or principles.

In the current study, **three teaching pedagogies** have been investigated, namely play, playworlds, and IBSE. Contrary to previous views on play and learning as incompatible, scholars theorise that play and learning are dimensions that stimulate each other and can be seen as an indivisible entirety that is part of children’s experiencing, which helps them to create an understanding of their surrounding world.

Lindqvist has investigated the nature of the connections between play and aesthetic activities and how these can influence children’s play. The development of adult-child joint play is made possible through the creation of a common fiction, which she calls a “playworld”. This concept has been further investigated and extended by scholars in various countries.

Using Lindqvist’s playworld model, Fleer (2017) has coined the scientific playworlds model. Fleer’s (2017) scientific playworlds model begins with the collective scientific imaginary situation, which draws upon a cultural device that is related to the science being learnt and which requests children to go on scientific journeys to produce dynamic imaginary scientific context.

The IBSE approaches rely on the assumption that learners will benefit if they try to find solutions to scientific problems encountered in everyday life, by asking questions, thinking of possible explanations, conducting investigations, and drawing conclusions (Gillies, 2020). Because of the specific development stage linked to a specific skill set, this methodology will be more applicable to older pre-schoolers going into the early years of formal school.

The child younger than five has a relatively limited command of language for reasoning purposes and a lack of physical experiences, which limit the questions the child can ask, the predictions the child can make about outcomes, and the child's ability to communicate about his or her findings. The five-year-old therefore needs extensive instruction scaffolding for productive scientific inquiry linked to phenomena in the child's environment.

Major intellectual developments also involve the overall cross-disciplinary concept understanding of "transformation". Children's physical knowledge develops through learning how objects move, how they change position and shape, and how they change in relation to themselves and other objects. The focus in early childhood education should be on the facilitation of transformational thinking. One key to such a focus is the child's representation of transformation. Another aspect concomitant with this is the ability of the young child to represent his or her findings in different modes of communication, including verbally, tactile, modelling, drawing, photographs, writing, and so forth.

Transformations in chemistry consist of play activities that can be either reconstructions or combinations. Transformation is a major focus in the natural world, for example in birth, growth, death, decay, and composition, that brings about changes in substances over time. Some of these transformations are difficult to observe because they take so long.

Children construct their own knowledge through a dynamic interactive process and are continuously engaged in building theories about science. Physical knowledge is constructed when the child is able to move an object, vary his or her own action, and observe the reaction of the object. The reaction of the object must be immediate.

In this study, suitable content domains to access and develop scientific reflection in different age phases while utilising the overall capacity of young learners have been investigated. These content domains identified are intuitive predecessors of the natural sciences that will be learnt in the Intermediate Phase (from age 10). The aim of this investigation was to identify and define appropriate content domains related to the specific capacity of the young learner in different age phases (birth - 4 years, 5-6 years, and 7-9 years) in terms of the four science domains, namely: “How can I make it move?” referring to experimentations that explore basic concepts in the area of physics; “How can I make it change?” referring to exploring concepts in the area of chemistry; and “How does it fit?” and “How do I fit?” which explore concepts in the area of biology and ecology. These four questions are the genesis of intuitive physics, chemistry, biology or ecology, and computers.

The young child of the 21st century is growing up in a world with electronic devices, requiring children to become digitally literate. This technologically changed world will influence and change the content and outcomes of education in general and science education in particular. In other words, many of the hands-on activities that children might do in real space are now presented as simulations on handheld computer devices.

Lastly, the research should be viewed as a lens through which to assist curriculum developers via a proposed framework for the teaching and learning of scientific reflection by young children as a process through the different age phases (birth - 1 year, 1-3 years, 3-6 years, and 7-9 years) in the South African context specifically but also internationally.

6.2 Framework for teaching science

By using the findings of the research questions, a working framework is suggested. This framework should include the use of play, playworlds, and IBSE in the different age groups, while also indicating the content of science relevant to each age group.

As indicated in Table 6.1, play originates from sensorimotor actions initiated by caregivers, where children learn the social use of objects while abilities such as language and imagination develop to make mature play possible. Mature play consists of actions in roles with rules that determine the actions as determined by the role. For school-age children, play is mainly part of games.

Table 6.1: The use of play, scientific playworlds, and IBSE for science learning over the age periods

Methodology	Birth - 1 year	1-3 years	3-7 years	7-9 years
Play	Sensorimotor actions; adults demonstrate use of toys	Object-orientated, e.g. objects roll or bounce; action with objects	Mature play with actions, roles, and rules	Play in games for children to be able to learn
Scientific playworlds			Imaginary situations, e.g. stories; use of cultural device relating to science; child goes on scientific journeys	
IBSE			From age 5, children can ask questions, offer possible explanations, conduct investigations, and draw conclusions	Children ask questions, find possible explanations, conduct investigations, and draw conclusions
Content	(i) How can I make it move?"; (ii) "How can I make it change?"; (iii) "How does it fit?" or (iv) "How do I fit?"		Intuitive physics, chemistry, biology, ecology, and technology	

To take part in playworlds, children need to be able to take part in an imaginary situation (see Table 6.1). The development of emotions and intellect is responsible for imagination in play. The child's ability to use imagination provides new possibilities in play, language, thought, and the self-regulation of emotions and will. It means that actions can now arise from ideas and not concrete objects only. So, this play phase is a very important pre-phase of development and preparation for the more advance IBSE type of inquiry later in their development. Playworlds can serve as a transfer period between the two main methodologies and can start by approximately age five. For children to be able to learn science through IBSE, they must be able to ask questions about scientific phenomena, offer possible explanations, conduct investigations, and draw conclusions.

The original questions about the world (content) around children, namely "How can I make it move?", "How can I make it change?", "How does it fit?" or "How do I fit?" will lay the foundation for intuitive physics, chemistry, biology, ecology, and technology when they enter the later school phases where the science subjects are more defined into physics, chemistry, biology, ecology, and so forth.

Figure 6.1 below is an integrated diagram that depicts the suggested framework to support teachers involved in different levels of working with young learners in the field of science education. It has three components that are interrelated, namely age phases on the x-axis, teaching methodologies as a progression from play through playworlds to IBSE on the y-axis evolving across the horizontal axis, and content domains, which are superimposed across both the x-axis and the y-axis. This framework has as its purpose a non-rigid interpretation of the relationship between the three components described in this research.

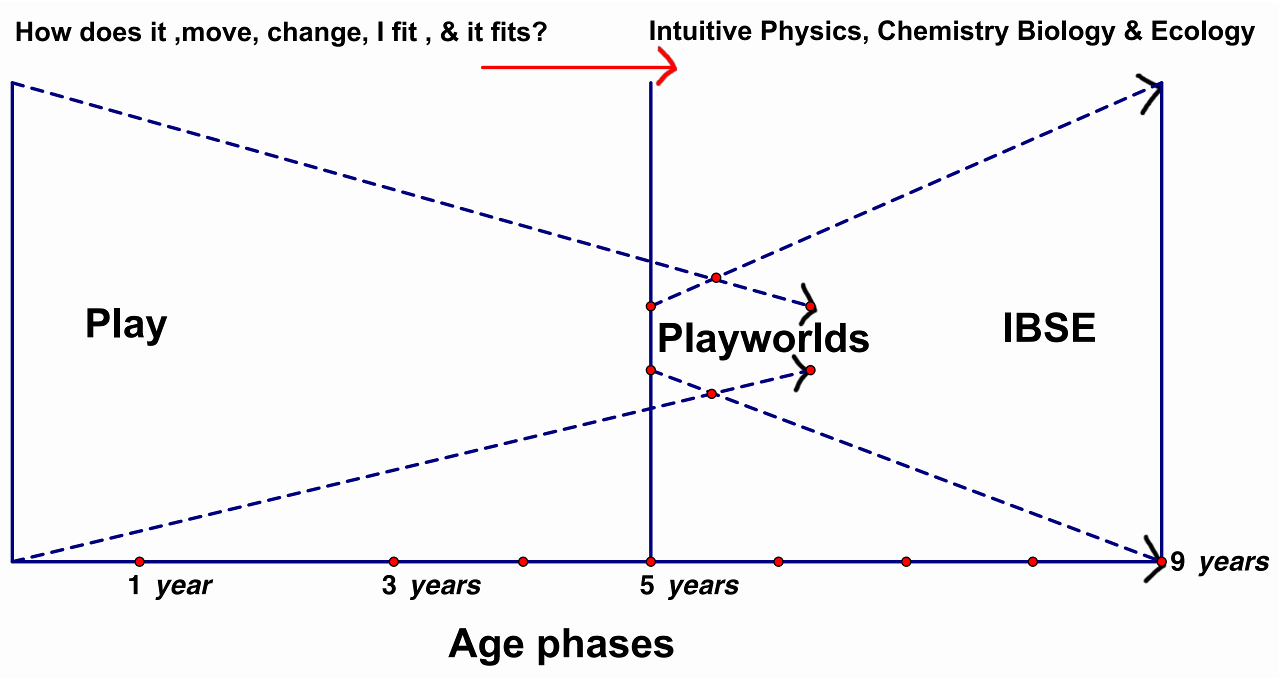

Figure 6.1: Framework for teaching science to young learners

6.3 Conclusion

As the young child develops and moves through the different age phases, the child's capacity for scientific reflection or thinking develops and improves. Make-believe play is the leading activity in the pre-school age that sets the tone for moving beyond make-believe play to a methodology of playworlds (scientific) towards IBSE.

Play is important for promoting the grounding development of mental and social abilities, while it also creates a zone of proximal development. Play separates thought from actions and objects, while developing self-regulation, imagination, and motivation. Moreover, play can be a method of learning, as scholars have found that play and learning are dimensions that stimulate each other and can be an indivisible entirety. Play is part of children's experiencing, which helps them to create an understanding of their surrounding world.

The scientific playworlds model begins with the collective scientific imaginary situation, which draws upon a cultural device that is related to the science being learnt and which requests children to go on scientific journeys to produce dynamic imaginary scientific context.

IBSE, as the third methodology, relies on the assumption that learners will benefit if they try to find solutions to scientific problems encountered in everyday life by asking questions, thinking of possible explanations, conducting investigations, and drawing conclusions. Because of their development, this methodology will only be practical for older pre-schoolers.

In other words, as children develop physically, mentally, socially, and emotionally, the methodology and content for science teaching should be adjusted too. First, learning of science will take place through play in social interaction, investigating natural phenomena in the child's environment. As the child's imagination and language develop, scientific playworlds learning become possible and science can be learnt in a collective scientific imaginary situation. The older pre-schooler has developed the necessary language skills to start asking questions, thinking about possible explanations, conducting investigations, and drawing conclusions in IBSE.

6.4 Further research topics

Further research is necessary to explore and address the following issues:

- The importance of language in the development of the young child has been highlighted in this research. More research is needed to determine how language and representing skills at different stages of development of the child will benefit the learning of science the most.
- Three possible methodologies, namely play, playworlds, and IBSE, have been investigated. More research is needed on how the transition from play to IBSE can be made and the role playworlds can play in the transition between play and IBSE.
- More research is necessary on specific content for the very young child.
- Modern technology is influencing the young child's living environment; so, more research is required to determine the type of technology needed for the support of content.
- Assessment has not been considered in this research; therefore, research on the role of assessment is necessary.
- The role of the teacher in play and playworlds and the importance of the teacher's subject knowledge have been highlighted. More research is required on the role of the teacher for the young child in learning science. The way teacher training should prepare teachers for these roles should also be explored.

This research has revealed a need for better coordinated and applicable science teaching and learning, while simultaneously considering three interrelated aspects, namely age, teaching methodology, and science content, of the young child. It is envisaged that this research will stimulate future discussion and research related to the importance of starting the teaching and learning of the sciences not only earlier than previously anticipated but also with a better reflection of the integrated nature of the three key aspects mentioned in this study.

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