THE RELATIONSHIP BETWEEN VISUAL LITERACY AND SCIENCE LITERACY AMONG ENGLISH SECOND LANGUAGE PRE-PRIMARY SCHOOL LEARNERS

by

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The relationship between Visual literacy and Science literacy among English Second Language Pre-Primary School learners.

I declare that the above dissertation is my work and that all the sources that I have used or quoted have been indicated and acknowledged using complete references.

I further declare that I submitted the dissertation to originality-checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

SIGNATURE

20/01/2023
DATE

DEDICATION TO MY GUARDIAN ANGELS

In loving memory of my father, Peter Mokhele, my grandmother Nokrismesi Luzombe, and my mentor Dr. Itumeleng Molobela. I know you are all so proud of my achievement. I love and miss you all so much. May your souls continue to rest in peace.

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LORD, where would I be if not your Grace? LORD, if it wasn't for your love for me, where would I be? You promised to carry me (Isaiah 46:4). You to never leave me nor forsake me (Deuteronomy 31:6) and today I can testify of your goodness and grace. Abba Father, you are worthy of all the praise.

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ABSTRACT

Early exposure to science-related content through visual literacy has the potential to enhance the interest in science among South African learners, particularly those who find the subject complex. Visual representation serves as valuable instructional support, stimulating learner engagement and facilitating meaningful science learning. The primary objective of this study was to assess the levels of visual literacy, science literacy, and scientific reasoning ability among pre-primary school learners, with the aim of supporting the effective integration of visual representations in science education. The research was underpinned by the Cognitive Theory of Multimedia Learning, which served as the theoretical framework to investigate the feasibility of integrating science education in pre-primary school using visual literacy. The research adopted a mixed-method approach, employing a purposive sampling method to select a sample of 208 Grade R learners from non-government English Medium Language pre-primary schools in Bloemfontein, South Africa. Quantitative data were collected through a survey questionnaire consisting of psychometric and content knowledge tests, while qualitative data were obtained via semi-structured interviews. The findings indicated that learners from STEM schools demonstrated higher levels of visual literacy, science literacy, and scientific reasoning ability. However, no significant positive relationship was observed between visual literacy and science literacy, challenging the assumption that early science education contributes to visual literacy development. In conclusion, it is crucial to prioritize the development of visual literacy and science literacy in pre-primary school, despite the absence of a significant positive relationship between the two. Early exposure to science education offers valuable benefits for cognitive development and future scientific pursuits. To promote comprehensive understanding and enhance scientific reasoning skills, it is recommended to integrate visual literacy activities and science content into pre-primary school curricula, utilizing age-appropriate visuals, interactive materials, and engaging instructional strategies.

Keywords: Grade R learners, Pre-Primary school, science literacy, scientific reasoning ability, STEM schools, non-STEM schools, visual literacy, visual representations

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ABBREVIATIONS

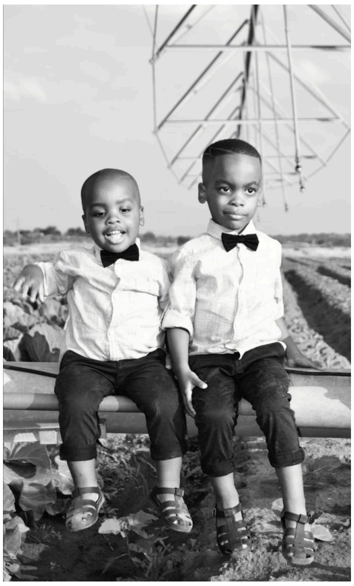
COVID-19	Coronavirus disease of 2019
CVI	Content validity index
ERs	External representations
FVI	Face validity index
MOE	Ministry of Education
SL	Science literacy
SRA	Scientific reasoning ability
VL	Visual literacy
VS/s	Visualisation skill/s

CHAPTER 1: THE SIGNIFICANCE OF MY RESEARCH

"The important thing is not to stop questioning; curiosity has its reason for existing."

Albert Einstein

1.1 How it all began



Rivhavhudi & Wavhudi Ramulumo
'The Ramulumo boys'

My personal involvement in this research stems from a deep personal connection. It was my two children, Rivhavhudi and Wavhudi, aged two and four respectively, who sparked my fascination with the readiness of young children to learn science. Despite their limited verbal skills, their curiosity about the world around them was evident. This prompted me to utilize digital educational games on my phone to harness their innate curiosity and facilitate their learning of science and mathematics. Notably, this approach had a significant impact on their vocabulary, particularly their word recognition abilities and even their ability to memorize the multiplication table. A pivotal moment occurred one day while I was engaged in the mundane task of washing dishes. Seizing the opportunity, I transformed this ordinary moment into a teachable one by explaining the concept of digestion to my children. I drew a parallel between using green sunlight dishwashing soap to remove oil (emulsify fats) from the plates after consuming French fries and the green bile in our bodies that aids in breaking down the oil from the food we eat. Their fascination and immediate curiosity were palpable, marking a eureka moment for all three of us. This experience served as a significant catalyst for the development of my research interest. As a science educator, I am well acquainted with the challenge of teaching learners who often lack interest in the subject. However, that particular 'aha moment' allowed me to fully appreciate the value of my years of experience as a science educator. It was at that precise moment that I realized the critical importance of introducing science to children during their early childhood, a time when their inherent curiosity about the world is at its zenith. This realization has ignited a profound motivation to delve further into research, aiming to explore ways to cultivate and sustain children's interest in science during this crucial developmental stage.

1.2 Setting the scene for the current research

The issue of learners' interest in science-related subjects remains a significant concern in South African schools, as many learners find science challenging and difficult to engage with (Potvin & Hasni, 2014). This decline in interest is evident from the data provided by the Department of Basic Education (2019), which shows a decrease in the number of learners choosing physical science and life science subjects. From 2016 to 2019, there was a significant decline in the participation of learners in these subjects. Learners often perceive science as complex, boring, and irrelevant due to its abstract ideas, laws, and theoretical concepts (Wellington & Ireson, 2008). However, the outbreak of the global COVID-19 pandemic has led to the disruption of traditional classroom learning, forcing schools to adopt online learning approaches, including the integration of technology in science education (Opere, 2021). With the introduction of digital learning models, science educators now have the opportunity to present complex scientific concepts in a visually engaging manner, addressing learners' difficulties and enhancing their understanding.

Among the various instructional strategies used by science educators to engage learners with complex scientific content, visual representations have proven to be highly effective (Roth et al., 2006). Visual representations are powerful tools that have become an integral part of science education, enabling scientists to interact with and present complex invisible phenomena (Evergorou & Erduran, 2015). By incorporating visual representations, educators can develop essential 21st-century skills among the digital generation of learners. These visual representations can take two ontological forms: internal representations and external representations (ERs) (Gilbert, 2010). Internal representations refer to mental imagery, representing what is in an individual's mind. On the other hand, ERs are external images that serve as visual and spatial displays, facilitating discovery, memory, inference, and calculation (Schonbörn & Anderson, 2006). ERs play a central role in learning science, practicing science, and communicating scientific ideas (Ainsworth & Newton, 2014). Various forms of ERs are used in science education, including physical and molecular models, photographs, diagrams, illustrations, drawings, analogical representations, graphs, multimedia, and virtual reality environments (Schonbörn & Anderson, 2006).

By incorporating these visual representations into science education, educators can overcome the challenges faced by learners and create a more engaging and accessible learning environment. Visual representations not only facilitate the understanding of complex scientific concepts but also promote critical thinking, inquiry, and communication skills. They provide learners with tangible and visible representations of abstract ideas, making science more relatable and meaningful. Furthermore, the integration of technology and digital learning platforms opens up new opportunities for interactive and immersive visual experiences, enhancing learners' engagement and motivation to learn science.

Pattison et al. (2018) assert that engaging learners in early childhood is an effective approach to fostering science interest. Research indicates that children's interest in science emerges as early as preschool, as they begin to conceptualize scientific information from the age of three (Worth, 2010). The National Research Council (NRC, 2007) emphasizes that play offers children opportunities to develop essential 21st-century skills while exploring their environment. Through play, children engage in activities that promote critical thinking, decision-making, problem-solving, and analysis within their play scenarios. Play also stimulates creativity as children imagine new scenarios, create stories, and devise solutions to challenges. Collaboration skills are developed as children interact with peers, fostering cooperation and social skill development. Communication skills are practiced and refined through interactions, negotiations, and expression of thoughts, ideas, and emotions. Problem-solving abilities are enhanced as children encounter and resolve challenges. Moreover, play encourages adaptability, resilience, imagination, emotional regulation, and self-directed learning, which are vital for overall development and highly valued in the modern world. Additionally, children's innate fascination with nature prepares them for science learning (Eshach & Fried, 2005). Therefore, it is the responsibility of science educators to preserve children's sense of wonder and harness their intrinsic motivation by introducing science at an early age.

Ryan and Deci (2000) posit that humans, from birth, possess a natural inclination for active learning and exploration. By introducing scientific vocabulary and concepts such as photosynthesis at a young age, children can grasp abstract scientific ideas even before formal schooling. This early exposure to science cultivates a positive attitude toward the subject (Eshach & Fried, 2005) and has a direct impact on learners' academic achievement and lifelong learning (Obi Nja et al., 2022). Furthermore, learners' attitude toward science serves as a strong indicator of their interest in pursuing science-related careers (Newell et al., 2015). In the next part of the research (sections 1.3 to 1.5), critical concepts important for the research will be defined. As previously described, the focus of the research is on the introduction of science education in early childhood using visual representations. According to Gangwer (2009), the use of visual representations as innovative learning activities can be used to strengthen the visual literacy (VL) skills of learners and enhance the learner's science literacy (SL). Furthermore, the research focuses on determining the relationship between VL and SL. According to Kobe (2020), understanding how to decode visual representations used in the science classroom assists learners in better grasping the science content.

Additionally, the development of the scientific reasoning ability (SRA) of learners has been shown to have a prolonged impact on the learner's academic achievement and understanding of science (Kambeyo, 2018). Therefore, as part of this chapter, I will introduce the key concepts presented in the research, namely, VL, SL, and SRA. Furthermore, I will also give my view of the concepts and provide a working definition for each of the concepts used in the research.

1.3 Defining visual literacy

The background section of this research establishes the integral role of VL in understanding scientific concepts. In the 21st century, significant changes in science education have led to the diversification of instructional methods, making visual learning a critical component for developing strong skills necessary for the Fourth Industrial Revolution (Schonbörn & Anderson, 2006). Proficiency in VL enables learners to construct meaning from visual images, thereby enhancing their 21st-century skills essential for navigating the Fourth Industrial Revolution.

VL, as defined by Serafini (2017), encompasses a set of visual competencies and strategies that enable individuals to comprehend visual images regardless of their context of production, reception, and dissemination. Mnguni (2014) identifies these competencies as VL skills vital for science education learners to correctly interpret ERs used in the curriculum. Consequently, developing the relevant VSs is essential for learners to read and comprehend photographs, drawings, and other visual materials accurately.

Additionally, Ametller and Pinto (2002) view VL as encompassing the ability to read (comprehend), write (create), and think in terms of images. These cognitive abilities of reading, writing, and thinking are crucial for processing visual information on contextual, metaphoric, and philosophical levels. Hence, learners require VSs to process and interpret visual information effectively (Pem, 2019).

Furthermore, Nkosi and Mnguni (2020) refer to the application of VSs for processing visual information as visuo-semiotic reasoning, which they define as a form of representational competence. This form of reasoning involves understanding how ERs depict information about their content (Rau, 2017). Thus, visuo-semiotic reasoning plays a critical role in cognitive learning, particularly in the ability to reason visually.

While there are various definitions of VL (Avgerinou & Pettersson, 2011), for the purposes of this research, VL is defined as the ability to use visuo-semiotic reasoning to interpret visual representations and produce visual models, which are crucial in science education. Understanding and analyzing the content of visual materials are fundamental aspects of VL, as highlighted in the aforementioned definitions.

1.4 Defining science literacy

One of the primary goals of science education is to cultivate critical thinking abilities that enable individuals to analyze new information, solve problems, and make informed decisions. SL is recognized as a crucial skill for the 21st century, extending beyond the confines of the classroom. SL provides a foundation for addressing societal challenges and is highly valued in the workplace, where candidates are expected to possess the ability to learn science, think logically and creatively, make sound judgments, and engage in problem-solving (Tripathy, 2020). Kaya et al. (2017) asserts that prioritizing SL from a young age is essential, as it allows learners to broaden their perspectives and apply scientific knowledge in their future lives.

Numerous definitions exist to elucidate the concept of SL. Coll and Taylor (2009) define SL as the ability of an individual to comprehend scientific laws, theories, phenomena, and concepts. From my perspective, comprehending scientific laws, theories, and phenomena necessitates a solid understanding of the fundamental concepts and processes in science education. However, acquiring such understanding requires the development of SRA (Section 1.5). Scientific reasoning entails critical, creative, and logical thinking, as well as the motivation to address societal issues influenced by science (Coll & Taylor, 2009). Consequently, in alignment with Coll and Taylor (2009), I argue that SL demands learners possess SRA in order to evaluate the quality of information and arguments presented by scientists.

Furthermore, I contend that SL encompasses not only the evaluation of scientific work conducted by others but also the ability to apply scientific knowledge in personal decision-making, active participation in civic and cultural affairs, and achieving economic productivity. In this sense, SL requires cognitive abilities commonly employed in scientific endeavors, including the capacity to evaluate new evidence and data, make informed decisions, employ 21st-century skills such as critical thinking, problem-solving, reasoning, analysis, interpretation, synthesis, assessment, independent initiation, collaboration, leadership, effective communication, creativity, and innovation, all of which are essential components of SRA.

1.5 Defining scientific reasoning ability

As previously mentioned, a significant objective in science education is the development of SRA, which has been shown to have a considerable impact on learners' achievement in science education (Colleta et al., 2008). According to Zimmerman (2007), SRA encompasses a range of thinking skills that enable individuals to systematically explore problems, formulate and test hypotheses, control and manipulate variables, and evaluate experimental outcomes, a view that aligns closely with the perspective advocated by Coll and Taylor (2009). Moreover, SRA encompasses the thinking skills required for inquiry-based learning, including conducting experiments, evaluating data, making inferences, and formulating new theories (Kambeyo, 2017).

Similar to Zimmerman (2007), Barz and Achimas-Cadariu (2016) define SRA as problem-solving abilities linked to various thinking skills, such as critical thinking, analytical thinking, innovative thinking, and creative thinking. Likewise, Zulkipli et al. (2020) consider SRA as the type of skill that engages learners in developing hypotheses about how things work and subsequently testing those hypotheses. Furthermore, Zulkipli et al. (2020) suggests that during the reasoning process, learners often connect the phenomena being investigated with their prior knowledge, correct any misconceptions, and thus generate new knowledge.

In line with Zimmerman (2007), Barz and Achimas-Cadariu (2016), and Zulkipli et al. (2019), I concur with Coll and Taylor (2009) that the ability to use evidence and data to evaluate the quality of information and arguments presented by scientists is essential for learners to develop their SL. Thus, for the purposes of this research, I define SRA as the ability to evaluate scientific information using cognitive skills such as problem-solving, logical reasoning, justification, rational thinking, and decision-making through the testing and revision of hypotheses or theories.

By furnishing precise definitions of the fundamental concepts VL, SL, and SRA that constitute the underpinning of this research, we establish a conceptual groundwork for comprehending and scrutinizing the research problem. These definitions lay the groundwork for the formulation of a conceptual framework (Section 1.6) that will augment my grasp of the interconnectedness between these pivotal concepts, thereby facilitating a holistic comprehension of the phenomena being investigate.

1.6 Conceptual framework - illustrating the relationships between the concepts essential to current research

Figure 1.1 The conceptual framework employed in this research encompasses a selection of key concepts derived from the essential definitions established earlier. These concepts are central to the investigation at hand and serve as the foundation for the analytical framework utilized throughout the research. By drawing upon the comprehensive definitions of VL, SL, and SRA, the conceptual framework captures the interrelationships and interdependencies between these concepts. It provides a systematic representation of how these concepts interact and influence one another within the context of the research problem.

This conceptual framework enables a structured and comprehensive examination of the phenomena under investigation. It serves as a guide for organizing and analyzing data, interpreting findings, and drawing meaningful conclusions. By aligning the research objectives with the defined concepts, the conceptual framework ensures a focused and coherent approach to the study. In essence, the conceptual framework constructed from the selected concepts derived from the essential definitions forms an integral part of this research. It provides a clear structure and framework for understanding and analyzing the complex relationships between VL, SL, and SRA, facilitating a systematic exploration of the research problem and contributing to a deeper understanding of the phenomena under investigation.

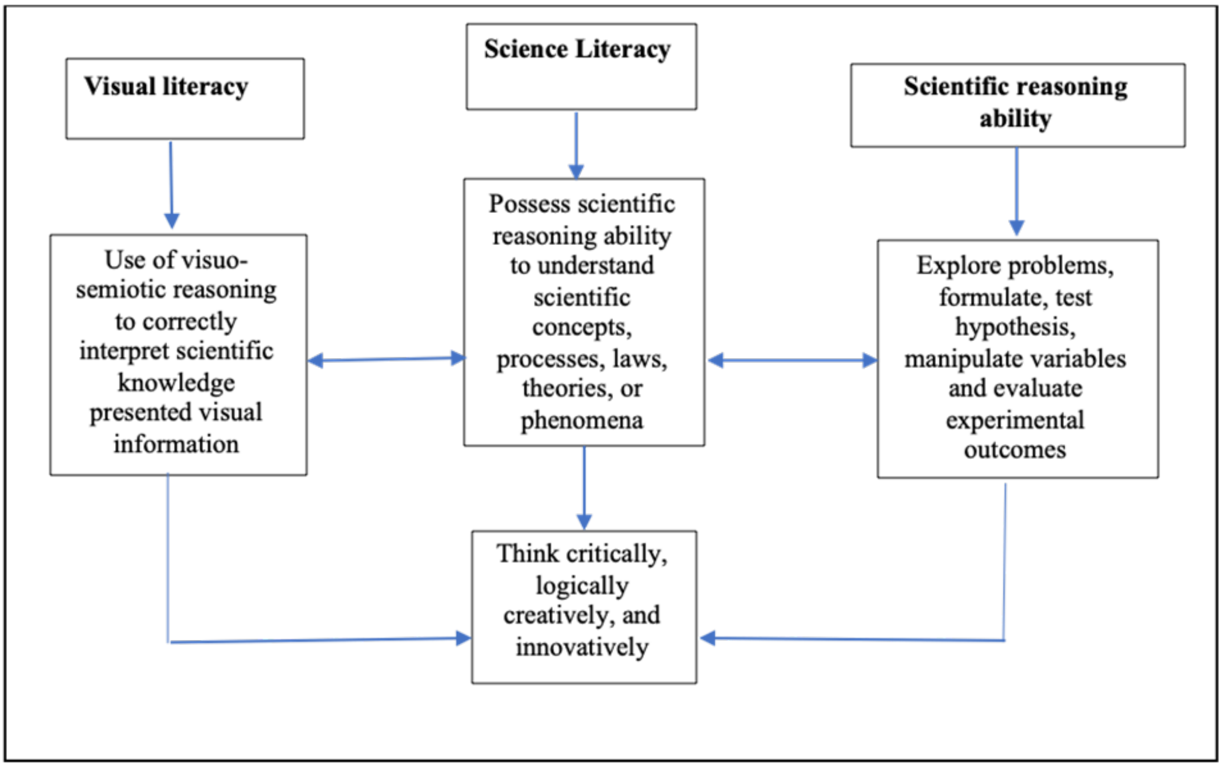


Figure 1. 1 The interrelationships among the key concepts: A Comprehensive Conceptual Framework

According to the depiction in Figure 1.1, it can be inferred that VL and SRA can be considered as subsets of SL. As previously elucidated, the comprehension of scientific concepts, processes, laws, theories, or phenomena necessitates the utilization of cognitive abilities commonly employed in the realm of science. These abilities encompass the capacity to assess novel evidence/data, draw logical inferences, and devise fresh theories, utilizing the 21st-century skills that are inherent in Self-Regulated Learning Activities. Furthermore, since the dissemination of content information in science heavily relies on the utilization of ERs, learners must possess the fundamental visuo-semiotic reasoning to grasp scientific concepts, processes, laws, theories, or phenomena as presented within the science curriculum. Consequently, it can be posited that the level of SL among learners is contingent upon the level of VL and SRA.

1.7 A description of the problem the current research is attempting to address

English is widely recognized as the language of science, and it is crucial to examine the significance of VL in science education, particularly for English Second Language learners. Existing research indicates that learners often encounter difficulties in effectively using and interpreting ERs utilized in science education (Colleta et al., 2008; Tripathy, 2020). The COVID-19 pandemic has accelerated the global digital transformation, resulting in a significant shift towards e-learning (Nielsen et al., 2020; Dey et al., 2022). This shift has exposed the limited digital and VL skills of learners, raising concerns about their ability to engage with visual media (Martínez-Alcalá, 2021).

The advancement of education through digitalization, as discussed by Jose (2021) and Simbirtseva (2020), presents new challenges that require innovative approaches to VL in schools. However, a critical issue arises from the lack of emphasis on visual vocabulary within educational institutions, leading to difficulties for learners in accurately understanding and visualizing ERs used in the science curriculum (Kedra & Zakeviciute, 2019). Although learners possess the ability to perceive and read images, they often struggle when it comes to interpreting and creating visual representations (Thompson, 2019).

Developing visual vocabulary is crucial to enhance learners' comprehension, allowing them to express scientific concepts using their own language and utilize visual images to demonstrate their understanding (Thompson, 2019). Visual vocabulary refers to the specific collection of visual terms, symbols, and conventions within a particular domain, such as science education. It involves comprehending and applying visual elements to effectively convey meaning (Thompson, 2019). In the context of science education, the cultivation of visual vocabulary enables learners to articulate their understanding of scientific concepts using their own words and utilize visual representations to demonstrate comprehension. Strategies aimed at enhancing visual vocabulary include explicit instruction, analysis and interpretation of various types of ERs, guided practice activities, discussions, and collaborative tasks (Thompson, 2019).

Despite educators' interest in transitioning from text to the use of ERs in the science classroom, explicit instruction in VL often remains overlooked (Duchak, 2014). This oversight is rooted in the assumption that learners possess sufficient VL skills acquired during their early science education (Kedra & Zakeviciute, 2019). However, this assumption hampers the development of critical visual skills in many learners, as specialized activities specifically designed to teach these skills are lacking (Kedra & Zakeviciute, 2019).

Science textbooks commonly incorporate a variety of ERs to represent abstract and complex concepts. However, the varying levels of abstraction employed in these representations can pose challenges for learners with underdeveloped VSs (Offerdahl et al., 2017). The lack of emphasis on the development of VSs is concerning, as it can impede effective learning with ERs (Mnguni et al., 2016) and subsequently impact SL and SRAs (Mnguni et al., 2016).

In conclusion, there is a need for further research focusing on the importance of VL in science education, particularly for English second language learners who depend on English as the language of science. Explicitly teaching VL skills, specifically during early childhood education, can significantly benefit learners by providing them with a solid foundation for accurately visualizing and comprehending scientific images. Therefore, it is essential to explore the significance of VL in science education and its impact on English second language learners, aiming to inform effective instructional practices and support their SL.

1.8 The rationale for conducting the current research

According to Mnguni et al. (2016), educators should be aware of learners' difficulties in interpreting and translating various types of ERs used in the curriculum on a daily basis. Schönborn (2005) emphasizes the importance of learners' interpretive competence and ability to translate between different ERs, as this enables them to construct integrated mental models of scientific phenomena. It further allows learners to develop cognitive strategies for effective interpretation of ERs. To enhance the interpretation of ERs, Kedra and Zakeviciute (2019) suggest that science educators and instructional designers should incorporate VL education across different grades and fields of science education. This approach can enhance the quality of teaching and learning practices by engaging learners in a more enjoyable manner.

Understanding how learners use and interpret ERs is important for educators and instructional designers. This research can provide valuable insights into the role of VL as a significant language of communication in science education. It can also assist science educators in developing effective teaching strategies for introducing science education at the pre-primary school level. Early acquisition of SL has been shown to enhance cognitive and linguistic development, especially when provided in an experiential environment like a science classroom (Gelman & Brenneman, 2004). Introducing science education in early childhood in South African pre-primary schools can promote physical development and offer learning opportunities that support social, cognitive, and emotional development (Darling-Hammond, 2000). Additionally, evidence suggests that early exposure to science education contributes to the development of SRA in learners, which is essential for pursuing science-related subjects (van Niekerk, 2019).

The value and significance of the current research lie in exposing children to science education at an early age to foster the development of 21st-century skills. Developing these skills early on provides learners with an advantage, particularly if they plan to pursue Science, Technology, Engineering, and Mathematics (STEM)-related subjects and careers. Furthermore, Eshach and Fried (2005) highlight that early exposure to science can lead to a positive attitude towards the subject, which is directly related to performance. When considering the use of ERs in the curriculum, instructional designers should consider learners' VL, SL, and SRA, as well as the Technological Pedagogical Content Knowledge of educators, which refers to the knowledge required to successfully integrate ERs in teaching (Schmidt, 2009). An advantage of integrating VL education into the curriculum is its applicability across different domains and the possibility of teaching it from an early age, similar to language acquisition. Previous literature also highlights several other benefits of developing VSs among early childhood learners, including improved critical thinking, metalinguistic skills, verbal and writing literacy, foreign language proficiency, and cost-effectiveness (Williams, 2007; Callow, 2008; Kaya, 2020; Takaya, 2016).

1.9 The research question along with the sub-questions explored in the current research

In an attempt to address the research problem, the research question being explored in the current research is: *What is the relationship between visual literacy and science literacy, for educators and curriculum designers to make the necessary changes to the curriculum to cater to 21st-century learners*?

The following are sub-questions that will be addressed to answer the research question at hand:

1. What is the level of visual literacy, science literacy, and scientific reasoning ability among pre-primary school learners?
2. What is the relationship between visual literacy, science literacy, and scientific reasoning ability?

1.10 The hypothesis underpinning the current research

From the above rationale, I hold the following hypothesis about the research:

1. Grade R learners who have been exposed to science education possess more of the following competencies as compared to those who are not learning science:
   - *Ability to understand scientific concepts, processes, laws, theories, or phenomena (science literacy) to learn science in pre-primary school.*
   - *Ability to evaluate, apply, or create conceptual visual representations (visual literacy) to learn science in pre-primary school.*
   - *Possess a conceptual understanding of science and inquiry skills (scientific reasoning ability) to learn science in pre-primary school.*

2. The level of SL correlates positively with VL and SRA among Grade R learners.

1.11 The aim and objectives set to be achieved in the current research

Given the aim to assist curriculum designers and educators in effectively using visual representations in science education in pre-primary school, the present objectives of the research are:

1. To determine the level of visual literacy, science literacy, and scientific reasoning ability among pre-primary school learners.
2. To determine the relationship between visual literacy, science literacy, and scientific reasoning ability.

1.12 The central principle for the chapter

Early childhood science education has not been prioritized in the South African education system. The research proposes using VL to enable science education in early childhood. According to Cook (2006), using ERs to present scientific data or concepts will reduce the learners' cognitive overload by providing clarity to abstract and complex phenomena. Additionally, VL is also known to enhance learners' 21st-century skills such as their VL skills, SL, and SRA. Lastly, according to Prayekti (2006), VL education has proven to play an essential role in SL and prepare learners to think critically, creatively, and logically, and have the initiative to respond to the issues in society that are caused by the impact of science and technology.

CHAPTER 2: THE EVALUATION OF AVAILABLE LITERATURE ON VISUAL LITERACY AND EARLY CHILDHOOD SCIENCE EDUCATION

"It's a great age to get the kids interested in science. Children love hands-on science. They're eager to learn and see how the world works. I know that we're thrilled to be part of this."

Nancy Young

2.1 Scholarly perspectives on the importance of visual literacy in early childhood science education

Building upon the background discussed in Chapter one, the current chapter explores the significant role of VL in the acquisition of SL skills and scientific readiness among children in pre-primary schools. Scientific learning heavily relies on the interpretation and utilization of ERs, making VL a crucial component in the field of science (Messaris, 2012). Extensive research demonstrates that VL is essential for learners to enhance their understanding of scientific concepts, processes, and phenomena.

Gersten and Baker (2000) assert that VL plays a significant facilitative role in science education, emphasizing its importance as a powerful tool in the educational context. Moreover, Anguiano (2004) highlights that the learning of science begins during the pre-primary years, where young learners engage with scientific concepts through their senses. This foundational sensory engagement, particularly through visual learning experiences, is a fundamental aspect of scientific learning. Establishing meaningful connections between scientific concepts and children's everyday experiences is pivotal for their mastery of these concepts (Gersten & Baker, 2000). Thus, this chapter advocates for the integration of visual aids in teaching and learning practices, particularly during early childhood, to enhance science education.

In summary, this chapter builds upon the established background and underscores the significance of VL in facilitating SL acquisition and scientific readiness among pre-primary children. Recognizing the importance of visual learning and its impact on scientific understanding, educators are encouraged to employ VL strategies to enrich science education experiences. Therefore, by utilizing ERs and promoting visual comprehension, educators can enhance the engagement, comprehension, and mastery of scientific concepts, particularly among children whose first language may not be English, considering English is commonly regarded as the universal language of science.

2.2 Visual literacy in the 21st-century society

In our contemporary society, science and technology education heavily rely on the use of ERs to convey information effectively (Lowe, 2000). Simultaneously, our social environment is increasingly saturated with visual content. Therefore, it is imperative to foster the development of visual communication, thinking, and learning skills, which involve both understanding and constructing visual images (Cope & Kalantzis, 2000a). Today's learners are born into a visually dominant world where the use of ERs has exponentially increased (Lowe, 2000). Consequently, there has been a surge in research and publications focused on incorporating ERs in educational settings (Buckely, 2000), driven by the need to cater to the preferences and needs of the *visual generation*. Paradoxically, despite the visual abundance in their lives, the post-millennial generation, characterized as technologically adept, often lacks VL skills (Kedra & Zakeviciute, 2019), which hinders their ability to effectively interpret and communicate using ERs (Brumberger, 2011).

According to Mnguni (2014), VL holds paramount importance in 21st-century education. Lundy and Stephens (2014) raise the question of what kind of learners educators aim to cultivate in this era, to which the resounding answer is a *visually literate* learner (Lundy & Stephens, 2015). Hattwig et al. (2013) assert that VL encompasses the ability to decode, interpret, and evaluate visual information successfully. Moreover, Lundy and Stephens (2014) emphasize the need for 21st-century learners to transition from passive recipients of ERs to active analyzers of visual messages, given the rapid technological advancements of today's world. Therefore, considering the aforementioned discourse, it is argued that VL is indispensable for 21st-century learners, enabling them to communicate effectively and participate meaningfully in the global dialogue.

2.3 Visual literacy in education

According to Felten (2008), schools have often focused on using words and text as sources of knowledge, even though learners struggle to visualize complex phenomena in education. Felten (2008) further stipulates that education should take advantage of using ERs for knowledge sharing across all disciplines. Kedran and Zakeviciute (2019) outline the advantages of VL in education: (1) ERs in knowledge acquisition assist learners in better understanding of the content; (2) the integration of VL in teaching develops the learner's creativity; (3) the use of ERs in teaching and learning enhances memory, which is beneficial for the learning process; (4) learning through ERs assists learners to articulate their thoughts and ideas better by improving their critical thinking skills. Therefore, in my view, by integrating VL into education, we can assist learners in developing their 21st-century skills as educators.

In addition to the advantages mentioned above for VL, Lehman (2015) makes a compelling case that educators need to find creative ways of introducing technology as part of their teaching strategies if they are going to be victorious in engaging with the post-millennial generation. Furthermore, Lehman (2015) stipulates the importance of VL in illuminating how our learners are being shaped in this image-dominated world. Lehman (2015) further proposes that we as educators make ERs an integral part of education, as there needs to be a shift in how learners are taught mathematics and science. Given the argument made by Lehman (2015), I argue that, that shift should be from the concept of *watching* science and mathematics to a more innovative way of conveying knowledge, where learners instead *do* science and mathematics through interactive activities that include visuals or simulations.

In light of the preceding argument, I support the statement made by Zull (2002) that educators should be making extensive use of ERs in their lessons to assist learners in better understanding the content. This can be done by teaching learners using ERs or by simply just asking learners to represent their knowledge in a visual form. Wieman (2007) supports this perception and argues that a range of ERs such as simulations must be included in every lesson, particularly in mathematics and science. Therefore, in line with Handelsman et al. (2007), my argument is that as educators introduce *visual frameworks* in their lessons, this will assist learners in understanding the content better and improving their 21st-century skills.

Nonetheless, in my opinion, regardless of how effective ERs are in the classroom, learners often face challenges in comprehending them. One of the reasons that learners often find it challenging to make sense of ERs is that educators often assume that the images used in the curriculum are self-explanatory (Lowe, 2000). This assumption is supported by research, revealing a huge discrepancy between educators and learners regarding their ability to interpret and comprehend ERs. In this regard, my argument is that this discrepancy is rooted in the fact that educators tend to have more conceptual knowledge of the subject matter than learners do. Additionally, educators tend to assume that learners are as visually literate as they are and would have automatically acquired the skills required to interpret and understand ERs during their learning. Furthermore, Schönborn and Anderson (2008) noted that one other contributing factor to learners' misinterpretation of ERs is that learners are not correctly taught the skills required to visualize and interpret the ERs used in the curriculum. Therefore, given the above discourse, I assert that to avoid learners misinterpreting the ERs, the skills needed to visualize and interpret ERs correctly should be explicitly taught to the learners.

In this chapter, I contend that the integration of VL in education is crucial, particularly considering the widespread access to smartphone devices among learners. Classrooms now serve as spaces where learners can actively engage in the creation and interpretation of visual messages, thereby contributing to global conversations (Lundy & Stephens, 2014). VL is not only significant in the educational context but also an essential aspect of general literacy. Vekiri (2002) posits that learners proficient in VL possess the ability to effectively locate, evaluate, and interpret information, thereby facilitating a higher degree of learning. Over the years, education has been in competition with the visual world, resulting in an increasing number of ERs incorporated into teaching and learning materials. Consequently, learners need to acquire the necessary skills to navigate and access the curriculum effectively.

Given the aforementioned discourse, it is affirmed that learners must possess the ability to perceive and analyze ERs, which entails understanding the purpose and employing appropriate techniques for accurate interpretation. In the realm of science education, these VL skills are particularly vital for effectively comprehending abstract scientific ERs, which differ significantly from interpreting ordinary pictures found in magazines or newspapers. VL encompasses various aspects, as discussed in Chapter one. Based on Avgerinou and Pettersson's (2011) latest theory, visual communication, visual language, visual learning, visual perception, and visual thinking constitute the five pillars of VL, briefly described as follows:

Visual communication is the effective conveyance of meaning or ideas using ERs, encompassing mediums such as maps, signals, paintings, illustrations, graphics, animations, web designs, and advertising (Ijaz, 2018). Visual language, although lacking a universally agreed-upon definition in the research community (Erwig et al., 2016), can be understood as a form of communication that relies on visual information rather than written text to convey meaning or ideas. Learners who prefer using ERs for learning are considered visual learners, relying on graphics, models, maps, and colorful diagrams to communicate their ideas and enhance their learning experiences. Visual perception, as discussed by Felten (2008), extends beyond the passive reception of stimuli through the eyes and involves the brain's active process of making meaning from visual stimuli. Visual perception is influenced not only by external stimuli but also by an individual's perspective and viewpoint, leading to different interpretations of the same object. Lastly, visual thinking refers to the ability to transform information into visual representations, such as pictures, graphics, or other forms that facilitate the communication of information effectively (Duchak, 2014).

Ametller and Pinto (2002) assert that VL in education encompasses the ability to read (comprehend observed ERs), write (create visual representations), and learn (think) and express oneself using visual images. This entails a progression from basic identification of observed ERs to the more complex task of interpreting them within a contextual, metaphoric, and philosophical framework. Based on the above discussion, it is argued that similar to teaching children how to read and write, they should also be taught how to interpret observed ERs from a young age to facilitate their access to the curriculum. Additionally, much like textual information requires specific reading skills for comprehension, ERs also demand specialized skills for accurate interpretation. Furthermore, it is contended that ERs, like text, can be misleading and subject to varying interpretations. Hence, VL has become an indispensable aspect of life in today's technologically driven world. Thus, with the proliferation of technological innovations, teaching learners how to correctly interpret, evaluate, organize, and construct visual information has become paramount.

2.4 Visual literacy in science education

According to Felten (2008), traditional education has primarily relied on words and text as the main sources of knowledge, often overlooking the difficulties learners face in visualizing complex biological and chemical processes in science education. While science textbooks often include biological and scientific illustrations, the question remains whether learners truly understand these illustrations. One of the major challenges in introducing VL in science education lies in effectively utilizing ERs in the science classroom. While learners may excel at reading and comprehending text, they often struggle to apply the same skills when interpreting diagrams and visual representations. As science educators, we frequently focus on teaching learners about the accompanying text of ERs, neglecting to explicitly explain the meaning of the images themselves, even in the absence of text (McTigue & Flowers, 2011).

Schönborn and Anderson (2008) argue for the explicit teaching of VL as an integral part of the modern science curriculum, presenting three reasons for its importance. Firstly, as learners are increasingly exposed to diverse and potentially confusing ERs in their learning experiences, they require higher levels of VL, especially in the context of science education. Secondly, to effectively interpret and comprehend ERs used in the curriculum, learners need to develop their own visual skills beyond what they acquire informally. Thirdly, learners with poor VL tend to struggle in interpreting and comprehending the ERs employed in the curriculum. Therefore, being visually literate should be considered a prerequisite for science education, as ERs have become a fundamental means of presenting information in the 21st century.

Based on the research conducted by Schönborn (2005), ten fundamental guidelines for teaching and learning with the use of ERs in science education have been identified. The first guideline involves recognizing current theories of how individuals learn from and visualize ERs, particularly focusing on constructivism, which explains how learners construct their own meanings and mental pictures based on prior knowledge. Additionally, the dual-coding theory, which emphasizes the connection between verbal and visual representations in the brain, can enhance visualization among science learners.

The second guideline emphasizes addressing key factors that affect learners' ability to visualize ERs. These factors include learners' general reasoning skills, their ability to read and interpret ERs, their skill in selecting relevant information from ERs, their understanding of the subject matter, the nature and quality of the ERs used, and the conceptual knowledge represented by the ERs. Therefore, by addressing these factors through integrated learning activities and curriculum design, learners' VL skills can be enhanced.

The third guideline highlights the significance of pedagogical content knowledge in visualization. Educators need to have a solid understanding of both the subject matter and how to teach it effectively, considering the nature of the concepts being taught. By aligning the curriculum design and teaching methods with the conceptual reasoning and VL levels of learners and educators, VL skills can be improved. The fourth guideline stresses the importance of making the message conveyed by ERs explicit to learners. Educators must explain the purpose of the ERs, their connection to the content topic, and the implied meaning they convey.

The fifth guideline emphasizes the need for learners to be familiar with the visual language and conventions used in ERs. Symbolism, which involves using visual symbols to represent ideas or information, needs to be explicitly taught to learners to enhance their visual language skills in science. The sixth guideline calls for learners to be aware of the limitations of each ER. By critically analyzing and discussing the limitations of ERs, learners can develop a more nuanced understanding of their representations. The seventh guideline advocates for a multiple-representation approach to ER visualization. Exposing learners to a range of ERs depicting the same phenomena helps build integrated mental models and cognitive strategies for interpreting ERs effectively.

The eighth guideline emphasizes the importance of empowering learners with the necessary skills to process scientific ERs. It is evident from research that there has been limited explicit teaching of VL to science learners. To develop learners' VSs, one effective approach is to expose them to a diverse range of tasks containing ERs. For instance, interpreting ERs depicting 3D shapes and interpreting 2D shapes require different sets of VSs. Visualizing 3D shapes correctly requires cognitive skills distinct from those needed to visualize 2D shapes (Schönborn & Anderson, 2006). Additionally, it is crucial for learners to develop transfer skills that enable them to link and transfer between ERs depicting the same phenomena but in different contexts. This development of transfer skills enhances learners' flexibility in applying their knowledge (Grayson, 1995).

Moving on to the ninth guideline, it focuses on the development of learners' metacognitive processing skills. Ametller and Pinto (2002) highlight the significance of providing learners with activities that stimulate their metacognitive skills in science education. It is essential for learners to engage in activities involving various ERs while reflecting on their own thinking process. Reflecting on the interpretation of ERs enhances learners' VL skills, enabling them to construct more robust mental images and derive deeper meaning from the ERs (Kedra & Zakeviciute, 2019). Schönborn and Anderson (2006) suggest multiple strategies for developing metacognitive skills in learners. One approach is to encourage learners to step back and continuously assess their understanding of the ERs or evaluate whether they are correctly interpreting the symbolism within the ERs. Furthermore, by consistently assessing their learning and understanding of the ERs, learners can determine if the ERs used are accurate representations of the phenomena or if they might be misleading. This ability to think about their own thinking during the learning process enhances learners' metacognitive thinking skills (Schönborn & Anderson, 2006). The tenth guideline emphasizes the use of learner-generated ERs to enhance learners' visualization of biochemical phenomena. Gobert and Clement (1999) suggest that having learners generate their own cellular and molecular structure diagrams can significantly improve their VL. Assisting learners in constructing and refining their ERs enhances their ability to process abstract ERs effectively (Lowe, 1991). Implementing guidelines for VL education in science can be demanding, as it requires a systematic introduction rather than overwhelming learners with all the guidelines at once. According to Kedra and Zakeviciute (2019), VL education necessitates revolutionary thinking, assessing, grading, and testing. They describe VL education as complex, characterized by its ephemeral, momentary, multitasking, simultaneous, random, and non-structural nature, often occurring in digital formats. Despite these challenges, VL education is achievable in the science classroom and holds significant importance. VL allows educators to discuss abstract scientific concepts that may not be easily explained verbally, helping learners grasp these concepts more effectively.

Additionally, the use of ERs in science classrooms, such as augmented reality or virtual reality, can make the invisible visible, enhancing learners' perception and understanding. However, a major challenge in VL education is the requirement for highly skilled and visually literate educators or instructors. Therefore, there is a pressing need to provide training for educators to develop their own VL skills and effectively transfer these skills to their students. Therefore, by doing so, educators can empower learners to develop critical thinking, problem-solving, communication, collaboration, technological competence, creativity, and information literacy skills, which are vital for success in the 21st century.

2.5 Visual literacy pre-primary school education

The challenges of not integrating VL into pre-primary school education are evident in the research conducted by Lopatovska et al. (2018) and supported by existing literature. VL is crucial in a child's early years as it enables them to navigate various modes of ERs and enhances the learning process (Barton, 2016). Additionally, VL promotes the development of different literacies, including spoken language, information literacy, and digital literacy (Avgerinou, 2003). The advantages of introducing VL in early childhood are numerous, such as improving critical thinking skills, inducing metalinguistic skills, promoting oral and written literacies, enhancing foreign language development proficiency, and fostering the ability to interpret artwork (Williams, 2007; Callow, 2008; Duchak, 2014; Tomaseviae-Daneeviae, 1999).

Although VL programs are being implemented in the educational system, the existing programs often neglect preschool children (Lopatovska, 2016). This lack of targeted programs poses a challenge in effectively incorporating VL into pre-primary school education. However, Lopatovska et al. (2018) conducted research to address this issue and proposed strategies for engaging pre-primary school learners in VL instruction. The study focused on developing and testing a VL program for children aged three to five years. The program consisted of four workshops covering the basic elements of VL, including color, line, shape, and texture. These workshops involved assessing prior knowledge, introducing VL elements through paint, photographs, and illustrations from children's books, assessing newly acquired knowledge, encouraging critical and creative thinking skills, and facilitating hands-on activities. The results indicated a significant improvement in the children's knowledge of VL skills after participating in the workshops.

In conclusion, the challenges of not integrating VL into pre-primary school education include the limited availability of targeted programs, missed opportunities for skill development, difficulties in understanding visual components of scientific concepts, limitations in observation and data interpretation skills, and obstacles in effective science communication. The research by Lopatovska et al. (2018) highlights the importance of addressing these challenges and provides strategies for engaging pre-primary school learners in VL instruction, leading to significant improvements in their VL skills.

2.6 Science education in pre-primary school

According to Kacan and Celikler (2017), "science education is a process that begins when children start to discover their surroundings" (p. 1). Children have a strong sense of curiosity. Their sense of curiosity and interest to explore their surroundings motivates them to learn (Bose et al., 2013). This quality is seen right from birth, as babies begin to realize and recognize their surroundings. Furthermore, the sense of curiosity can extend until one becomes an adult. However, in my opinion, not many educators or parents regard it to be of importance. Often educators and parents tend to suppress the child's sense of curiosity, intentionally or unintentionally. However, much like Kacan and Celikler (2017), I argue that in the process of realizing and recognizing their environment, children are working on developing their cognitive abilities.

2.6.1 Learning science by questioning

As children begin to ask questions about their surroundings and explore their environment, this sense of curiosity leads to their questions meriting scientific explanations. Kecan and Celikler (2012) argue that "children, who ask various questions and receive answers about their science-related surroundings, grow more interest in science and start to ask more questions about such subjects" (p.2). Consequently, the authors argue that raising children interested in science while still in pre-primary school will increase their motivation to choose science-related courses in tertiary school. Research has also shown that the earlier children are exposed to science, the better, as children who are exposed to science in early childhood, tend to be more comfortable with the subject as they progress with their education (Dejoncheere, 2016). In this regards, Brenneman (2011), stipulates that early childhood exposure to science is important for school readiness and foundations for future learning. In addition, Mantzicopoulos and Samarapungavan (2007) further reiterate that the earlier children are introduced to the culture of science, the better their development of scientific knowledge.

Children are known to pose many questions to their families, friends, and even educators during their early years of development. According to Chouinard (2007), children's questions while they are in pre-primary school play an important part in their cognitive development. Additionally, questions allow children to get the information they require to develop their cognitive skills closer to that of an adult (Chouinard, 2007). As stated by Chouinard (2007), if questions are important for cognitive development, then the following statements should be maintained throughout their early years of education: (1) children should ask questions to get information; (2) children should be provided with answers that are accompanied by logical explanations to develop their logical-reasoning ability; (3) children should be encouraged to ask specific questions to obtain information to further their knowledge, and not just to get attention; (4) children should ask information-seeking questions that are related in the topic, in order to structure their cognitive development; (5) as educators we must recognize questions that children ask, as they are important for their cognitive development and assist them in asking questions for a purpose, in order for them to receive accurate information to build on their existing knowledge.

According to Chin and Osborne (2008), questioning by children forms an integral part of science learning. As stated by Cuccio-Schirripa and Steiner (2000), "questioning is one of the thinking processing skills which is structurally embedded in the thinking operation of critical thinking, creative thinking, and problem-solving" (p. 210). It is important for us as educators not to dismiss the questions children bring to us but rather to provide them with logical explanations to help build their reasoning ability. Therefore, in this respect, I argue that children should be encouraged to ask questions, as this will foster their scientific curiosity by engaging them in science inquiry-based learning.

2.6.2 Learning science through inquiry-based learning

According to Hodson (2014), science is best learned by *doing* which encourages learners to engage in the science content. In line with Hodson (2014), Dejonckheere et al. (2016) stipulates that learners can learn science or *do* science through scientific inquiry-based learning. According to Dejonckheere et al. (2016) scientific inquiry-based learning is based on giving the learners opportunities to investigate a problem by asking questions, making observations, and collecting evidence that would test the ideas or possible explanations for the problem. Harlen (2013) stipulates that inquiry-based learning can grow a single view, which may be obtained through observation and expand into a big idea through the development of theories that explain why this phenomenon exists. The activities for inquiry-based learning should be designed to stimulate the learners intellectually and challenge them to ask questions to find answers to their problems. Inquiry-based learning offers learners a variety of opportunities to make sense of their surroundings, rather than just learning about isolated bits of information regarding their surroundings. In this regard, I support the argument made by Harlen (2013) that activities designed for inquiry-based learning should be created to promote the development of cognition among children, which involves children asking questions, solving problems, and even thinking independently. Furthermore, in line with Harlen (2013), Caballero-Garcia and Diaz (2018) deem the inquiry-based learning as an approach that "represents a revolutionary advance in autonomous and critical thinking, as it encourages learners to become good communicators and reflective people, willing to play an active role and make a difference in the world" (p. 50).

2.6.3 Role of educators in pre-primary school science education

Pre-primary school educators must be able to discern the needs of their learners to support them during their learning process. According to Bose et al. (2013), pre-primary school educators should be designing science-related activities that give children "opportunities to develop fundamental values, skills, and understanding of different aspects, for example, to develop an understanding of basic properties of numbers and weight" (p.44). Brenneman (2011) stipulates the importance of pre-primary educators possessing relevant science content knowledge and pedagogical knowledge to meet the learner's needs. Furthermore, Darling-Hammond (2000) argues that “educators who have greater knowledge of teaching and learning are more highly rated and are more effective with learners, especially at tasks requiring higher order thinking and problem-solving” (p. 167). Therefore, in my view, educators must understand the role that they play in supporting scientific knowledge of learners.

Considering the above discourse, this also highlights the importance of developing pre-primary school educators with basic science knowledge that will nurture the learners’ curiosity. In a review done by Edwards and Loveridge (2011), the research describes two factors that may influence the pre-primary school educator’s prospects of supporting children to learn science in pre-primary school. These factors included: (1) the educator’s attitude and beliefs and (2) the educators’ level of science content knowledge and understanding. The above-mentioned factors are also found in research done by Saçkes (2011), who investigated how often pre-primary school educators incorporated life science, physical science, and earth and space science in their lessons. The research revealed variables that influence the educator’s likelihood of incorporating science in their daily lessons. The research further uncovered that educators with a science education background were more likely to integrate science concepts in their lessons. Another example included educators who were more concerned about nature and preserving the environment and were more likely to teach the learners about science concepts that relate to preserving the environment. On the other hand, the educators’ years of teaching experience or their ability to cope with managing the curriculum were not noted as some of the variables that are likely to influence the educator’s frequency of incorporating science in their lessons.

Alternatively, Timur (2012) investigated pre-primary school educators’ attitudes towards teaching science in pre-primary school and the reasons behind their attitudes. The research revealed that one of the reasons why pre-primary educators are reluctant in integrating science into their lessons is due to their lack of science content knowledge. Timur (2012) further argues that “effective teaching of science in pre-primary school is dependent on the pre-primary school educators’ attitudes towards science and the factors that affect the development of their attitudes” (p.2998). Considering that most of the science concepts in pre-primary school are presented through activities, the adequacy and development of the educators’ pedagogical science content knowledge should be prioritized (Ayvacı, 2010). In contrast, research shows that most educators tend to just replace science activities with art, due to their lack of basic science content knowledge. Consequently, the reluctance of pre-primary school educators to teach science in pre-primary school results from their inadequate pedagogical science content knowledge development. Therefore, in light of the above discourse, Novianti et al (2020) regards “the educators’ attitudes toward teaching science as a significant factor in predicting developmentally appropriate teaching practices in science” (p. 2).

Considering the above findings, I support the argument made by Sackes et al. (2011), that children are most likely to be disadvantaged in their development of cognitive skills that form the foundation of scientific thinking ability. According to Kecan and Celikler (2012), it is therefore important that prospective pre-primary school educators be well-trained and developed for them to transfer science knowledge to the curious children they find in their classrooms. Therefore, in this regard “raising prospective preschool educators with good science qualifications will significantly affect the interest of children in science and research” (Kecan and Celikler, 2012, p.2).

2.7 Current opportunities for learning science in pre-primary school

Research shows that opportunities for pre-primary school learners to be exposed to science education in their classrooms is limited (Piasta, 2014). Notable findings from a few studies suggest that pre-primary school learners are not exposed to science in their classrooms as they should be. This is seen in a study done by La Paro et al. (2004), whereby the researchers studied 970 pre-primary school learners from six states in the United States of America. The research investigated the time spent teaching mathematics, science, and language literacy to pre-primary school learners. The findings of the research found that, on average, pre-primary school learners spend about 6% of their time in school learning mathematics, 14% on language literacy activities, and only 6% on learning science. Therefore, the findings of the study imply that pre-primary school classroom educators devote less and less time to teaching science.

Early et al. (2010) on the other hand discovered that pre-primary school learners spent 11% of their time at school doing science activities and only 8% on mathematics. In a similar research, Connor et al. (2006) examined 156 learners in pre-primary schools and found that on a daily basis, an average of 15 minutes were spent on language literacy, while 8 minutes were spent on mathematics and only 3 minutes were spent on science activities. The one research that I am aware of, that measures and describes the science learning opportunities of pre-primary school learners in great detail is that of Tu (2006). The research examined the availability of *formal* and *informal* science learning opportunities in pre-primary school classrooms. In the research, it was found that only 120 minutes, or 4.5%, of the daily class time, was devoted to formal science learning, which included educator-led activities such as setting up an experiment. In contrast, only 8.8% of the activities were informal science, which included free-choice activities in which learners used magnifying glasses to examine objects in their environment. Similarly, Piasta's (2014) research revealed that only 13.6% of the classroom activities are devoted to science learning, however, the study does not disclose the type of science activities the learners engaged in.

Although a great deal of literature focuses on the importance of early childhood science education, very little attention is given to pre-primary school learners' science learning experiences in the classroom (Piasta, 2014). Due to the above reason, Piasta (2014) conducted research that provided an in-depth snapshot of science learning opportunities offered to pre-primary school learners. The research investigated the unit of time devoted to science learning in pre-primary schools. This research discovered that pre-primary school learners were given a variety of science learning opportunities. Contrary to the findings documented by Connor et al. (2006), the research indicated that more time was spent providing pre-primary learners with unique science learning opportunities. According to Piasta (2014), 26 minutes a day were devoted to science in pre-primary school, which is eight times more than the amount of time reported by Connor et al. (2006).

2.8 The world's view on pre-primary science education

The implementation of the science curriculum in pre-primary schools forms the foundation of a child's journey of learning science (Havu-Nuutinen et al., 2021). Even though, science curricula in pre-primary schools may differ across the different countries on different continents, the mandate of any curriculum is to serve as a guide to educators in planning their lessons, implementing their lesson plans, and assessing their pedagogy at very different levels and from different ideologies (Smith and Gunstone, 2009). In this regard, Havu-Nuutinen et al. (2021) regard the curriculum as the foundation "that tracks for education by creating different values, discourses and cultures to implement it" (p. 2).

2.8.1 Nordic countries

According to Broström (2015), science in preschool, is defined as "all concrete experimental activities children carry out in social interaction, which contribute to children's interest and slowly emergent understanding of nature, technology, health, mathematics, biology, chemistry and physics" (p. 107). It is through these activities that a child gets to gain knowledge on "plants, animals, the circuit of nature, natural phenomenon plus nature regularity and accordingly understand subjects like light, water, magnetism, electricity and air current" (p. 107). In Nordic pre-primary schools, nature and natural phenomena (nature science and technology science) form part of the daily schedule (Broström, 2015). This can be seen in most of the Nordic science curricula of pre-primary schools.

A. Sweden

Sweden is experiencing a surge in science education (Andersson & Gullberg, 2012), as Sweden is among the few countries embracing science education in pre-primary schools. In 2010, Sweden updated its national curricula for pre-primary schools and the objectives of science education in pre-primary school include: (1) "pre-primary school learners being able to acquire and nuance the meaning of concepts, see connections and discover new ways to understand their surroundings; (2) pre-primary school learners developing an interest in and understanding of cycles in nature and how people, nature and society influence one another; (3) pre-primary school learners developing an understanding of science and relationships in nature, such as knowledge of plants and animals as well as simple chemical processes and physical phenomena; (5) pre-primary school learners developing the ability to differentiate, explore, document, pose questions about and discuss science" (Brodin & Renblad, 2014, p. 306).

According to Sweden's national curriculum for pre-primary school, science education generally is based on nature, and not on identifying specific fields of content knowledge. This means that educators would choose their science topic relating to relevant science content to achieve the above-mentioned objectives when planning and developing activities for learners. The freedom to choose topics by pre-primary school educators is based on the research that revealed the inadequacy level of pre-primary school educators regarding science content knowledge and pedagogical content knowledge (Appleton, 2007). However, unlike other countries, pre-primary schools in Sweden strive to assist pre-primary school learners to develop a greater interest in mathematics and science by utilizing everyday activities.

2.8.2 European countries

A. Belgium

Unlike in Sweden where the national curriculum has been updated by integrating science education in pre-primary, in Belgium, science in pre-primary schools does not receive enough attention that it should. Brenneman (2011) argues that educators' lack of science content knowledge and pedagogical understanding is one of the reasons why science in pre-primary schools does not get enough attention. Furthermore, Brenneman (2011) states that pre-primary educators lack the SRAs that are necessary for science education, which I argue disadvantages learners by preventing them from learning science and by underemphasizing their development of cognitive and SRAs (Sackes et al., 2011). According to Lorch et al. (2008), another reason that science is not getting enough attention in pre-primary schools is that pre-primary school educators lack the skills to translate scientific inquiry into classroom practice.

Furthermore, according to Dejonckheere et al. (2016), for us to steer clear of the challenges mentioned above, pre-primary school educators need to be assisted with pedagogical knowledge. Dejonckheere et al. (2016) further recommend that Belgium pre-primary educators be trained based on inquiry-based pedagogy in science, which should also be simple enough for educators to implement. With inquiry-based learning, children must be assisted by their educators to develop the right skills for scientific investigation. Dejoncheere et al. (2016), stipulate that literature shows that children want to test the wrong variable during a scientific investigation, which may lead to inconsistent results and conclusions. Therefore, it is our responsibility as science educators to guide and support children to develop the right skills for scientific investigation (Harlen, 2000).

Additionally, a science pre-primary science educator should be able to design environments that will allow a child to explore, play, and learn simultaneously. In this regards, pre-primary school educators should be able to "guide their learners by supporting self-regulation skills, asking probing questions, focusing the children's attention to causes and effects or helping them reflect on what was found. In that way, the focus should be on the process skills rather than formal knowledge and conceptual change" (Dejoncheere et al., 2016, p. 538).

B. Turkey

Much like Belgium, Ocler (2017) stipulates that there is a need for Turkey to create science content standards for pre-primary school learners, as the majority of pre-primary school educators have challenges with selecting the relevant science concepts to present to the learners. This often results in educators completely neglecting to teach science in pre-primary school classrooms. As Wilson (2002) emphasized, pre-primary school educators have a misconception that science must always be presented formally because the subject is abstract and theoretical. According to Ocler (2017), many pre-primary school educators perceive science to be difficult to understand and would be challenging to teach, as they are often motivated to teach subjects/concepts that they feel comfortable and confident in teaching. From the same perspective, Hope et al. (2013) claims that pre-primary school educators avoid providing low-quality science experiences to learners due to their lack of science content knowledge and pedagogical knowledge. As a result, educators completely avoid presenting any science lessons to their learners.

Furthermore, there is a dearth of research focused on early childhood science education in Turkey (Soylu, 2016). When science education in schools is investigated in Turkey, the research often focuses on primary and high schools, neglecting pre-primary school education (Ata-Akturk et al., 2017). Also, when early childhood education studies are conducted, they tend to focus primarily on the perceptions of in-service and pre-service educators (Bedel, 2008) rather than the learning science of pre-primary school children (Atalay-Turhan et al., 2009). Despite the growing interest in pre-primary school education, it is clear that science education in early childhood has not received the much-needed support it should. This is based on the question that still arises among pre-primary school educators: "Can young children cope with scientific concepts?" (Senocak et al., 2013, p. 2218). According to Tu (2006) "Science education has been strongly advocated in the primary school curriculum for its importance to young children" (p.247).

2.8.3 Asian countries

A. Singapore

Like Sweden, Singapore's Ministry of Education (MOE) Kindergarten Curriculum Framework (MOE, 2012) demonstrates the importance of play in early childhood science education. The MOE (2012) emphasizes the importance of play as "a way for children to learn in pre-primary school, based on the notion that young children learn best when they play by themselves or with their friends and siblings" (p. 67). Purposeful play is when an educator plans to set a fun and exciting activities that require the active participation of the learners to achieve specific learning objectives (MOE, 2012). The MOE's kindergarten curriculum framework specifies the discovery of the world as one of the learning areas (MOE, 2012, p. 67). This learning area mainly deals with how learners experience the world around them. Even though science is not formally taught in pre-primary schools until primary school, the MOE deems it crucial to start developing the science process skills of children from as early as infancy. The learning area affords learners opportunities for scientific investigative skills such as observing, comparing, and asking questions (MOE, 2012). Therefore, the focus of the MOE concerning the discovery of the world learning area is to introduce science to Singapore pre-primary schools through fun and playful activities.

B. Thailand

Among the countries promoting the importance of science education in pre-primary schools in Thailand. Thailand has been promoting science education in pre-primary schools since 2010 through the national project called *Little Scientists* House in Thailand. In Germany, the project was adopted from the *Haus der kleinen Forscher* Foundation (Seetee & Dahsah, 2017). Around the country, about 20 000 prep-primary schools are involved in the project. Each school is awarded a certificate of completion at the end of each academic year if it successfully implements 20 science learning activities and one scientific investigatory project with its pre-primary school learners (Seetee & Dahsah, 2017). The end goal of this initiative is to support pre-primary schools in developing science process skills among pre-primary school learners (Seetee & Dahsah, 2017). According to Choirunnisa et al. (2018), "science process skills are important in science learning as the basis for improving the other thinking skills which are much more complex such as 4C that has been explained before" (p. 1).

2.8.4 United States of America

In California, according to the California Department of Education (2007), more than one in three pre-primary school learners are English learners. Mammino (2010) deems learning science in a second language to be a barrier. This is based on the reason that learning science can be complex, due to the complexity of the scientific content, which may include abstract ideas, laws, and theoretical entities (Wellington & Ireson, 2008). Studies show that many second language learners tend to have challenges with learning English, and so they would often find it challenging to comprehend science content knowledge due to the language barrier (Desai, 2001), as a result, this adversely affects their academic performance. Diverse cultures and multilingualism characterize countries like the United States of America, even though the United States of America does not have an official language (White, 2012), English is still the preferred language of instruction and learning in most educational systems.

According to Spycher (2009), one instructional approach for assisting English learners in understanding science better is inquiry-based learning. In the state of California, where most pre-primary school learners find themselves in English-only classrooms, they are often taught science by educators who do not speak their first language and have not been trained to respond to the language barriers that the learners may be experiencing (Gándara et al., 2003). Lee et al. (2006) suggest that inquiry-based science is effective for English learners for the following three reasons: (1) hands-on activities that form the basis of inquiry-based learning tend to reduce the linguistic burden that pre-primary school learners may be experienced by participating in the science-related activities, while also learning the English language; (2) the collaborative nature of inquiry-based learning provides the English learners with opportunities to interact in science-related activities in a meaningful manner, through learning the science language, which will improve the learners level of English proficiency; (3) inquiry-based learning caters for learners with diverse learning styles to demonstrate their understanding of the content, promoting their understanding, which promotes their language and communication skills.

Findings from two of the largest studies on this subject matter (Amaral et al., 2002; Lee et al., 2005) support the aforementioned reasons suggested by Lee et al. (2006). The studies investigated "the effects of inquiry-based instructional interventions to promote science content knowledge and improve the learners' English language proficiency. The findings revealed that both areas are enhanced when learning occurs in linguistically, socially, and cognitively meaningful contexts and supportive to learners" (Spycher, 2009, p. 362).

Another pedagogy for early childhood science education that seems to be a growing influence in the United States of America is the Reggio Emilia Approach. This appears to be very compatible with science education at the early stages and the development of science process skills (Stegelin, 2003). According to Stegelin (2003) the Reggio Emilia Approach is defined as "a philosophy that approaches pre-primary school pedagogy, in a different manner, where the community and environment of the child play an important role in the child's early childhood education. This approach joins the child's education, well-being, and fundamental rights, with the support given to/by the child's families" (p.1).

Additionally, Stelegin (2003) asserts that pre-primary school educators that implement this approach in their classrooms emphasize the following concepts are critical: "(1) the view of the child as a learner; (2) the integrated, emergent curriculum and project work; (3) the educator–child learning relationship; and (4) the documentation of learners' thinking processes and products" (p. 163). These concepts align with what is expected in science classrooms in pre-primary schools. Most of these concepts are compatible with the early childhood science curriculum. Harlan and Rivkin (2000) highlight that the benefits of this approach are the development of 21st-century skills, which fit perfectly well with constructivist theory and inquiry-based learning in pre-primary school science education in the USA.

Furthermore, in a Reggio Emilia pre-primary science classroom, Reggio Emilia educators are encouraged to engage in active education by creating science-related projects that will challenge the learner's science content knowledge while developing the learner's science process skills. Moreover, a Reggio Emilia classroom exposes learners to real-life scenarios that give learners the motivation to solve problems through collaborative learning, which forms the basis of social constructivism and inquiry-based learning (Farland-Smith, 2019). Lastly, a critical aspect of this approach is that it does not follow any specific curriculum or programme. Instead, it is based on providing a child to learn by self-experience, which is ideal as it offers a learner-centered approach to introducing science and gives a more hands-on experience for the learners.

2.8.5 Australia

In Australia, the first Early Years Learning Framework (birth to five years) is the main core Australian science curriculum used in pre-primary schools up to Grade 2 (Australian Government Department of Education and Training, 2019). The major component of this curriculum is based on the need for pre-primary school educators to support children in building their independence during their time of self-discovery. According to Havu-Nuutinen (2021), even though there is no set curriculum for early childhood science education in Australia, the curriculum encourages the development of the learners' science process skills through their self-discovery activities by implementing the constructivism approach, which draws attention to the constructivist pedagogy (Branscombe et al., 2013). In this regard I argue that this approach can ensure that children are supported in developing 21st-century skills, which also helps create a strong sense of self-awareness in children. Additionally, implementing the constructivism approach in pre-primary school classrooms improves problem-solving skills among the learners. It encourages the learners to participate in scientific investigations and develop other social skills through inquiry dispositions (Australian Government of Department of Education and Training, 2015).

According to Archer et al. (2014), the constructivist perspective for pre-primary school science emphasizes that pre-primary school educators play a critical role in developing critical thinking skills, problem-solving skills, and children's thinking and ideas in science topics support problem-solving and social interaction skills. Additionally, the constructivist perspective for pre-primary school science education does away with the educator-centered approach and encourages a learner-centered learning approach (Fleer 2018). This perspective suggests that pre-primary school science educators engage their learners in inquiry-based science investigations to develop their science conceptual knowledge (Branscombe et al., 2013).

However, the one challenge limiting the learners through this approach is the lack of educators' understanding of science concepts (Hammer & Manz, 2019) and the nature of science (Duruk et al. 2019). As a resolution to this challenge, Fluckiger et al. (2018) suggest that more work needs to be done by the Australian Government Department of Education and Training to encourage pre-primary school educators to implement science education in their classrooms. Additionally, the role of the pre-primary school science educator is to take notice of the constructivist perspective and use them to the benefit of the learners. Havu-Nuutinen (2021) proposes the need for a curriculum with clear standards and guidelines to empower pre-primary educators with content and pedagogical knowledge relevant to science education in early childhood.

2.8.6 African countries

A. Botswana

In Botswana, Bose et al. (2013) studied the existing practices in terms of science education in pre-primary schools. From 80 pre-primary schools around Botswana, 64 pre-primary school educators participated in the research (Bose et al., 2013). Pre-primary school educators were asked probing questions to reveal whether their educator training qualification had prepared them to teach science in pre-primary schools. The research showed that many (84%) educators felt that they had relevant science content knowledge to teach science to their learners (Bose et al., 2013). Of the 84% of the educators who felt that they had the relevant science content knowledge to teach science in pre-primary school, 75% indicated that their educator training qualification had prepared them to teach science in pre-primary school (Bose et al., 2013).

The researchers further asked the educators probing questions that would investigate the types of activities that educators engage in with their learners during science learners. Only 16% revealed indulging in science-related activities in their classrooms (Bose et al., 2013). The activities that the educators would engage with include “seasons, weather, mass, volume, sources of light, balancing, plantation, living & non-living things, body parts, sounds, seed planting, use of human senses, gardening, and games, nature walks, activities related to hygiene and road safety” (Bose et al., 2013, p. 46). Of the 16% that revealed indulging in science-related activities in their classrooms, very few educators focused on developing the learner’s science process skills through inquiry-based learning (Bose et al., 2013).

Based on the research findings, the researchers recommend that pre-primary educators be assisted with some organized workshops, short courses, or refresher courses that would empower the educators with the necessary science content and pedagogical knowledge to implement science-related activities in their classrooms. According to Bose et al. (2013), “an idea of a science center where the children could be taught using varying methods, fundamental scientific concepts in a straightforward and play-way method could be well articulated at this juncture” (p. 51). Bose et al. (2013) proposed the idea of a science center that could also be used for educators’ professional development to improve the educator’s science content and pedagogical knowledge through simple, fun science activities, including learners doing experiments, investigating, and exploring their environment. Furthermore, from my point of view, Botswana’s Ministry of Education needs to formulate a well-organized curriculum for all pre-primary schools that will act as a guide to the educators on which science concepts learners are to master, along with science-related activities the educators are to engage in that would specifically enhance the development of science process skills among their learners.

B. South Africa

In South Africa, there are no set curricula for science learning in pre-primary schools. Pre-primary educators must rely on The South African National Curriculum Framework for children from birth to four (The Department of Basic Education, 2015), which only guides educators to develop their programmes when working with pre-primary school children, as science is not a priority in many primary schools in South Africa (Campbell & Chittleborough, 2014). Similar to Campbell and Chittleborough (2014), I concur that the importance of learning science in pre-primary school is indeed disregarded in South Africa.

Currently, pre-primary school educators are only "teaching the learners the foundational knowledge and providing opportunities to develop the appropriate skills linked to numeracy, literacy and life skills" (James et al. 2019, p. 2). According to Appleton (2003), this is due mainly to the pre-primary school educators' lack of interest in incorporating science teaching in their lessons. Appleton (2003) and Fleer (2009) further explain why South African pre-primary school educators are reluctant to teach science in their classrooms. South African pre-primary school educators are limited in their knowledge of science content and science pedagogical science content. Therefore, based on the above, I argue that the lack of the educator's science content knowledge, along with pedagogical knowledge, hinders pre-primary school educators from providing our children with fun and exciting opportunities to engage in science-related activities.

In conclusion, the comparative overview reveals that different countries adopt distinct approaches to science education in early childhood, each presenting unique strengths and challenges. Nordic countries prioritize science education in pre-primary schools, using hands-on experimental activities to foster children's interest and understanding of scientific concepts. Belgium faces the challenge of limited science content knowledge and pedagogical understanding among educators, necessitating training and support in inquiry-based teaching methods. Singapore integrates science process skills through purposeful play and enjoyable activities, recognizing the significance of play in early childhood science education. Thailand's *Little Scientists* project focuses on developing science process skills through engaging learning activities and investigatory projects. In the United States, particularly in California, inquiry-based learning supports English learners by addressing linguistic barriers and accommodating diverse learning styles. The Reggio Emilia Approach, emphasizing the child as a learner and an integrated curriculum, is gaining recognition for its positive impact on science education. Australia promotes open-ended exploration and inquiry-based learning aligned with the Early Years Learning Framework to foster children's independence and self-discovery. Botswana acknowledges the need for professional development and a science center to enhance educators' science content knowledge and pedagogical skills, aiming to increase science-related activities. South Africa faces challenges in providing science education opportunities due to the lack of established curricula and limited educator interest, highlighting the need to prioritize science education for well-rounded early childhood development.

2.9 The effects of visual literacy and inquiry-based learning

In my perspective, I maintain the belief that the amalgamation of VL and inquiry-based learning harbors substantial potential for endowing learners with notable advantages, particularly individuals facing language barriers, such as those whose primary language is not English. As outlined in Pardieck's (2011) research, the ability to accurately interpret visual information involves the higher-order thinking skills of reading and analyzing visual images, extending beyond the scope of Bloom's Taxonomy. By incorporating questioning techniques during the analysis of visual materials, learners are prompted to reflect on their prior knowledge and experiences, leading to a deeper understanding of the visuals. This approach, in line with Best Practice Principles, encourages reflection, holistic thinking, and cognitive engagement. Moreover, modeling the process of asking questions and facilitating discussions on the meaning of photographs, images, and graphics allows learners to actively employ their cognitive processes while examining and validating visual images (Pardieck, 2011, p. 29).

These questioning and learning strategies, which are part of visual thinking strategies emphasized by Tillmann (2012), adopt an inquiry-based approach. Learners are consistently presented with questions as they engage with visually stimulating research materials and actively participate in classroom discussions, all aimed at enhancing their understanding of the content. Additionally, Rawlinson et al. (2007) suggest that visual thinking strategies, as a learner-centered approach, not only promote the development of VL skills but also contribute to improving students' SL levels and SRA.

For learners with language barriers, the integration of VL and inquiry-based learning becomes particularly advantageous. Visuals provide a means of communication that transcends language barriers, allowing learners to access and comprehend scientific concepts without relying solely on language proficiency. By engaging with visually rich materials and participating in inquiry-based activities, these learners can develop their VL skills, which can compensate for any language limitations and enhance their overall understanding and engagement with the subject matter. Consequently, the integration of VL and inquiry-based learning can create more inclusive and effective learning environments, accommodating the diverse linguistic backgrounds and promoting equitable educational opportunities for all learners.

2.10 The significance of the chapter

In conclusion, this chapter emphasizes the immersion of contemporary learners in a visually oriented world, where ERs play a crucial role in acquiring scientific knowledge. Nurturing learners' VSs from the pre-primary school stage holds the potential to effectively support the development of 21st-century skills and enhance students' SL acquisition. The integration of SL through inquiry-based learning and VL in pre-primary education not only stimulates learners intellectually but also promotes their active engagement with visually captivating research materials. Science educators play a pivotal role in guiding learners' exploration, fostering their understanding of scientific concepts, and facilitating the development of SRA. It is essential to recognize the particular significance of VL in early childhood education, especially for individuals facing language barriers, such as those whose primary language is not English. Given that science education is primarily taught in English, these individuals may encounter challenges in comprehending scientific content. Thus, Figure 2.1 highlights the importance of VL in providing a solid foundation for the scientific journey of all learners, ensuring inclusivity and effective science education even for those with language barriers.

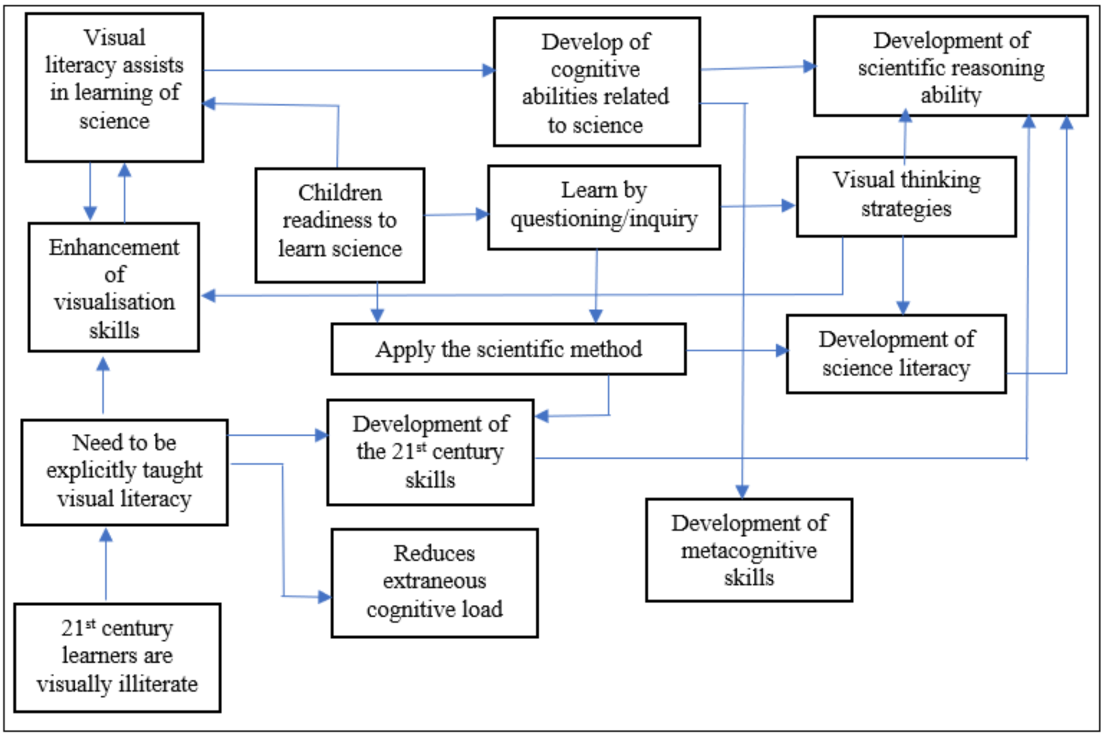


Figure 2. 1 A contextual framework of knowledge available in the literature on the importance of VL in early childhood science education.

CHAPTER 3. THE DEVELOPMENT OF A MULTI-THEORETICAL FRAMEWORK UNDERPINNING THE CURRENT RESEARCH

"Are we forming children who are only capable of learning what is already known? Or should we try to develop creative and innovative minds, capable of discovery from the preschool age on, throughout life?"

Jean Piaget

3.1 The introduction of theoretical perspectives central to conceptualizing new knowledge in the current research

Having conducted a literature review on the influence of VL on SL acquisition and SRA among pre-primary school learners, this chapter aims to present the theoretical framework employed to frame the current research. The theoretical framework utilized in this study encompasses various theoretical perspectives that conceptualize key elements of the research, including the readiness of pre-primary school learners to learn science despite their limited language skills or language barriers, achieved by explicitly teaching VL to enhance their SL and SRA. This framework serves as a guide for the research methods employed and the interpretation and discussion of the collected data.

The core hypothesis examined in this research centers around the potential of ERs to improve learners' SL and SRA. To comprehensively explore how science learners effectively acquire knowledge through ERs, a multi-theoretical framework was developed. This research synthesized and integrated the following theoretical perspectives, which informed the design of an assessment tool to evaluate VL, SL, and SRA levels among Grade R learners:

- *Cognitive Theory of Multimedia Learning*
- *Post-Piagetian Theory of Cognitive Development*
- *The Evidence-Based Reasoning Framework*

Therefore, by incorporating these theoretical approaches, the research aimed to investigate the impact of VL and ERs on SL and SRA among pre-primary school learners. The multi-theoretical framework provided a comprehensive perspective through which the research methods were structured, and the collected data was analyzed.

3.2 Understanding the role of multimedia in science education

3.2.1 The use of the Cognitive Theory of Multimedia learning in education

In the pursuit of investigating the teaching of VL in pre-primary school, this research employed Mayer's (2003) Cognitive Theory of Multimedia Learning to elucidate the cognitive processing of ERs during learning. Notably, Mnguni et al. (2016) emphasized the lack of VL in science education as a significant contributing factor to learners' poor content understanding. The theory was utilized to explore how the development of VSs can facilitate meaningful learning through VL, while also shedding light on how educators can effectively support learners by creating instructional materials that engage appropriate cognitive processes, thereby promoting meaningful learning outcomes.

To establish a clear understanding of the level of visual skills required by learners, it is essential to examine how visual information is perceived and processed using educational resources. Richard Mayer's Cognitive Theory of Multimedia Learning, conceptualized in 1997, draws on Paivio's (1986) dual coding theory, Baddeley's (1992) model of working memory, Sweller's (Sweller et al., 1990) cognitive load theory, and Mayer's (1996) SOI model of meaningful learning, all of which are briefly discussed in this section. This theory was selected due to its capacity to elucidate the cognitive processes underlying learners' engagement with ERs.

Mayer (2014) defines multimedia as the presentation of both words (e.g., spoken or written text) and pictures (e.g., illustrations, graphs, diagrams, maps, or photos). Multimedia materials can be presented through various mediums, including paper, computer screens, handheld devices, or face-to-face interactions, contrary to the notion that multimedia is restricted to computer programs. Mayer's (2014) definition encompasses materials presented through both verbal and pictorial forms, regardless of the medium employed.

According to Mayer (2014), for material to be classified as multimedia, it must be presented in two or more forms of presentation. A view requires auditory and visual senses, such as narration and animation or lectures and slides.

The Cognitive Theory of Multimedia Learning rejects the delivery media view, focusing instead on the learner's cognitive processes rather than the technology employed. This theory seeks to explain how learners process verbal and pictorial representations to construct knowledge. It is based on three assumptions about information processing in multimedia instruction: the dual-channel assumption, the limited-capacity assumption, and the active-processing assumption.

According to this theoretical perspective, the human mind comprises two separate channels for processing auditory and visual information. This dual-channel assumption aligns with Baddeley's (1992) working memory model and Paivio's (1986) dual-coding theory. Working memory, akin to short-term memory, has limited capacity and is responsible for holding and processing small amounts of information. Unlike short-term memory, working memory facilitates information processing, enabling tasks that require manipulation, planning, reasoning, and problem-solving.

In summary, this research employs Mayer's Cognitive Theory of Multimedia Learning to explore the teaching of VL in pre-primary school. By understanding how learners process visual information through ERs, educators can enhance instruction and promote meaningful learning experiences. The theoretical framework offers valuable insights into the cognitive processes underlying multimedia learning and guides the investigation of learners' engagement with visual materials and the development of their visual skills.

3.2.2 The working memory model and its limited capacity

Based on Baddeley’s (1992) view, the working memory model describes visual and auditory information processing after perceiving sensory organs. The model “proposes separate channels for processing visual and auditory information” (Mariano, 2014, p.1). Much like Baddeley’s working memory model, which focuses on dual channels of visual and auditory information, Paivio’s (1986) dual-coding theory “emphasizes dual channels for verbal and non-verbal information” (Mariano, 2014, p.1). According to Mariano (2014), the verbal and non-verbal channels function independently, yet they are interconnected. This is seen as the verbal channel processes spoken or written information, while the nonverbal channel processes information represented by pictures, gestures, and music. In this regard, both Baddeley’s working memory model and Paivio’s dual coding theory emphasize information being processed through the dual channel. However, the interpretation of *dual channels*, e.g., visual/auditory versus verbal/non-verbal, is what is different (Mariano, 2014). For this research the sensory modality approach (already discussed in Section 3.1) will be used to distinguish between visual and auditory information. In contrast, “the presentation-mode approach is what will distinguish between the construction of pictorially based and verbally based models in working memory" (Mayer, 2014, p. 34).

Mayer's (2014) limited-capacity assumption suggests that the working memory's storage and processing capacity is limited. This means that the human brain limits the amount of information it can store and processes in a given moment. Based on the dual-channel assumption, "each channel in the human information-processing system has limited capacity, and only a limited amount of cognitive processing can occur in each channel at any given time" (Mayer & Moreno, 2003, p.44). Therefore, in this regards I argue that this probably explains why one would find it difficult to concentrate on watching the news while having a conversation simultaneously. Furthermore, according to Mayer (2014), the working memory can only retain approximately seven *chunks* of information and can only process about four chunks at a given time (Cowan, 2001). However, based on the above view, my argument is that individuals with a stronger metacognition, have greater working memory capacity, which allows them to process even more complex ideas. The process whereby one thinks about their thinking during the learning process is known to be the highest order of thought, called metacognition. Metacognition actively involves controlling some cognitive functions, such as planning the approach used in a given learning task, monitoring comprehension, and evaluating one's progress during completing a task (Livingston, 2003).

Nonetheless, Mayer's (2014) limited capacity assumption is central to Chandler and Sweller's (1991) cognitive load theory and Baddeley's (1992) working memory model (already discussed in Section 3.1.1). The cognitive load theory is based on the notion that human cognitive structures have limitations (Sweller, 2010). According to Navaneedhan and Kamalanabhan (2017), cognitive structures are the basic mental patterns such as the working memory that people use to store, process, and understand information. Therefore, as science educators, we need to be aware of the capacity limitation of working memory when designing instruction and take it into account (Sweller, 2010) to ease the learners' cognitive load of processing information beyond what their brains can handle.

When coming to the working memory load, also known as the cognitive load, refers to the amount of information that the working memory can retain at any given time. According to Kilic et al. (2010), there are three types of cognitive load, namely: (1) intrinsic, (2) extraneous, and (3) germane. According to Sweller (2010), "intrinsic cognitive load is determined by the intrinsic nature of the information being studied, more specifically by the number of chunks that the learning task/material comprises” (p. 32). In line with Mnguni (2014), for learning to take place, learners need to develop their understanding of the content taught during their learning process by actively participating in the learning task/material, rather than all the information being *spoon-feed* to them (Thompson, 1995; Mnguni, 2014). This is the same foundation upon which the educational theory of constructivism is based (Mnguni, 2014).

3.2.3 The support of the constructivism theory in multimedia learning

As previously discussed in Chapter 2, constructivism is another educational theory closely related to multimedia learning. Constructivism posits that learners construct knowledge through their unique experiences (Singh & Yaduvashi, 2015). It represents a shift from behaviorism to cognitive theory, emphasizing the learners' interaction with their environment as crucial for successful learning (Singh & Yaduvashi, 2015).

While behaviorists focus on factors such as learner intelligence, lesson objectives, knowledge levels, and reinforcement, constructivists argue that learners' interaction with the environment determines learning outcomes (Singh & Yaduvashi, 2015). By integrating the constructivist theory with the cognitive theory of multimedia learning, educators can gain a better understanding of how learners process visual and auditory information, taking into account the limited capacity of working memory when designing instructional materials.

Drawing from the constructivist learning approach, learners engage with the learning task or material by following the Selecting, Organizing, and Integrating (SOI) model of information processing (Reigeluth, 2012). In this model, learners select relevant information from the presented pictures and explanations in words, as the limited capacity of working memory allows only selected information to be retained for further processing, preventing overload (Bilbokaitė, 2008). Figure 3.1 illustrates this step of selecting relevant information, where incoming pictures are chosen for processing in the visual working memory and incoming words are selected for processing in the auditory working memory (Jairam et al., 2014; Reigeluth, 2012).

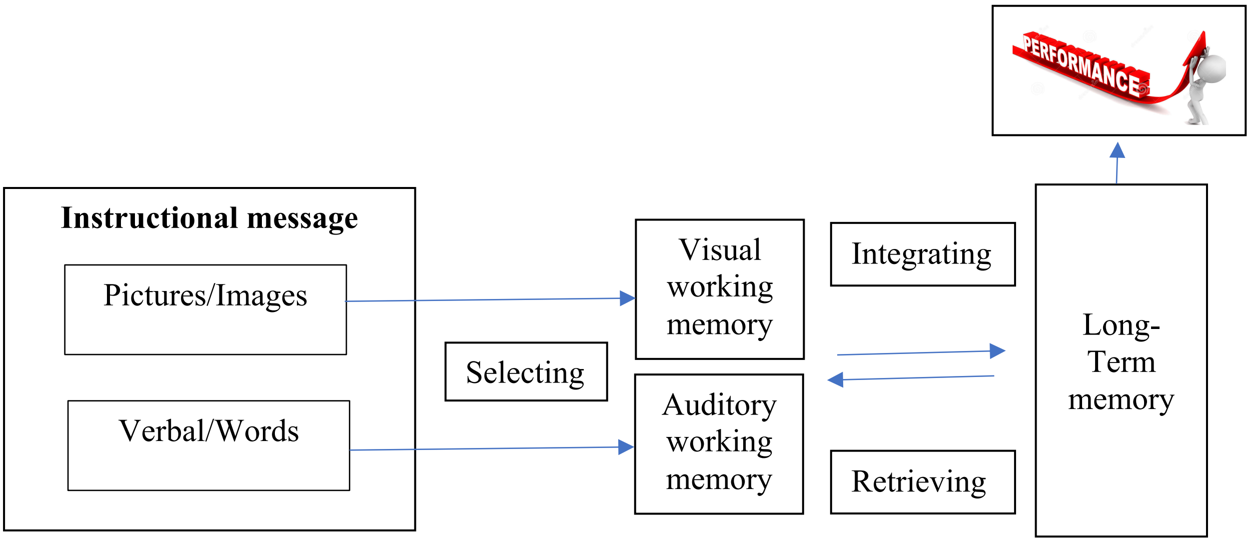


Figure 3. 1 SOI model of constructivist learning from words and pictures. Adapted from Mayer (2000).

Based on Figure 3.1, the second cognitive process involves organizing the selected pictures and words retained in working memory into coherent cognitive structures. Drawing from the cognitive theory of multimedia learning, once the images and words are stored in working memory, the process of organizing information entails arranging the selected pictures into a coherent visual representation and organizing the selected words into a coherent verbal representation (Mayer, 2002).

An important aspect of linking constructivism and the cognitive theory of multimedia learning is the belief that learners construct knowledge by integrating the organized information in working memory with prior knowledge stored in long-term memory. This integration process involves reactivating old information in long-term memory while incorporating new information, as suggested by van Kersteren et al. (2018). As learning progresses, the multiple information elements are consolidated into a single mental schema stored in long-term memory. It is worth noting that long-term memory appears to have unlimited capacity, although the stored cognitive schema is easily accessible and can be reactivated and processed in working memory when needed. Gilbert (2005) suggests that mental schema can be retrieved as pictures in some cases, such as drawing a picture on paper. These views support the notion that mental schema formed using visuals is retained in long-term memory as visuals, facilitating easy access and reducing cognitive load.

Similar to constructivism and the cognitive theory of multimedia learning, the theoretical cognitive process of visualization proposes that learning involves the input of information from the external environment, which is then processed within cognitive structures and subsequently externalized (Mnguni, 2014). In essence, the theoretical cognitive process of visualization entails the interaction between the internal and external domains to process visual information and externalize the understanding derived from that information.

According to Mnguni (2014), the cognitive process of visualization can be divided into three non-linear overlapping stages: internalization of visual models, conceptualization of visual models, and externalization of visual models (see Figure 3.2).

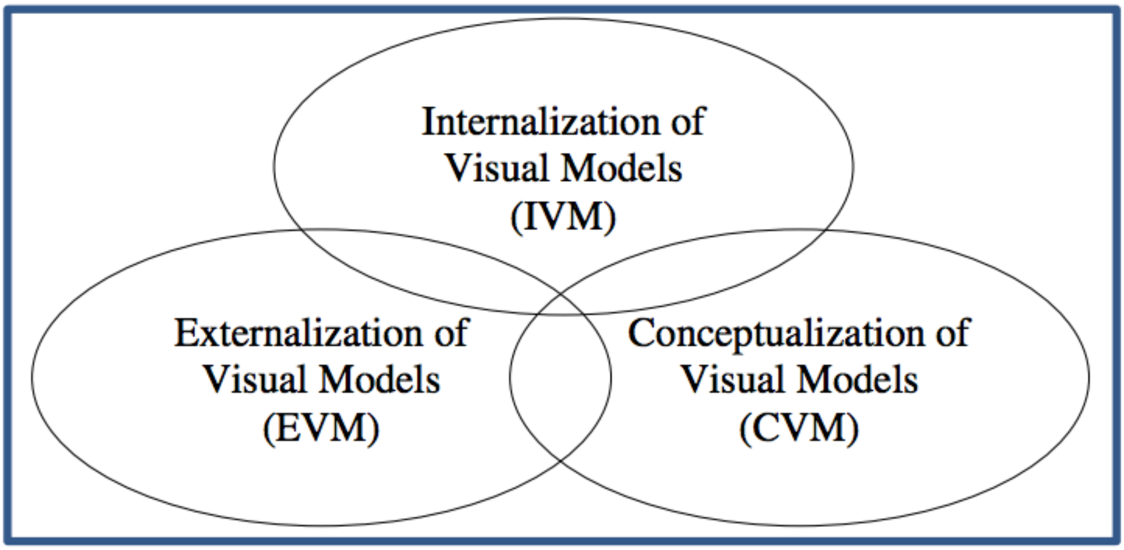


Figure 3. 2 The overlapping stages of the cognitive process of visualization. Taken from Mnguni (2014).

From Figure 3.2, the internalization of visual models refers to the "process whereby the sense organs such as the eyes work with the brains to absorb information from the world" (Mnguni, 2014, p. 3). While the conceptualization of visual models refers to the process whereby meaning is made from the information that is gained and during which cognitive visual modes are constructed (Burton, 2004). Lastly, the externalization of visual models is the production of external visual models by expressing cognitive mental schemes (Mnguni, 2014).

The second type of cognitive load is the extraneous cognitive load. According to Gupta and Zheng (2020), the extraneous cognitive load refers to "the mental load caused by improper instructional design like imposing redundant information in learning materials that requires additional processing effort. The extraneous cognitive load is irrelevant to learning and should be eliminated" (p.1). Extraneous cognitive load makes it very difficult for a learner to process information due to the distraction it causes from intended learning. Given the view of Gupta and Zheng (2020), it is my view that an example of extraneous load would be when an educator uses images or examples that are not closely related to the learning objective or are not even meant to solidify learning. On the contrary, the extra information distracts the learners from learning due to the extra effort the learner would have to process the extra amount of information, making learning difficult.

The last type of cognitive load is germane cognitive load. According to Sweller et al. (1990), "germane cognitive load refers to the load imposed on the working memory by the process of learning" (p. 259). Like Sweller et al. (1990), I understand the germane cognitive load to refer to the energy invested in the working memory during learning information. Moreover, two important aspects of this cognitive overload are automaticity and reactivation of mental schema stored in long-term memory. Automaticity involves behavioural, mental, or physical tasks that require little cognitive effort or impose little to no cognitive load on the cognitive systems. An example of germane would be the act of driving. At first, you may find driving to be such a daunting task. However, I affirm that the more your practice, the more you will find that you do not need to think about driving, it almost becomes automatic.

As for the reactivation of mental schema in the long-term, it is my view that as educators, we need to make sure that our instructional designs only reactivate the mental schema that is relevant to the task at hand and does not increase the extraneous cognitive load of the learner. According to Gupta and Zheng (2020), for the germane cognitive load to occur, the task must be challenging enough for the learners to motivate the learner to want to the learner, but not too difficult, which may discourage the learner from completing the task. In the same line, Zheng and Gardner (2020) stipulate that "the design of instruction should thus follow what Vygotsky described in 1978 as the zone of proximal development where the content is challenging enough, but not cognitively overwhelming, which "induces learners' germane cognitive load to engage in meaningful and sustained effort in knowledge acquisition" (p. 73).

The third assumption is the active processing assumption. This assumption supports the notion that learners actively engage in cognitive processing to construct coherent mental representations of what they are learning (Mariano, 2014). The hypothesis asserts that learners learn by passively absorbing information. However, they need to actively engage with the learning task/material to process information. For meaningful learning to occur, the learner must engage in cognitive processing of the learning task/material by “identifying and selecting relevant material, organizing it into visual and verbal models, and integrating those new models with prior knowledge” (Mayer, 2010, p. 70).

Lastly, it is important to acknowledge that despite the proposed goals of the cognitive theory of multimedia learning in terms of instructional design, the theory does have certain limitations, particularly concerning the cognitive processes involved. When considering pre-primary school learners, one may question how a three- or four-year-old child would be capable of controlling the selection, organization, and integration of information within their minds. According to Mayer's limited capacity assumption, the learner is expected to choose relevant images and words for processing in working memory during the learning process. However, it is worth noting that the same young learner would still need to organize the selected elements into coherent models and activate prior knowledge stored in long-term memory, which would then be brought into working memory and integrated with new knowledge. In conclusion, while the cognitive theory of multimedia learning offers an ideal framework for visual learning, it should be acknowledged that the theory may not fully account for all the complex cognitive processes occurring within the human brain.

3.2.4 Application of the Cognitive Theory of Multimedia Learning in the current research

In an attempt to answer the research question, the Cognitive Theory of Multimedia Learning will be implemented when assessing the level of VL among pre-primary school learners. Regarding assessing the VL of pre-primary school learners, the research will focus on two critical VL skills: Patterning skills and visual-spatial skills (Rittle-Johnson et al., 2018).

Recognizing patterns is a critical skill required in early childhood science education. According to Hessman (2020), when such a skill is developed in early childhood and advanced throughout the primary school years, learners have the "opportunity to acquire visual cognitive skills that are needed to increase future academic achievement in science and mathematics education” (p.5). In line with Rittle-Johnson et al. (2018), learners' ability to complete patterning skills such as repeating patterns will be assessed using the research-based patterning assessment. Based on previously validated studies, the research-based assessment measures preschool learners' ability to duplicate, extend, abstract, and identify units of repeating visual patterns (Rittle-Johnson et al., 2018).

Furthermore, based on the Cognitive Theory of Multimedia Learning, pattern recognition involves matching information-selected information working memory with prior knowledge in long-term memory (Figure 3.3). Since the working memory consists of two separate channels: one for the processing of visual information and one for the verbal processing information, each channel has a relatively limited capacity, resulting in the channels easily becoming overloaded (Sweller, 2010). Consequently, my argument is that presenting information in both visual and verbal forms allow learners to use both information processing channels simultaneously, rather than just overwhelming one. In this regard, this will enable the learner to construct mental representations from both words and pictures, which are to be processed and integrated with the prior knowledge, making the retrieval of the models much easier in the future. Therefore, in essence, this theory proposes that "by combining information from the two channels, the information is transferred from short-term to working memory to be processed in-depth with the help of prior knowledge, and that processing helps the information stay in the learners' long-term memory" (Yue et al., 2013, p. 378).

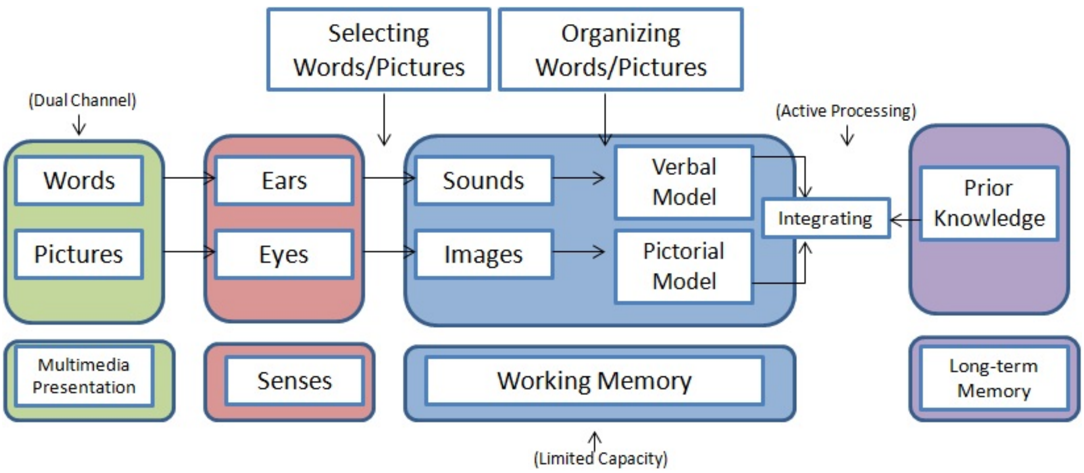


Figure 3. 3 The Cognitive Theory of Multimedia Learning. Taken from Mayer (2005).

With regards visual-spatial skills, these skills play an integral part in learning science and are crucial for the success of learners in STEM education (Delahunty et al., 2016). According to Cary (2004), learners with enhanced visual-spatial skills can perceive, analyze, and understand visual information correctly. In line with Rittle-Johnson et al. (2018), when assessing visual-spatial skills, I will mainly focus on the three cognitive skills usually evaluated at the pre-primary school level: (1) visual perception, (2) spatial visualization, and (3) visual-spatial working memory. In my view, visual perception is based not only on the external stimuli that enter our eyes but also on other aspects, such as the viewpoint that a learner has toward an object. This is why people would see the same object differently, as no two views are alike. For assessing this skill, I will be looking at the learners' visual perception of structures and patterns. On the other hand, spatial visualization assesses the learner's ability to imagine and mentally transform spatial information. At the same time, spatial visualization looks at the learner's ability to copy and distinguish shapes from other shapes, including symbols. Lastly, when assessing visual-spatial working memory, I would be looking at the learners' ability to hold the locations of different objects and landmarks in their working memory. According to Shipstead et al. (2016), "high working memory capacity is argued to facilitate reasoning through accurate maintenance of relevant information" (p.771). For instance, those with high working memory capacity may master the interpretation of ERs correctly and with ease. Therefore, my view is that learners with high visual-spatial ability would be able to hold and manipulate mental images with minimum mental effort. Lastly, when designing the instrument, Mayer (2001) suggests that "to maximize learners' cognitive processing of multimedia elements, the instrument must be consistent with the Cognitive Theory of Multimedia Learning principles to reduce extraneous processing." (p. 40).

3.3 The readiness of pre-primary school children for science education

3.3.1 The Post-Piagetian Theory of Cognitive Development

Gelman's (1990) Post-Piagetian Theory of Cognitive Development has had a profound influence on research in the field. According to Darling-Hammond (2020), this theory provides solid theoretical support for young children's abilities to engage in science learning.

To support the argument presented by Eshach and Fried (2005), the Post-Piagetian Theory of Cognitive Development suggests that children in pre-primary school are ready to be taught science at their level. This theory underpins the notion that pre-primary school learners possess strong cognitive competencies for science education (Kuhn & Pearsall, 2000). However, according to Jean Piaget's theory of cognitive development, although pre-primary school learners may be able to identify and use symbols such as words, signs, or pictures to effectively express their thoughts and emotions, they are not ready to be taught science as they lack the ability for abstract thinking. Abstract thinking involves higher-order or complex thoughts that go beyond what is obvious, allowing individuals to draw conclusions and illustrate relationships among concepts (Apps, 2008).

Contrary to Jean Piaget's theory, my argument is that the Post-Piagetian Theory of Cognitive Development supports the notion that children between the ages of 4 and 6 years are motivated to learn science content. French and Woodring (2012) argue that discouraging the introduction of science education at the pre-primary school level may result in children losing their curiosity and interest in pursuing scientific research later in life. Clements (2001) further suggests that introducing science education at the pre-primary school level is associated with primary and secondary school readiness, enhanced causal reasoning, increased interest in science education at a later stage, and improved learner performance in higher grades, including at the tertiary level.

Jean Piaget's theory, on the other hand, argues that pre-primary school learners have limited abilities to learn science as it involves abstract principles and controlled experimentation with multiple variables (French & Woodring, 2012). In contrast, the Post-Piagetian theory argues that pre-primary school learners have domain-specific organizing structures specific to knowledge (Gelman, 1990). Domain-specific knowledge refers to memorized information that allows individuals to perform specified tasks in a particular discipline or field, such as science (Tricot & Sweller, 2010). As children process this domain-specific knowledge, they demonstrate reasoning abilities such as making observations, predictions, and interpreting data, as suggested by Hatano and Inagaki (1994). These scientific inquiry skills provide learners with the structure and processes necessary for understanding scientific content. Furthermore, Bowman et al. (2001) argues that as children are exposed to a wide range of experiences in processing domain-specific knowledge in specific disciplines like mathematics or science, their reasoning abilities become more complex. Neuroscience research also supports the notion that domain-specific understanding develops most efficiently during the pre-primary school years (Kallery et al., 2009).

According to Collins (1997), one important aspect of pre-primary school science competency is learners' science content knowledge, which is critical for their understanding of the curriculum. Science content knowledge encompasses the breadth and depth of knowledge about facts, concepts, laws, and theories that describe, explain, and predict natural phenomena

(Collins, 1997). Plummer and Krajcik (2010) emphasize that children's science content knowledge, particularly those taught science at the pre-primary school level, is crucial for their understanding of more complex scientific concepts and the development of higher-order thinking skills. Guo et al. (2015) conducted research on pre-primary school learners' science content knowledge, and their findings were consistent with the Post-Piagetian Theory of Cognitive Development, indicating that children can develop essential scientific understanding and knowledge during their early childhood years. Therefore, it is essential for science educators to identify potential indicators of science competency that can help understand how children learn and comprehend science. Guo et al.'s (2015) research suggests that achievement in science is also associated with factors such as family socioeconomic status, gender, cognitive level, mathematics literacy, and language proficiency. Identifying such indicators could help identify children who may struggle with understanding the curriculum and require additional support.

3.3.2 Application of The Post-Piagetian Theory of Cognitive Development in the current research

From a cognitive development perspective, the Post-Piagetian Theory of Cognitive Development aligns with the belief that young children are cognitively ready to learn science. This theory suggests that children's science content knowledge continues to increase with exposure to the subject, and the earlier they are exposed, the better (French & Woodring, 2012).

However, one aspect that the theory fails to address is the limited capacity of the working memory, which is crucial for providing children with a meaningful learning experience. To prevent overloading the working memory, the Cognitive Theory of Multimedia Learning can be used by educators to design instructional materials that incorporate both words and images, thus reducing cognitive load.

Additionally, the Post-Piagetian Theory of Cognitive Development supports the idea that science learning begins as early as infancy when children start developing their own ideas, beliefs, and explanations about the world around them. Guo et al. (2015) suggest that children between the ages of three and five can learn scientific concepts, which is why science education is emphasized as an essential learning area in pre-primary school according to American learning standards. The three broad content areas of pre-primary school science (Life Science, Physical Science, and Earth/Space Science) will form the basis of the SL component of the data collection instrument.

To assess SL, the National Science Education Standards can provide guidance on what pre-primary school learners should know, understand, and be able to do in science education (National Research Council, 1996). Following the Research on Curricular Development model, specifically the subject-centered curriculum design, can be useful in designing and developing the data collection instrument to evaluate pre-primary school learners' SL. This model, known for its methodology in designing mathematics and science curricula for young children, can inform the understanding of learners' science knowledge and skills.

Using the Research on Curricular Development model, the specific domains and science content to be explored may include topics such as the distinction between living and non-living things, classification of plants and animals (Life Science), weather and the change of seasons (Earth Science), forces, properties of matter (e.g., weight), balancing of objects, and measurement of temperature (Physical Science) (Kinzie et al., 2015). By incorporating these domains and content areas, educators can effectively assess and promote pre-primary school learners' scientific understanding and skills.

3.4 Elements required for scientific reasoning ability

3.4.1 Evidence-Based Reasoning Framework

Several theories may explain how SRA can be assessed among science learners. But I selected the Evidence-Based Reasoning Framework based on the belief that children learn science through inquiry; evidence plays an essential role in developing the learners' understanding of scientific ideas (Futak et al., 2008). For this research, evidence will be regarded as any form of visual, auditory, or written data from which conclusions can be drawn to prove a premise.

The theory provides the foundation for assessing learners' ability to reason from evidence obtained in the classroom. The framework is not an assessment tool; however, it will provide the researcher with a theoretical lens that is critical for identifying the elements and structure for assessing SRA among pre-primary school learners. Therefore, in support of the argument made by Driver et al. (2000), I argue that evidence should not only be collected in the science classroom but should be utilized as a premise to support SRA.

In the following section, I will focus on identifying the elements necessary for assessing the level of SRA as described in Furtak et al. (2008):

- *Scientific method*
- *Premise*
- *Claim*
- *Rule*
- *Data*
- *Evidence*

In a science activity, the premise is often described as the subject in the sentence which contains the claim. According to Brown et al. (2010), the premise is defined "as one or more statements describing the specific circumstances acting as an input that will result in the outcome described by the claim" (p.132). This can be seen in a science classroom, as a premise would often identify an object and its relevant feature or property (e.g., This box is heavy). On the other hand, a claim is often the verb in the sentence describing what the premise is doing, has done, or will do. According to Brown et al. (2010), a "claim is regarded as a statement about a specific outcome or state phrased as either:

- *a prediction of what something will do in the future (e.g., This box will sink),*
- *an observation of what something has done in the past (e.g., This box sank) or*
- *a conclusion about what something is in the present (e.g., This box sinks)" (p.132).*

For example, in the above statements, the subject in the sentence being the box is regarded as the premise, while the verb (will sink, sank, or sink) is regarded as the claim. On the other hand, the rules link the premise and the claim. "Rules are statements describing a general relationship (e.g., Something that is heavy will sink)" (Brown et al., 2010, p.132). According to Brown et al. (2010), the Evidence-Based Reasoning Framework does not regard the rule as either correct or incorrect, even scientific, or intuitive.

In some cases, a scientific rule can be accepted, such as Archimedes' Principle, which states that 'any object immersed in a fluid is buoyed up by force equal to the weight of the fluid displaced by the object' or an intuitive theory like 'heavy things sink'. In this framework, data as discrete reports of past or present observations, for example, 'the red block sank and my blue toy boat floated in the bathtub'. Furthermore, according to Brown et al. (2010), evidence consists of “statements describing observed relationships” (p. 132). An example of such a statement would be ‘the heaviest blocks sank and the lightest blocks floated’ representing the relationship between the weight and the sinking behaviour of the object. Lastly, in this framework, data is defined as discrete reports of past or present observations, for example, ‘the red block sank and my blue toy boat floated in the bathtub’.

Based on Duschl’s (2004) framework for the assessment of inquiry, a premise (input) is processed through three distinct steps (analysis, interpretation, and application) to produce a claim as the output. Furthermore, Furtak et al. (2008), regard the process of analysis as “multiple data which are compared and integrated or synthesized. Additionally, analysis aims to establish the probability or necessity of the evidence, often by extrapolation in simple cases” (p.5). Moreover, interpretation involves transforming evidence into a generalized statement with enough generality that it can be applied in a new situation. In a science classroom, a generalized statement would be ‘these heavy blocks sank; therefore, buoyancy depends on mass’. Lastly, application is regarded “as the process by which the rules are brought to bear in the specific circumstances described by the premise. It establishes the probability or necessity of the claim given the information described by the premise and the relationships described by the rule” (Brown et al., 2010, p.132). One example that illustrates the application of the scientific method is the utilization of informal deductive logic, as exemplified by the statement "*this box is heavy, heavy things sink. Therefore, this box will sink*." This logical reasoning demonstrates a hypothesis derived from empirical observation and a general principle. The scientific method refers to a systematic approach employed in scientific inquiry to comprehensively investigate and comprehend various phenomena. It involves a series of interconnected steps, starting with the careful observation of a phenomenon or situation, followed by the formulation of a testable hypothesis. To evaluate the hypothesis, experiments or data collection are conducted, and the obtained results are analyzed. Based on the analysis, conclusions are drawn, allowing for the formulation of scientific theories or explanations. The scientific method emphasizes the objective evaluation of evidence, the reliance on empirical data, and the utilization of logical reasoning to make informed judgments. Therefore, by requiring that claims made by learners be supported by data, evidence, or rules, the Evidence-Based Reasoning Framework emphasizes the fundamental principles that underpin the scientific method.

3.4.2 Application of the Evidence-Based Reasoning Framework in the current research

In line with Furtak et al. (2008), I will make use of the Evidence-Based Reasoning Framework to assess the learners' scientific inquiry skills by evaluating the different elements of scientific methods that are important for determining the level of SRA among pre-primary school learners:

- *Premise*
- *Claim*
- *Rule*
- *Data*
- *Evidence*

According to Clarke-Midura et al. (2012), given the nature of the scientific method, assessing the level of SRA is a challenge for educators. Therefore, much like for assessing the level of VL and SL, I will be making use of images to determine the learner's science inquiry skills as research shows that learning science through inquiry-based by using clipart or images can be essential in enhancing the learners 'problem solving and critical thinking skills (Pardieck, 2011).

3.5 Summing up my theoretical perspective on the readiness of pre-primary school learners to learn science through visual literacy

Figure 3.4 provides a lens on how I view the theories and framework discussed in this chapter to support the rationale of the current research by demonstrating the readiness of pre-primary school learners to learn science using VL for meaningful learning. In the first framework (frame #1), the assumption is that pre-primary school learners exhibit enough cognitive competency to learn science. In line with the Post-Piagetian Theory of Cognitive development, I argue that by age four to five, children have developed domain-specific knowledge and adequate science content knowledge to succeed in learning science by fostering their curiosity during play, making observations, and asking questions.

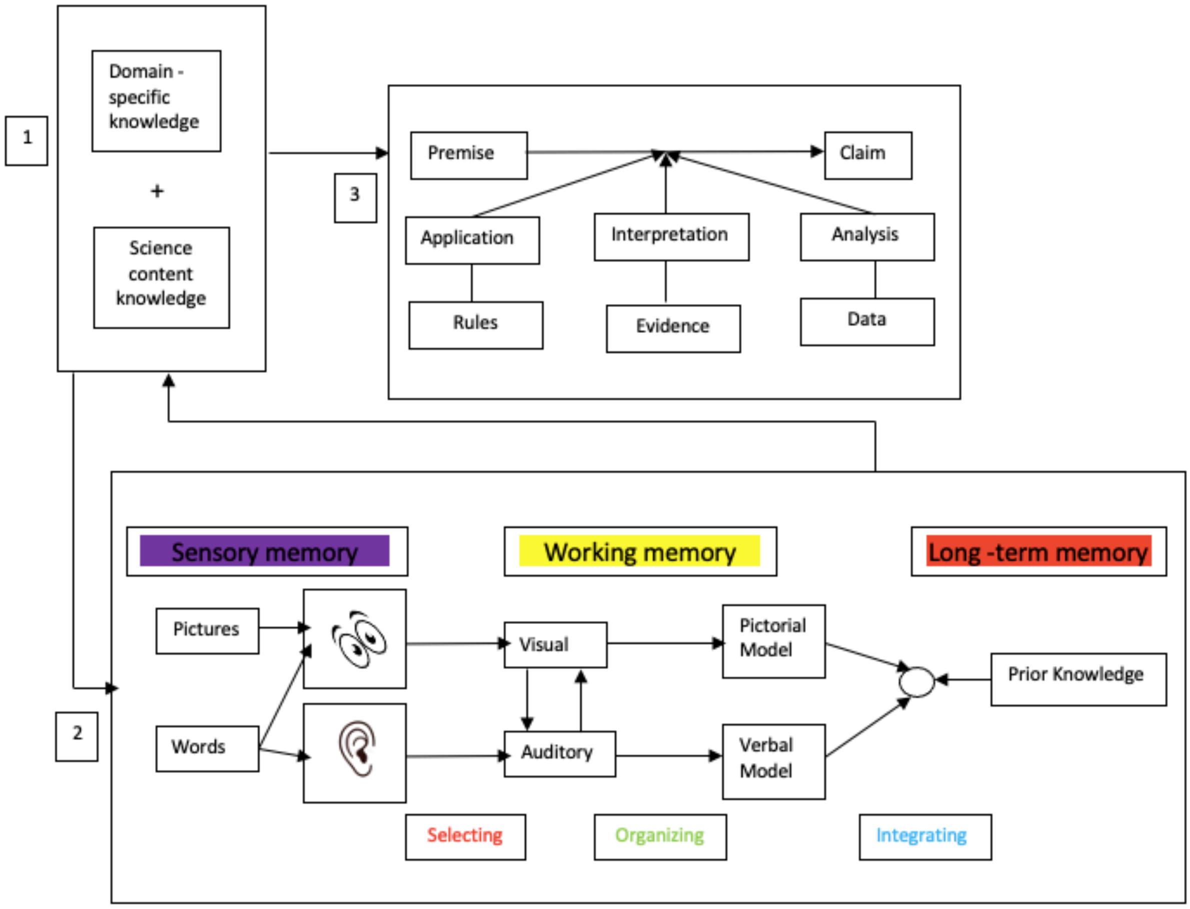


Figure 3. 4 The researcher's theoretical framework. Adapted from Mayer (2010) and Brown et al. (2010).

During a multimedia lesson, I propose using the second framework (frame #2) to explain the processes occurring in learners' minds to ensure meaningful learning. These processes can be understood within the context of the Cognitive Theory of Multimedia Learning, as adapted from Mayer (2001). This theory is based on three assumptions that describe information processing.

The first assumption is the dual-channel assumption, which is demonstrated by multimedia presentations containing both pictures and words that are perceived through the eyes and the ears. According to this assumption, there are two channels for processing information in sensory memory. For example, when learners listen and watch a 3-D animation on a computer screen, the animation will be processed in the visual-pictorial channel, while the spoken words by the animation will be processed in the auditory-verbal channel.

The second assumption is the limited capacity assumption, which explains that each channel in the dual-channel system has a limited capacity for processing information. This assumption recognizes that learners have a finite capacity for processing information in working memory.

The third assumption is the active processing assumption, which proposes that learners are actively engaged in processing information in both channels within the working memory during the learning process. Learners actively select and organize words and pictures, integrate them with prior knowledge from long-term memory, and construct meaningful mental models that align with what they have learned.

In the third frame (frame #3), I draw on the scientific method proposed by Brown et al. (2010). In this frame, during inquiry-based learning, learners make claims about the subjects being researched. These claims should be supported by data, evidence, or rules, which are processed through analysis, interpretation, or application, respectively, to determine their validity. This stage of the learning process allows learners to develop scientific inquiry skills such as making observations, predictions, and interpreting data, which ultimately contribute to the development of SRAs.

Overall, as children are exposed to science through multimedia, they begin to develop domain-specific knowledge and acquire adequate science content knowledge, which enhances their visual-spatial abilities. Moreover, as learners engage in inquiry-based learning and are exposed to more science content, their SRAs is further developed, along with their 21st-century skills. The theoretical framework presented here informs how data will be collected and analyzed in the current research.

In the next chapter, I will discuss the rationale for the specific procedures and techniques that will be applied in identifying, selecting, processing, and analyzing information to address the research problems (Bryman, 2008).

CHAPTER 4: METHODOLOGICAL APPROACH TO THE RESEARCH

"Science is the process that takes us from confusion to understanding."

Brian Greene

4.1. Introduction to the overarching strategy and rationale for the current research

The current chapter presents the action plan undertaken to investigate the research problem of this study. The chapter outlines the rationale behind the selection and application of specific methods, procedures, or techniques for identifying, selecting, processing, and analyzing data to gain a deeper understanding of the research problem (Bryman, 2008). In the context of this research, distinct approaches, designs, methods, and procedures were employed for data collection and analysis at different stages of the research. Additionally, this chapter addresses an essential aspect of research, namely reproducibility. Thus, it also reflects on the validity, reliability, credibility, and trustworthiness of the research findings.

4.2 Understanding and applying the research paradigm

Understanding and defining the research paradigm is a critical step in the research process (Kivunja & Kuyini, 2017). According to Rehman and Alharthi (2016), researchers must possess a clear understanding and ability to articulate their beliefs regarding the nature of reality, the possibilities of knowledge acquisition, and the methods employed to attain this knowledge (p. 51). These beliefs are rooted in the assumptions made about ontology, epistemology, and methodology (Kivunja & Kuyini, 2017) within the research. Essentially, paradigms serve as our framework for comprehending and interpreting the world around us (Rehman & Alharthi, 2016).

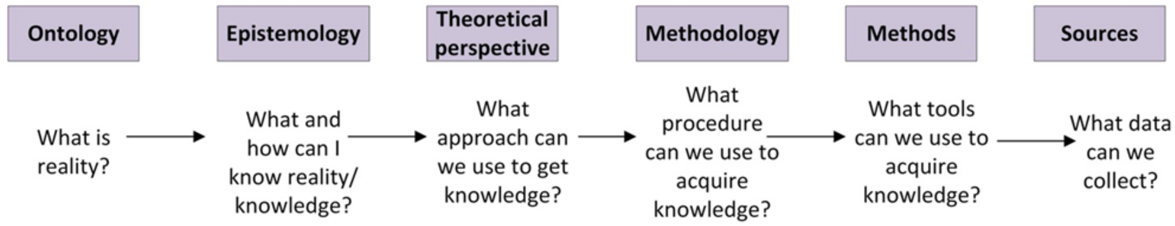


Figure 4. 1 The interrelatedness of ontology, epistemology, theoretical framework, and methodology. From:http://salmapatel.co.uk/academia/the-research-paradigm-methodology-epistemology-and-ontology-explained-in-simple-language/

The current research was conducted within the framework of the post-positivism paradigm. According to McCall (2002), post-positivism emerged as a response to the limitations of the positivist paradigm. While positivism posits an objective reality (Ryan, 2006), the post-positivist paradigm acknowledges that theories, hypotheses, background knowledge, and the values of the researcher can influence observations. In this sense, post-positivism recognizes a certain level of subjectivity in perceiving reality and moves away from the purely objective position embraced by strict positivists (Ryan, 2006).

4.2.1 A reflection on ontology

While I have adopted the post-positivism paradigm for the current research, I acknowledge that several other paradigms could have been utilized to frame this study, including critical realism, interpretivism, social constructivism, and pragmatism. The critical realism paradigm distinguishes between the *real world* and the *observable world*. Critical realists argue that reality exists independently of human perception, theories, and constructions. Gorski (2013) suggests that critical realism is an encompassing paradigm that integrates elements of both positivist and constructivist approaches to provide a comprehensive account of ontology and epistemology. Ontology, as highlighted by Richards (2003), pertains to our belief system regarding the nature of reality. Kivunja and Kuyini (2017) emphasize that these ontological assumptions are crucial in understanding and making sense of the data gathered in research. Like positivists and constructivists, critical realists are concerned with differentiating between reality and human perceptions, arguing that reality exists independently of human understanding.

Similar to interpretivism, critical realists posit that reality is shaped by human experiences (Easterby-Smith et al., 2009). However, in contrast to interpretivists, critical realists argue that our reality comprises the domains of the real (structures and mechanisms), the actual event, and the empirical (human experiences) (Khaze, 2018). From an ontological standpoint, post-positivists agree with critical realists in recognizing that what is observed in research cannot be accurately perceived or observed, making complete objectivity unattainable due to the biases of the researcher. While post-positivists accept subjectivity as an aspect of reality, they strive to approach objective answers by acknowledging and understanding their biases. Additionally, much like critical realists, positivists acknowledge the potential for errors in observations (Trochim, 2002) and the limitations of knowing reality with absolute certainty.

However, according to Chilisa and Kawulich (2012), some degree of objectivity can be achieved by using multiple measures and observations, triangulating the data to gain a more comprehensive understanding of reality. From an ontological perspective, post-positivists often employ multiple measures to collect and analyze data, aiming to address the same research question. This approach provides the researcher with diverse perspectives, enabling a well-rounded view of reality while mitigating preconceptions and biases, ultimately leading to the development of more credible theories and arguments.

4.2.2 A reflection on epistemology

Epistemology, as defined by Gall et al. (2003), is the branch of philosophy that examines the nature of knowledge and the process by which knowledge is acquired and validated. It focuses on understanding how knowledge is formed, acquired, and communicated. Post-positivists argue that knowledge is derived from human conjectures, which may not be entirely objective. They also acknowledge that not everything is fully knowable (Krauss, 2005). On the other hand, critical relativists assert that knowledge is obtained by observing and interpreting meaning from the collected data to explain the elements of reality that existed before human experiences occurred (Wynn & Williams, 2012).

In contrast to post-positivists and critical realists, positivists contend that knowledge is derived from the direct experience of the world (Hjørland & Wikgren, 2005). They argue that the researcher should be objective and independent, devoid of personal interests in the research. In contrast, interpretivism posits that the researcher is not separate from the subject of study (Bryman, 2008). The researcher is an integral part of the research process as they interpret the data, and therefore, complete objectivity is unattainable. According to Saunders et al. (2009), interpretivism suggests that knowledge is constructed from human actions and perceptions. Constructivists, like positivists, believe that knowledge is constructed from our experiences in the world. Meanwhile, critical realists argue that knowledge is obtained by observing and interpreting the meaning of what is observed to explain the elements of reality that must exist prior to events and experiences (Wynn & Williams, 2012). However, critical realists maintain that positivist reasoning alone is insufficient to understand the world, recognizing the influence of the researcher's perceptions and experiences on observations.

Pragmatists argue that knowledge can be obtained through the use of various methods to achieve optimal results (Johnson and Onwuegbuzie, 2004). Pragmatism emphasizes that each person's ability is unique and shaped by individual experiences (Nowell, 2015). Furthermore, pragmatists assert that knowledge and the belief in its truthfulness depend on real-world experiences and interests (Nowell, 2015). The pragmatic viewpoint justifies the integration of multiple sources of knowledge to find practical solutions to problems. Similarly, post-positivism advocates for a plurality of epistemological stances, recognizing that there are multiple valuable ways of acquiring knowledge in any given research context (Miller, 2008).

From an epistemological perspective, I have chosen the post-positivism paradigm based on its post-foundationalist stance. Post-foundationalism, as described by Page (2008), rejects assumed or given authority for specific beliefs or actions and seeks a rationale for thought or action through dialectical reasoning. It emerged as an attempt to move beyond the deadlock between classical foundationalism and anti-foundationalism. In contrast to the post-positivism paradigm, positivists adhere to classical foundationalism, which asserts that all knowledge derived from research is firmly based on human experience (observation) and irrefutable reason (Phillips & Burbules, 2000). Anti-foundationalism, as associated with pragmatism, rejects the philosophy of foundationalism by rejecting the notion of a fundamental belief or principle serving as the basis for inquiry and knowledge (Childers, 1995).

Post-positivists, like anti-foundationalists, reject the foundationalist approach of positivism. However, unlike the anti-foundational approach of pragmatism, post-positivism acknowledges that our knowledge is incomplete and imperfect and should be revisited in light of new evidence (Phillips & Burbules, 2000). The post-positivism paradigm provides researchers with a range of choices for investigating a phenomenon. Post-positivists prioritize evidence that is valid and reliable in terms of the existence of the phenomenon in question rather than seeking absolute truth through generalization and laws (Maree, 2008).

4.2.3 A reflection on axiology

Axiology, as defined by Patton (2002), refers to the ethics or belief system that a researcher adheres to. It represents what researchers argue to be true. In terms of axiology, post-positivists acknowledge that bias is undesired but inevitable. The axiology of post-positivism recognizes that theories, hypotheses, prior knowledge, values, and the researcher's beliefs can influence objectivity, thereby introducing the possibility of bias (Robson, 2002). Post-positivism's axiology is highly influenced by the philosophical assumptions of critical realism, which also acknowledges the potential for data collection errors (Trochim, 2002).

In contrast, pragmatists place a greater emphasis on the researcher's beliefs or values in interpreting results. Unlike positivism's axiological assumption of maintaining an objective stance, pragmatists argue that researchers should adopt both objective and subjective viewpoints.

Positivism's axiological assumption suggests that research is conducted in a value-free manner, such as through the use of surveys. Positivists also argue that the researcher is independent from the data collection and analysis process. Conversely, interpretivism recognizes that the researcher is an integral part of the research and cannot be separated from it. Similar to interpretivists, post-positivists acknowledge that the researcher's subjectivity can introduce bias into the research. Therefore, from an axiological perspective, post-positivists need to be aware of how their beliefs and values may influence their research, including their choice of data collection and analysis methods (Chilisa & Kawulich, 2012). It is important for post-positivists to understand and address their biases to strive for objectivity. Hence, in adopting the post-positivism paradigm for the current research, I have clearly addressed how I have accounted for and mitigated the potential introduction of bias in the research.

4.2.4 A reflection on methodology

Lastly, the term *methodology* refers to the research design, methods, approaches, and procedures used in research (Rehman & Alharthi, 2016, p. 52). According to Ellis (2013), the methodological process reflects the researcher's assumptions regarding data collection, participants, data collection instruments, and data analysis methods. Post-positivists emphasize the importance of using multiple methods to enhance the validity and reliability of research (Chilisa & Kawulich, 2012).

Unlike positivism, which favours quantitative research, the post-positivism paradigm embraces methodological pluralism and recognizes the validity of both quantitative and qualitative research (Morris et al., 2009). Post-positivists may solely use quantitative methods or combine them with qualitative methods to gain a holistic understanding of the variables under study. Similarly, pragmatism, based on the epistemological assumption of multiple realities, also advocates for the use of mixed methods (Lipscomb, 2011).

Quantitative and qualitative research triangulation is a means to explore these multiple realities and is supported by critical realists (Sobh & Perry, 2006). However, there is ongoing debate regarding which paradigms inform the integration of quantitative and qualitative research. The pragmatic paradigm is a primary advocate for mixed-method research, although critical realism and post-positivism also acknowledge the cross-validation of quantitative and qualitative approaches. In contrast to positivism and post-positivism, interpretivism asserts that objectivity is unattainable. Interpretivists lean towards qualitative methods such as in-depth interviews and grounded theory research to collect and analyze data (Saunders et al., 2009).

In terms of methodology, I have chosen the post-positivism paradigm. Like positivism, post-positivism recognizes the importance of theory-based observations (O'Leary, 2009). Post-positivist researchers begin with a theory, collect data, and determine whether the results support or refute the theory. However, unlike the logical positivist movement, which emphasizes the independence and detachment of the researcher, post-positivism acknowledges the mutual influence between the researcher and the research (Krauss, 2005). Post-positivism also acknowledges the subjectivities and preferences of the researcher, in contrast to positivism's denial of bias.

To pursue objectivity, which is valued in post-positivism, I find the possibility of triangulating data to be advantageous in my research. Triangulation involves using multiple data sources to validate results and provide a more accurate depiction of reality (Olsen, 2004). Given the methodological pluralism philosophy of post-positivism, triangulation is often favoured by post-positivist researchers to address the scepticism associated with solely using quantitative or qualitative methods. Similarly, I believe that a mixed-method approach, combining quantitative and qualitative data, is most suitable for my research, as it minimizes the limitations of each approach when used independently, aligning with the critical realist perspective.

4.3 Selecting a suitable research approach for the current research

As stated in Section 4.2, a mixed-methods research approach was adopted for the current study. According to Mohajan (2019), a research approach refers to a systematic plan of action employed by the researcher to effectively and comprehensively conduct the research. In this study, a mixed-methods approach was utilized, as defined by Greene (2006) as "an approach to investigating the social world that ideally involves more than one methodological tradition and thus more than one way of knowing, along with more than one kind of technique for gathering, analyzing, and representing human phenomena, all for better understanding" (p. 93).

Tashakkori and Creswell (2007) offer a simpler definition, describing mixed-method research as "an approach in which the researcher collects, analyzes, and integrates both quantitative and qualitative data in a single or multiphase program of inquiry" (p. 4). In the current study, the adopted definition for the mixed-methods approach is as follows: a research method that combines qualitative and quantitative approaches to address the same research question.

4.3.1 The benefits of combining quantitative and qualitative research

Creswell et al. (2004) assert that mixed methods research goes beyond the mere collection of qualitative and quantitative data. They argue that a mixed-method approach involves integrating, relating, comparing, or mixing both types of data at some stage of the research process. The authors emphasize that the rationale for mixing methods lies in the recognition that neither qualitative nor quantitative methods alone are sufficient to capture the intricacies and patterns of the phenomena under investigation. Instead, a comprehensive analysis can be achieved by combining both types of data, as they complement each other (Creswell et al., 2004).

Johnson and Onwuegbuzi (2004) support this viewpoint by stating that mixed methods research encompasses induction (discovering patterns), deduction (testing theories and hypotheses), and abduction (uncovering and relying on the best set of explanations to understand results). They highlight the value of integrating qualitative and quantitative approaches to gain a more comprehensive understanding of research outcomes (Johnson & Onwuegbuzi, 2004).

Sale (2002) offers another perspective on the combination of qualitative and quantitative research by emphasizing their shared goal of understanding the world and improving the human condition. Sale argues that both approaches share a unified logic and inference rules, provide different perspectives to study phenomena, facilitate cross-validation through combining theories and data sources, and enable complementary results by leveraging the strengths of each method (Sale, 2002).

The advantages of using mixed methods research include enhancing the validity, reliability, and credibility of research results by incorporating both qualitative and quantitative data (Johnson et al., 2017). Hall and Howard (2008) recommend the synergistic use of quantitative and qualitative approaches, where quantitative methods contribute objectivity and qualitative methods provide explanations for the research phenomenon. Integrating both approaches allow for a more comprehensive understanding of the research problem than using either approach alone (Fetters & Freshwater, 2015).

Additionally, mixed methods research allows researchers to elaborate, clarify, or validate the results obtained from one method with the results from another. The convergence of quantitative and qualitative data can strengthen the foundation for drawing conclusions and making evaluations. Researchers can also use different methods for different inquiry components to expand the breadth and depth of their investigation. For example, qualitative data can be incorporated during the design of an intervention, during its implementation to explore participants' experiences, and after its completion to help interpret the results (Palinkas et al., 2011).

In summary, the central premise of mixed methods studies is the combination of quantitative and qualitative approaches to gain a deeper understanding of research problems and complex phenomena. This integration allows for a more comprehensive analysis and contributes to a more robust understanding of the researchedtable 4.1 phenomena compared to relying on a single approach (Creswell & Plano Clark, 2007).

4.3.2 Using quantitative research to overcome the shortcomings of qualitative research

While there were various research approaches available to address the research question at hand, the decision was made to adopt a mixed-method approach based on the compatibility of the post-positivist paradigm with the use of both quantitative and qualitative data to investigate the same research question. Sole reliance on either qualitative or quantitative methods would have posed limitations in the current research. The choice of the mixed-method approach is further supported by the argument presented by Libarkin and Kurdziel (2002), which suggests that employing a mixed-method approach enhances the validity, reliability, and credibility of research findings by mitigating the inherent biases associated primarily with qualitative research methods.

Qualitative research methods have traditionally been criticized for their perceived lack of rigor, impressionistic nature, and subjective interpretations (Mackieson, 2019). This is attributed to the researcher's role as the instrument of data collection, analysis, and interpretation, where personal beliefs and judgments can influence the outcomes (Daniel, 2016). The interpretive researcher's calibration and objectivity are often called into question, particularly due to the philosophical stance of the interpretivism paradigm. By utilizing a mixed-method approach in the current research, it becomes possible to capitalize on the strengths of quantitative methods to address the weaknesses of qualitative methods and vice versa.

To address the limitations mentioned above regarding the qualitative approach, the inclusion of a quantitative approach was deemed necessary. Quantitative methods are characterized by structured tools such as surveys, polls, or questionnaires, and any deviations must be supported by substantial arguments (Mnguni, 2007). Furthermore, quantitative methods employ deductive reasoning, formulating hypotheses based on existing theory, and objectively testing them to either support or reject them. Each step of the research process is standardized to minimize bias during data collection and analysis. This standardized approach provides a reliable framework for researchers to extrapolate data from a sample to a larger population, as the research approach relies on hypothesis testing. Researchers can rely on established guidelines and objectives rather than relying on guesswork (Lichtman, 2013). The significant advantage of employing this approach is that the results obtained are considered valid, reliable, and generalizable to a larger population.

In conclusion, the adoption of a mixed-method approach in the current research allows for the integration of quantitative and qualitative methods, leveraging their respective strengths to overcome limitations associated with each approach. This approach enhances the validity, reliability, and generalizability of the research findings, contributing to a more comprehensive and robust understanding of the research question at hand.

4.3.3 Using qualitative research to overcome the shortcomings of quantitative research

Despite its strengths, quantitative methods also have their limitations. One such limitation is the potential oversight of respondents' experiences and perspectives (Ary et al., 2013). This occurs because there is no direct interaction between researchers and participants during the data collection process in quantitative research, leading to the collection of objective data. Furthermore, quantitative research focuses on obtaining precise measurements and analyzing target concepts to address the research question, relying on structured and predetermined responses rather than intuitions or guesswork (Desai, 2019). The use of quantitative surveys is particularly advantageous when collecting data from large and representative samples, enhancing the generalizability of the results (Pilot & Beck, 2010).

However, the use of closed-ended questionnaires in quantitative surveys has limitations when it comes to capturing responses beyond the predetermined categories (e.g., strongly agree or disagree). To compensate for these limitations in the current research, qualitative research will be employed. Qualitative data can complement quantitative data by providing depth and perspective to statistical findings. It stems from human perception and experience, offering insights that quantitative data alone cannot capture and allowing for a richer and more holistic understanding of participants' behavior. In the current research, participants will have the opportunity to provide reasons for their responses in the quantitative surveys, enabling them to attribute meaning to their choices in the closed-ended questionnaire. This approach is considered appropriate and will contribute to a more comprehensive analysis of the research topic.

4.3.4 Ensuring validity, reliability, and credibility in mixed methods approach

In consideration of the preceding discussion, it is imperative to address the viability and, more importantly, the credibility of the mixed-method approach (Scott, 2014). Scott (2014) presents an argument supporting this approach, emphasizing its ability to integrate qualitative and quantitative methods into a cohesive mixed-methods framework that offers assurance through triangulation. Triangulation, as described by Cohen et al. (2000), involves the use of multiple methods in research to enhance the validity, reliability, and credibility of the findings. It is worth noting that triangulation can be employed within and across different research approaches. For instance, in a quantitative approach, data triangulation can be achieved through the use of survey questionnaires, knowledge tests, document analyses, and so on. Similarly, in a qualitative approach, data triangulation can be accomplished through interviews, observations, artifact analysis, and other methods. This demonstrates that triangulation does not necessarily imply the use of mixed methods alone; it can be employed within quantitative, qualitative, and mixed-method approaches. Nevertheless, triangulation is often utilized in studies that combine both quantitative and qualitative methods to address the same research question (Salkind, 2010), despite their distinct epistemic and ontological foundations (Scott, 2014). Consequently, integrating qualitative and quantitative research approaches frequently enhances the reliability and validity of the research findings.

4.3.5 Justification for choosing mixed-method research approach

Hence, considering the aforementioned justifications, I have determined that the mixed-method approach is the most suitable choice for addressing the research sub-questions. Despite the post-positivist paradigm's inclination towards quantitative research, the integration of both qualitative and quantitative methods remains valid. Critical realists contend that qualitative methods heavily rely on the researcher's subjectivity, lacking established criteria for analyzing and interpreting qualitative data (Bengtsson, 2016).

To overcome the limitations of qualitative methods, positivists suggest incorporating quantitative methods to reduce subjectivity in research. Pragmatists argue that employing multiple data collection approaches, such as observations and interviews (qualitative data) alongside traditional surveys (quantitative), enhances the research's validity, reliability, and credibility. Conversely, positivists emphasize that knowledge derived from research is grounded in measuring the objective reality of the world. However, post-positivists argue that relying solely on quantitative methods, such as quantitative surveys, would be disadvantageous in the current research.

Therefore, combining structured questionnaires and semi-structured interviews in mixed-method research produces confirmatory results, where the outcomes of one method are used to augment, elaborate, or clarify the findings of the other method, despite differences in data collection, analysis, and interpretation approaches (Harriss and Brown, 2010).

Based on these considerations, I have chosen to integrate both qualitative and quantitative methods in addressing research sub-question 1 (Section 1.8), which aims to determine the levels of VL, SL, and SRA among pre-primary school learners. However, for research sub-question 2 (Section 1.8), which seeks to establish causal relationships or associations between multiple variables, utilizing statistical methods to test the strength and significance of these relationships would be sufficient (Fraser Health Authority, 2011).

4.4 The overall framework of the current research design

According to Kothari (2004), a research design is the master plan or blueprint of the overall strategy to be undertaken by the researcher to answer the research question/s. This includes the procedures or processes to be followed when collecting, analyzing, interpreting, and reporting the research data (Creswell & Plano Clark, 2007). Additionally, “a research design should be scientifically grounded, trustworthy, and reliable” (Lacobucci & Churchill, 2010, p. 58).

4.4.1 The types of mixed methods research designs

Creswell (2013) presents six types of mixed methods designs, namely sequential explanatory design, sequential exploratory design, sequential transformative design, concurrent triangulation design, contemporary embedded design, and concurrent transformative design. In the current research, only the sequential exploratory, sequential explanatory, and concurrent embedded research designs will be discussed, as they are commonly employed.

The sequential exploratory research design focuses on exploring the phenomenon by defining the problem and gathering additional information, especially in the absence of previous studies. Methods such as in-depth interviews, focus groups, and projective techniques are used to explore the research problem and hypotheses (Austin & Sutto, 2014). Sequential exploratory studies typically employ interpretive research methods, such as observations, in-depth interviews, focus groups, and projective techniques, to address research questions related to *what*, *why*, and *how* (Austin & Sutto, 2014), drawing upon the naturalistic approach of interpretive research methods.

In contrast, sequential explanatory research designs aim to explain and account for descriptive information (Boru, 2018). While descriptive studies may seek to answer what type of research questions, sequential explanatory design goes a step further by investigating the causes and reasons behind the phenomenon (Baserville et al., 2016).

Concurrent embedded research designs involve one dataset playing a supportive, secondary role within a primarily data-based research design (Creswell et al., 2003). According to the same researchers, concurrent embedded mixed-method design entails collecting both quantitative and qualitative data, with one dataset complementing the other within the overall design. This design is intended to leverage the strengths of quantitative methods together with the strengths of qualitative methods to enhance the research's integrity.

4.4.2 Evidence of the use of mixed methods research design in literature

An example of a successful research study that utilized mixed methods is the work conducted by Penuel et al. (2009). The authors aimed to explore how the structure of educators' social networks could provide insights into the cohesion of a school community regarding reform goals. To collect data, a combination of surveys and interviews was employed. Surveys were used to gather information from educators about their professional networks, specifically identifying colleagues they sought help from regarding instructional matters. The responses were then used to generate sociograms that depicted the network structure of each school. Interviews with a sample of educators were conducted to uncover information that surveys alone could not reveal, helping to explain the network structure. The authors successfully integrated mixed methods in their research by arguing that understanding the underlying reasons for network structures and their potential for reform requires both quantitative and qualitative data, with each method complementing the other. This approach enabled them to address questions regarding educators' interactions, reasons for divisions within school communities, and the sociograms representing the network structure.

Another successful research study employing mixed methods was conducted by Kim et al. (2014). The research aimed to develop a transformative approach to improve the future lives of disadvantaged children in Korea. The study involved collaboration with community volunteers, adults in the community, and children from a specific center dedicated to fostering the motivation and commitment to learning among the participating children. Focus groups were conducted with the adult participants to understand their perspectives on helping the children. Additionally, a focus group was conducted with the children to gather insights into their desired activities and learning preferences. The data from the focus groups informed the development of two surveys administered to all participating adults and children, respectively. The findings revealed that the children had limited experiences that motivated them to learn. Based on these findings, the author employed action research to develop, implement, and evaluate an intervention. Kim argued that utilizing mixed methods was crucial for this research, as relying solely on quantitative analysis of demographic data would not have been sufficient to conceptualize the problem or design the intervention. The surveys, which were informed by the focus group discussions, played a vital role in formulating intervention goals.

4.4.3 Justification for choosing the concurrent embedded mixed method design

The concurrent embedded mixed method design chosen for this research is less commonly used compared to the sequential exploratory and explanatory research designs (Creswell, 2008; 2007). The concurrent embedded mixed method design is a research design that involves the simultaneous collection and analysis of both quantitative and qualitative data within a single study. Despite its lower prevalence, the concurrent embedded design offers several advantages over other designs. One advantage is the ability to collect and analyze data concurrently, which can save time and resources in the research process. Creswell (2006) suggests that concurrent embedded research designs are particularly suitable when researchers have limitations in terms of time or resources for extensive quantitative and qualitative data collection. In this design, one type of data is not prioritized over the other, but rather both types are collected and analyzed in parallel. In contrast, sequential exploratory and explanatory research designs would typically require more time to implement, as data collection and analysis are carried out sequentially.

The concurrent embedded design allows for a more comprehensive and holistic understanding of the research topic. By integrating quantitative and qualitative data collection and analysis, researchers can gain deeper insights into the phenomenon under investigation. This design enables the exploration of different aspects and dimensions of the research question, providing a richer and more nuanced perspective. However, it is important to note that the concurrent embedded design requires careful planning and consideration to ensure the successful integration of quantitative and qualitative data. Researchers must design appropriate data collection instruments and employ suitable analytical techniques for each type of data. This design also necessitates researchers' familiarity and expertise in both quantitative and qualitative methodologies. In the current research, the use of a correlational model, which is a variant of the concurrent embedded research design, is required based on the explored research question (Section 1.8) (Creswell, 2006). This model allows for the incorporation of qualitative data within quantitative research, facilitating the collection of qualitative data to provide explanations for any relationships established from the quantitative data.

The suitability of a sequential exploratory research design for the current research is questionable. Huang (2019) states that sequential exploratory research design is typically used as a hypothesis-generating approach, where the researcher does not start with prior assumptions or hypotheses. However, in the current research, the underlying hypothesis (Section 1.10) and the research's aims and objectives (Section 1.11) do not primarily focus on explaining the levels of VL, SL, and SRA. As a result, the sequential explanatory research design is not appropriate. Taking inspiration from Mnguni (2012), who effectively incorporated qualitative research elements to explore meanings embedded in quantitative data, the concurrent embedded research design is considered more suitable for the current research.

While the concurrent embedded research design gives equal priority to both quantitative and qualitative data, in the current research, a primarily quantitative approach was employed, with the qualitative approach playing a secondary role in cross-validating the results from the quantitative research. Survey questionnaires were used to collect data on the levels of VL, SL, and SRA among pre-primary school learners, and the data were primarily analyzed using quantitative methods such as descriptive statistics (e.g., frequencies). Additionally, qualitative methods were utilized to extract meanings embedded in the responses (Table 4.1; Creswell, 2008), and the qualitative data were analyzed using thematic coding to explain the quantitative statistics. It is important to note that although the embedded research design was adopted, similar to Nkosi and Mnguni (2020), the qualitative data from interviews were not employed to confirm the quantitative data but rather to provide explanations through an explanatory mixed method format. The interview protocol included items that encouraged participants to elaborate on their responses to the quantitative measures, enabling a deeper understanding of the reasons behind their levels of VL, SL, and SRA. By incorporating qualitative data to explain or expand upon quantitative results, the research incorporates elements of an explanatory research design, as suggested by Creswell et al. (2003). This approach allows for the identification of quantitative findings that require additional explanation, such as statistical differences among groups, individuals with extreme scores, or unexpected results. To determine the relationship between VL, SL, and SR and the responses to research sub-question 2 (Section 1.8), the data obtained from survey questionnaires were utilized to calculate inferential statistics such as correlations (Table 4.5; Creswell, 2008). The specific application of these methods for each research sub-question is discussed in subsequent sections.

4.5 Methods used for responding to the research questions

4.5.1 A conceptual description of methods used for data collection and analysis

Looking at the main research question of the current research, the research aimed to determine the relationship between VL, SL, and SRA among Grade R learners in pre-primary school. In response to the main research question, I broke down the main question into two research sub-questions (Section 1.8) and addressed each sub-research question individually. Therefore, each research sub-question also determined the type of data collection and analysis methods used in the research. Below I will discuss the research methodology used to respond to research sub-question 1, and the research methodology used to respond to research sub-question 2, which will be discussed later (Section 4.5.3).

A. Quantitative methods used for determining the level of visual literacy, science literacy, and scientific reasoning ability

As mentioned previously, the chosen research design for this study is the concurrent embedded mixed-method design, which aims to incorporate both quantitative and qualitative data. The research methodology utilized for data collection and analysis is summarized in Table 4.1, providing an overview of the procedures employed.

To address the research sub-question 1 (Section 1.8), a questionnaire comprising closed-ended questions was administered to gather data pertaining to the learners' levels of VL, SL, and SRA. The quantitative data obtained from the questionnaire were analyzed using descriptive analysis techniques such as frequency distribution, measures of central tendency (e.g., mean, median), and measures of variability (e.g., standard deviation).

In addition to the quantitative approach, semi-structured interviews were conducted to gather qualitative data. An interview protocol containing open-ended questions was utilized during the interviews to allow for in-depth exploration and understanding of the participants' perspectives. The qualitative data obtained from the interviews were subjected to thematic analysis, a method used to identify and analyze recurring themes or patterns within the data.

To strengthen the validity, reliability, and credibility of the research, a triangulation approach was employed, combining both quantitative and qualitative data. By integrating multiple sources of data, this approach helps to enhance the robustness and comprehensiveness of the findings. Triangulation enables researchers to gain a more comprehensive understanding of the research topic by corroborating or contrasting the results obtained from different data sources or methods.

Overall, the concurrent embedded mixed-method design, along with the specific data collection and analysis procedures outlined in Table 4.1, allowed for a comprehensive exploration of the research sub-question 1, integrating both quantitative and qualitative perspectives to provide a more comprehensive understanding of the phenomenon under investigation. In an attempt to answer the sub-research question 1, the quantitative and qualitative parts of the research were done in two phases concurrently:

- *Phase one: collecting and analyzing quantitative data to assess the learners' VL, SL, and SRA levels.*
- *Phase two: collecting and analyzing qualitative data to explain the learners' reasoning for their responses in the quantitative part (phase one) of responding to research sub-question 1.*

Table 4.1 demonstrates the outline of the research methodology used to determine the level of VL, SL, and SRA among pre-primary school learners in order to respond to the research sub-question 1, which includes phases one and two.

Table 4. 1

An outline of the research methodology used to respond to the research sub-question 1

Research sub-question 1	Phase	Methods used
Methodological approach	Phase one	Quantitative
	Phase two	Qualitative
Data	Phase one	Quantitative: 208 Grade R learners (87 Grade R learners from the STEM schools and 121 Grade R learners from the non-STEM schools). Sampling of the 208 Grade R learners will be discussed in phase one of the quantitative part of responding to research sub-question 1.
	Phase two	Qualitative: 12 Grade R learners (6 Grade R learners from one STEM school and 6 from one non-STEM school). Sampling of the 12 Grade R learners will be discussed in phase one of the qualitative part of responding to research sub-question 1.
Data collection method	Phase one	Quantitative: The questionnaire consisted of closed-ended items (quantitative)
	Phase two	Qualitative: The questionnaire also consisted of open-ended items (qualitative) but administered through semi-structured interviews.
Data analysis approach	Phase one	Quantitative: Questionnaire analysis
	Phase two	Qualitative: Thematic analysis - using written text to explain statistics
Analysis procedure	Phase one	Quantitative: Descriptive statistics - measuring frequencies
	Phase two	Qualitative: Thematic analysis - using written text to explain statistics

Sampling method used for selecting the participants

As previously mentioned, the concurrent embedded mixed-method research design was chosen for this study. The research methodology used to collect and analyze data is outlined in Table 4.1. For addressing research sub-question 1 (Section 1.8), purposive sampling was employed to select participants from the eligible population. Purposive sampling is defined by Andrade (2020) as a non-probability sampling method where characteristics relevant to the research purpose define the sample.

Purposive sampling differs from probability sampling, such as simple random sampling or stratified random sampling, where all population members have an equal chance of being selected. In non-probability sampling, individuals are not selected based on equal opportunities, and the researcher's judgment plays a subjective role (Deshmukh, 2013). While probability sampling aims to create a sample for generalization purposes, purposive sampling focuses on specific population characteristics of interest, facilitating theoretical, analytic, and logical generalizations (Sharma, 2017).

Convenience sampling, another non-probability method, could have been an alternative choice. However, unlike purposive sampling, convenience sampling relies on accessibility for participant selection, which may introduce bias due to the absence of predetermined criteria (Andrade, 2020). An example of a study utilizing purposive sampling with set criteria is the research by Nkosi and Mnguni (2020), where Grade 11 chemistry learners were purposively selected from two under-resourced government township schools in South Africa based on the absence of teaching resources.

The selection of participants for the current research was based on predefined criteria to address the subjectivity inherent in purposive sampling. Similar to the approach taken by Nkosi and Mnguni (2020), a group of Grade R pre-primary school learners was purposively chosen from six non-government English Medium Language pre-primary schools in Bloemfontein, Free State, South Africa, in 2022. The group of Grade R pre-primary school learners were chosen in order to specifically target the age group and educational level relevant to the research objectives. Grade R represents the final year of pre-primary education, typically taken by children aged 5 to 6 years old. Therefore, by focusing on this particular grade level, the research can examine the readiness of learners in their early educational journey to engage with STEM education.

The choice of Bloemfontein, Free State, as the sample site was primarily driven by the presence of a substantial number of STEM schools in the Free State province compared to other provinces in South Africa. This characteristic made Bloemfontein an ideal location for investigating the integration of STEM education in pre-primary schools. By selecting Bloemfontein as the research site, the study aimed to explore the specific context of STEM education within the pre-primary school setting and tap into the available STEM schools in the region.

The decision to focus on pre-primary schools was primarily based on the fact that they accommodate a significant number of Grade R learners, typically aged between four to six years. This age group was deemed suitable for the study as it allowed for an examination of the early stages of STEM education and its impact on young learners.

The selection of both STEM and non-STEM schools was driven by the research's aim to compare and analyze the impact of STEM education on the cognitive skills of Grade R pre-primary school learners. The rationale behind selecting STEM schools was based on their explicit focus on STEM subjects, as indicated by the information provided on their websites. These schools were chosen to represent the context of pre-primary education with an emphasis on STEM subjects, which aligns with the research's theoretical framework and objectives. On the other hand, the non-STEM schools were selected to provide a point of comparison and contrast with the STEM schools. These schools were assumed to follow The South African National Curriculum Framework for children from birth to four, which does not explicitly emphasize STEM subjects. By including non-STEM schools in the research, a comparison can be made between the cognitive skills of Grade R learners exposed to a dedicated STEM curriculum and those who follow a broader curriculum framework.

Therefore, the selection of both types of schools allows for a comprehensive examination of the impact of STEM education on the cognitive skills of pre-primary school learners. It provides an opportunity to explore the potential benefits and differences in the development of VL, SL, and SRA between learners in STEM and non-STEM educational settings. The contrasting environments of the STEM and non-STEM schools offer insights into the role of specific educational approaches in nurturing these cognitive skills during the crucial Grade R phase.

In the context of this research, STEM education is defined as the purposeful integration of science, technology, engineering, and mathematics skills and processes within the science classroom context (Jones et al., 2020). STEM education is regarded as both a curriculum and a pedagogy, providing learners with problem-solving, innovation, logical thinking, and technological literacy opportunities (Hasanah, 2020). A STEM school, therefore, refers to a school that has STEM education as its core, aiming to improve STEM literacy among its learners (Holdren & Lander, 2010).

Sampling procedures for selecting the suitable population

According to Jones et al. (2020), STEM schools are characterized by a unique curriculum that incorporates personalized instructional approaches, project and problem-based learning, and inquiry-based methods. This curriculum emphasizes interdisciplinary learning, technology integration, and real-world connections. These defining characteristics were used as criteria to identify potential STEM schools in Bloemfontein for participation in the research.

Before commencing the study, ethical clearance was obtained, and the process for obtaining ethical approval will be discussed in detail later in this chapter to address the ethical considerations associated with the research.

In the specific context of Bloemfontein, South Africa, all pre-primary schools in the area that self-identified as STEM schools based on the information provided on their respective websites were invited to participate in the research. Out of the pre-primary schools in Bloemfontein, only three schools identified themselves as STEM schools and were part of a network of non-government schools managed by the same organization. These three STEM schools, situated within the Motheo district in Bloemfontein, were the exclusive STEM schools within the district and willingly agreed to take part in the research.

Non-STEM schools, on the other hand, were identified based on their recognition by the Department of Education as non-STEM schools. From a pool of non-STEM schools, five schools were invited to participate in the research. However, only three of these schools ultimately agreed to participate. All six schools, both STEM and non-STEM, are registered with the Free State Department of Education in South Africa, ensuring that they meet the necessary educational standards and regulations.

The primary language of instruction at all six schools is English. However, recognizing that some learners may have a different home language, the schools employ multilingual educators who can provide support to those learners. This approach ensures that language barriers are minimized during the data collection process, as educators are available to explain questionnaire items in learners' mother tongues if necessary.

The selection of both STEM and non-STEM schools aimed to closely match them in terms of being non-government English medium schools, having similar learner populations and demographics, and representing a range of school contexts from affordable to high-end fee schools. This selection process allows for a more comprehensive and balanced comparison between STEM and non-STEM schools in the research, enhancing the validity and generalizability of the findings within the specific research context.

A description of the sampled participants

From the six schools, encompassing both STEM and non-STEM schools, all Grade R learners were invited to participate in the research. However, only 208 learners from these schools agreed to take part in the study, as indicated in Table 4.2. Prior to their participation, parental or guardian consent was obtained for each learner, ensuring adherence to ethical guidelines (which will be discussed in detail later in the chapter).

For both the quantitative and qualitative components aimed at assessing the levels of VL, SL, and SRA among pre-primary school learners, data were collected from both the STEM and non-STEM schools, treating them as two independent sample groups. The first sample group consisted of Grade R learners from the three schools affiliated with the STEM network, while the second sample group included Grade R learners from the three non-STEM schools. All the Grade R learners included in the study were between the ages of five and six years old. The specific sample sizes for each group will be discussed in subsequent sections of this chapter.

Considering the research objectives outlined in Section 1.11 and the theoretical framework presented in Chapter 3, the selection of STEM schools aligned with the rationale of the study, which emphasizes the significance of introducing science education in pre-primary schools. STEM schools are known to incorporate scientific inquiry and laboratory investigations into their curriculum and pedagogy. Therefore, Grade R learners enrolled in STEM schools during the 2022 academic year were deemed suitable candidates for the research. By comparing the levels of VL, SL, and SRA between Grade R learners from STEM and non-STEM schools, the importance of introducing science education in pre-primary schools could be established.

Moreover, assessing the VL, SL, and SRA of Grade R learners at the outset of the program can provide insights into their readiness to engage in science education. This evaluation also creates opportunities for future studies beyond the current research, where the same skills can be assessed at the end of Grade R. Comparing the results of the subsequent assessment with the findings of the present study would enable the determination of whether the skills (VL, SL, and SRA) have improved among Grade R learners who were exposed to science education throughout the 2022 academic year.

Table 4. 2

Summary of schools and Grade R learners that participated in the research

School ID	**School type**	**Total number of Grade R learners**	**Grade R learners from STEM schools**	**Grade R learners from non-STEM schools**
SCH – 1	STEM school	20	20	0
SCH – 2	STEM school	50	50	0
SCH – 3	STEM school	27	27	0
SCH – 4	non-STEM school	46	0	46
SCH – 5	non-STEM school	55	0	55
SCH – 6	non-STEM school	10	0	10
Total number of learners		**208**	**87**	**121**

Nevertheless, before collecting data from the target participants, I had to make sure to coincide with ethical care. I will therefore discuss how I obtained ethical clearance below.

Obtaining ethical approval to conduct the current research

Ethical clearance (APPENDIX A) was obtained from the University of South Africa's College of Education Ethics Review Committee (Reference 2022/02/09/51915987/28/AM) to ensure responsible and ethical conduct of the research. In addition, ethical approval was sought from the Free State Department of Education, and approval (APPENDIX B) was granted, although it was required only by the principal of one school.

To ensure the ethical protection of the participants, informed consent forms were used. These forms clearly explained the nature of the research and the implications of participating. As the participants were minors, the consent forms were signed by their parents/guardians. The informed consent process emphasized the voluntary nature of participation.

To maintain the confidentiality of the learners, data collection was conducted anonymously. Participants were not required to provide personal information or disclose their identities, such as their names or dates of birth, to ensure their privacy. Moreover, the questions asked during data collection were non-sensitive, with no inquiries relating to personal experiences or psychological well-being of the participants.

Having sampled the Grade R learners from both the STEM and non-STEM schools, all 208 (Table 4.2) Grade R learners from both the STEM and non-STEM schools participated in phase one of the quantitative part of responding to research sub-question 1, which aims to assess the level of VL, SL, and SRA among pre-primary school learners.

I. Phase one - assessing the learners' level of visual literacy, science literacy, and scientific reasoning ability

Determining the sample size of the sampled population

The total sample for the quantitative part of responding to research sub-question 1, consisted of 208 Grade R learners in the academic year of 2022. After receiving permission from the schools and the parents (Section 4.5.2) to conduct the research at the schools, a total of 121 Grade R learners, from non-STEM schools (Table 4.2) were included in the one sample group. Additionally, the other sample group consisted of 87 Grade R learners, which were all Grade R learners from the STEM schools (Table 4.2). The total sample size reflected the total number of learners whose parents gave consent to be part of the research. To determine the suitable minimum sample size, I used Bonett's (2015, p.336) formula $n = [\{(2k/ k - 1) (z\alpha /2 + z\beta)2\}$

/ln (δ˜)2] + 2. Similar to Bujang (2018) sample size was calculated based on a power of 90% (Power = 1–β) with the alpha value (α) set at .05 at all times for the 15 items (close-ended items) in the questionnaire. The minimum sample size required for each of the samples was 18. Therefore, the sample size of 87 and 121 were considered to be adequate for survey research with a questionnaire of 15 items.

Furthermore, in research by Nkosi and Mnguni (2020), the authors considered Gogtay's (2010, p. 518) formula (n = [(Z + Z)2 x σ2]/d) "for estimating the minimum sample size required for two means in quantitative data in determining the suitable minimum sample size" (p. 598). The authors wanted to determine the number of learners required at 80% power and 5% significance with an effect size of .2 to detect an average difference with a standard deviation of 30% and calculated the minimum sample size required to be 24. This further indicates that sampled measures in the current research are indeed adequate. I will now discuss how I designed and validated the data collection instrument.

Designing and validating the data collection instrument

The type and design of the data collection instrument

For phase one of the research, a non-experimental survey method was employed to collect data (Maree & Pietersen, 2007). Survey methods, as described by Kabir (2016), are effective for measuring population characteristics, self-reported and observed behavior, program awareness, attitudes, opinions, and needs. This method is particularly useful when phenomena are not easily measurable or observable (Schofield & Forrester-Knauss, 2013). Questionnaires are commonly used in survey methods, and they can be administered verbally or in writing.

In the current research, a questionnaire was utilized as the data collection instrument. The design of the instrument was guided by the theoretical framework (Chapter 3). Given that the aim was to assess the learners' levels of VL, SL, and SRA, the survey questionnaire consisted of two types of assessments: a psychometric test and a content knowledge test. The psychometric test questionnaire was essential for obtaining the learners' overall level of VL skills (as discussed in Section 3.2.4 of the theoretical framework) and their level of SRA (as discussed in Section 3.4.2 of the theoretical framework). On the other hand, the content knowledge test questionnaire was suitable for evaluating the learners' content knowledge in specific science domains (as discussed in Section 3.3.2 of the theoretical framework).

The design of the instrument, particularly the presentation of visuals, was informed by the theoretical framework and relevant research literature. Specifically, the adoption of the Cognitive Theory of Multimedia Learning by Mayer (2001) and the 12 Principles of Multimedia Learning by Richard Mayer (2011) provided a solid foundation for the design decisions. The Cognitive Theory of Multimedia Learning emphasizes the importance of optimizing learners' cognitive processing by minimizing extraneous processing and promoting meaningful learning experiences. In line with this theory, the questionnaire was designed to present information in a visually engaging and comprehensible manner. The use of visuals in the questionnaire aimed to enhance learners' understanding and reduce cognitive load by leveraging the dual information processing channels of visual and verbal modalities.

Richard Mayer's theory of the 12 Principles of Multimedia Learning further guided the design process. This theory emphasizes the significance of simplicity, coherence, and relevance in multimedia learning experiences. To adhere to these principles, the questionnaire items were carefully crafted to include simple text and visuals that directly related to the learning process. Unnecessary text was eliminated to avoid overwhelming the learners, and only essential information was included to support comprehension. The rationale behind these design choices was to optimize the learners' cognitive processing and create effective multimedia learning experiences.Therefore, by aligning the questionnaire design with the principles of the Cognitive Theory of Multimedia Learning and Richard Mayer's 12 Principles of Multimedia Learning, the research aimed to facilitate a more meaningful and engaging assessment of the learners' skills and knowledge.

It is important to acknowledge that the design approach being described here was not exclusively centered on visual aspects but also incorporated other elements of the questionnaire, including content and language considerations, particularly for children whose first language is not English. The language was simplified and made appropriate for the children's age and proficiency level, avoiding complex vocabulary and ambiguous terms. Therefore, by incorporating these considerations, the questionnaire design aimed to create a comfortable and inclusive environment, promoting accurate and meaningful responses. The overarching objective was to facilitate learners' cognitive processing and optimize the validity and reliability of the collected data.

Furthermore, the questionnaire was based on previously validated studies conducted by Johnson and Zippert (2018), Kinzie et al. (2015), and Brown et al. (2010) to address research sub-question 1 (Section 1.8). The purpose of the questionnaire was to assess three central concepts in the current research: VL, SL, and SRA.

For VL assessment, the research focused on four critical skills: patterning, spatial visualization, visual-spatial working memory, and visual perception, as discussed in Section 3.2.2 of the theoretical framework (Welsh and Wright, 2010). The questionnaire items were designed based on the Cognitive Theory of Multimedia Learning, presenting information in both visual and verbal forms to engage learners' information processing channels and reduce cognitive load.

Regarding SL assessment, the National Science Education Standards (1995), as outlined in Section 3.3.2 of the theoretical framework, provided guidance on what learners should know, understand, and be able to do in pre-primary school science education (Kinzie et al., 2015). The questionnaire items were developed based on previously validated research by Kinzie et al. (2015), who utilized the Research on Curricular Development model to design and develop the data collection instrument. The specific domains and science content assessed aligned with the standards outlined in the National Science Education Standards (1995):

- *Life Science (Living vs non-living),*
- *Earth Science (Weather),*
- *Physical Science (Mass).*
- *Physical Science (Temperature)*

SRA - lastly, in line with Furtak et al. (2008), the Evidence-Based Reasoning Framework (discussed in section 3.4.2 of the theoretical framework) was used to assess the learners' scientific inquiry skills by evaluating the different elements of scientific methods that are important for determining the level of SRA among pre-primary school learners:

- *Premise*
- *Claim*
- *Rule*
- *Data*
- *Evidence*

Developing the items of the questionnaire

The items were presented as closed-ended and open-ended questions. Close-ended questions are question types that ask respondents to choose from a distinct set of pre-defined responses. However, closed-ended questions limit the respondent to the collection of alternatives being offered. Open-ended questions on the other hand, allow the respondent to express their opinions freely, the options do not restrict them. In this regard, the respondents can express their views without being influenced by the researcher (Ursa et al., 2003). And so, it is for these reasons that I decided to add the open-ended questions, as they can add richness to questionnaire results when added as follow-ups to closed-ended items. Considering that I adopted the mixed-method approach for the current research, I found it to be appropriate to incorporate both types of questions in the research instrument.

In developing the items, the open-ended items correspond to each closed-ended item. Moreover, each open-ended item was to be used as a follow-up to the close-ended item to elucidate why learners gravitated toward the specific answers in the closed-ended items. This was deemed to be an appropriate approach due to closed-ended questions known to limit the participants' responses to the pre-determined response.

Furthermore, given that the assessment aimed to evaluate the learners' literacy skills, I recognized the importance of including the option "I don't know" among the response choices. This option acknowledges that not all learners may have the answers to the questions and aligns with the approach suggested by Jenn (2006). By providing this option, I aimed to avoid forcing learners to guess, thereby minimizing my influence on the research process.

Additionally, Choi and Pak (2005) highlight the significance of addressing bias in questionnaires, particularly in quantitative research. They emphasize the potential issues related to wording problems, complex or double-barreled questions, technical jargon, uncommon or vague words, faulty scales, insensitive measures, leading or sensitive questions. To mitigate such bias in the questionnaire design, I adopted the post-positivism paradigm and sought to validate the questionnaire through a panel of experts, as discussed later in this chapter.

In Appendix C, I will delve into the development of each item in the questionnaire. Furthermore, the scoring tool, which serves as an instrument to mark or score the learners' responses, will be discussed and validated in Appendix D, following the validation of the data collection instrument by the panel of experts.

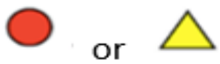
For items assessing visual literacy, the following skills were evaluated:

Patterning skills: The items were adopted from the Research-based patterning assessment (Rittle – Johnson & Zippert, 2018) as discussed in the theoretical framework (Section 3.2.2). Like Rittle – Johnson & Zippert (2018), I assessed the patterning skills among pre-primary school learners. Zippert & Rittle-Johnson, (2019) argues that an "educator-friendly, valid and reliable instrument for assessing patterning skills among pre-primary school learners currently does not exist" (p. 3). Therefore, it is for this reason that I saw it fit for me to adopt the research-based patterning assessment for the current research, as it has been previously validated and found to be reliable by researchers such as Zippert et al. (2022). He also adopted the research-based patterning assessment to develop a numeracy screening assessment for pre-primary school for Grade 3 learners.

The item was designed to assess the learners' ability to identify units of repeating visual patterns based on previously validated studies (Rittle-Johnson et al., 2013; Rittle-Johnson et al., 2015). According to (Rittle-Johnson & Zippert, 2018), "research-based patterning assesses pre-primary school learners' ability to duplicate, extend, abstract, and identify units of repeating visual patterns" (p.14). Previous studies (Rittle-Johnson et al., 2013; Rittle-Johnson et al., 2015) have corroborated the current research on the research-based patterning assessment. These studies' findings indicate that patterning and spatial skills are unique predictors of mathematics and science knowledge and growth. The studies emphasize the early development of mathematics and science standards, which should be expanded to incorporate a role for repeating patterning and spatial skills.

Closed-ended item: Choose the correct missing shape in this pattern.

1



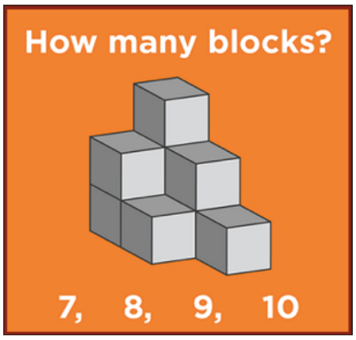
2

Open-ended item: What is your reason for choosing this answer?

Figure 4. 2 Example of an item assessing the learner's ability to identify units of a repeating visual pattern

Spatial visualization skill: Spatial visualization describes one's ability to imagine and mentally manipulate 2D and 3D presentation of spatial information (Rittle – Johnson & Zippert, 2018). The item was designed (as discussed in section 3.2.2 of the theoretical framework) to measure spatial visualization among pre-primary school learners and was adopted based on previously validated studies (Rittle-Johnson et al., 2013; Rittle-Johnson et al., 2015).

Closed-ended item: How many blocks are in the picture?



1

2

Open-ended item: What is your reason for choosing this answer?

Figure 4. 3 Example of an item assessing the learner's ability to imagine and mentally manipulate 2D and 3D presentation of spatial information.

Visual-spatial working memory skill: In section 3.2.2 of the theoretical framework, I discussed that when assessing visual-spatial working memory, I would be looking at the learners' ability to hold the locations of different objects and landmarks in their working memory. The item for assessing the learners' visual-spatial working memory was designed to assess their ability to remember what they perceived. This item is adopted from research by Kessels and Postma (2018), who developed an assessment for assessing visual-spatial working memory. Similar to Kessels and Postma (2018), the item instructed the learners to remember what they were shown and replicate it by drawing from remembrance, however, in Kessels and Postma's (2018) research, the learners had to click on the items they recalled seeing, by using a computer.

Closed-ended item: Look at the picture on the left and redraw the picture on the folded side of the paper based on what you can remember seeing. How many apples were in the picture I showed you?

- 2
- 4
- 3
- I don't know

Open-ended item: What is your reason for choosing this answer?

Figure 4. 4 Example of an item assessing the learner's ability to remember what they visually perceived.

Visual perception skill: As already discussed in section 3.2.2 of the theoretical framework, visual perception looks at the individual's ability to make sense of what has been perceived in their surroundings through the light that enters their eyes. The item for assessing visual perception items was designed to assess the learner's ability to make sense of structures and patterns that were presented in the item. The items were based on previously validated studies (Rittle-Johnson et al., 2013; Rittle-Johnson et al., 2015).

Closed-ended item: Count how many trees at the top match with the trees at the bottom based on their shape.

- 4
- 5
- 10
- I don't know

Open-ended item: What is your reason for choosing this answer?

Figure 4. 5 Example of an item assessing the learner's ability to perceive the differences in the item's structures and patterns and shape.

For items assessing science literacy, the following content knowledge was assessed:

Life Science Literacy: According to Olcer (2017) "Life sciences contains content information about physical properties of human, animal, and plants such as parts, colour, shape, texture, and all other features, classification of plants and animals, the life cycle of organisms, inheritance, the relationship between organisms and environment" (p.146). Here learners realize relationships among people, plants and animals (Eliason & Jenkins, 2008). The item was designed to assess the learner's ability to (Section 3.3.2 of the theoretical framework)

- *Differentiate between living and non-living*

Closed-ended item: Circle/choose a thing/things that are/are alive.

1

2

Open-ended item: What is your reason for choosing this answer?

Figure 4. 6 Example of an item assessing the learner's ability to differentiate between living and non-living organisms.

Earth Science Literacy: The item was designed to assess the learner’s conceptual knowledge of concepts such as (Section 3.3.2 of the theoretical framework):

- *The weather*

Closed-ended item: Match the clothes to the weather.

1

2

Open-ended item: Why does the boy need glasses and a hat when playing in the sun?

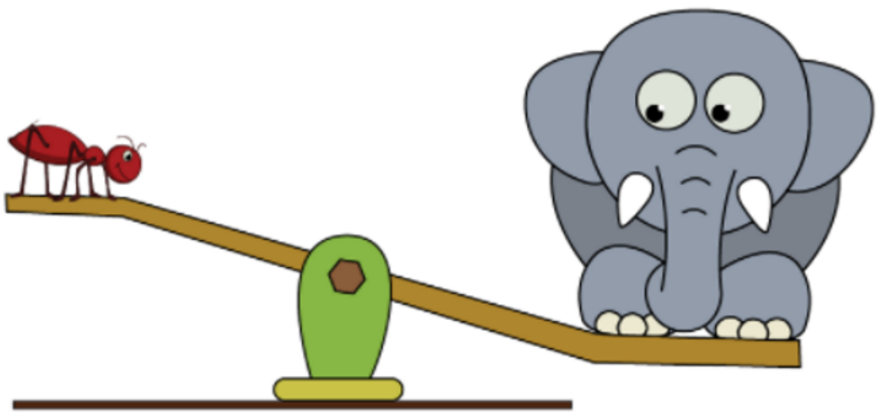
Figure 4. 7 Example of an item assessing the learner's ability to choose the appropriate clothing based on the weather.

Physical Science Literacy: According to Bozkurt and Olgun (2015) physical science mainly includes science concepts such as properties of matter, states of matter, change and a mixture of matter, classification of objects and materials, mass of objects, energy, movement of objects and heat,. The item was designed to assess learners' understanding of concepts such as (Section 3.3.2 of the theoretical framework):

- *Mass of objects*
- *Balancing of objects*

Closed-ended item: Circle/choose the heavier animal.

- Ant
- Elephant
- I don't know



Open-ended item: What is your reason for choosing this answer?

Figure 4. 8 Example of an item question assessing the learner's ability to compare the mass of different objects with a balance scale.

Physical Science Literacy: The item was designed to assess the learner's understanding of concepts such as (Section 3.3.2 of the theoretical framework):

- *Temperature*

Closed-ended item: Circle/choose the item/thing that has a higher temperature.

1 2

3

Open-ended item: What is your reason for choosing this answer?

Figure 4. 9 Example of an item assessing the learner's understanding of the temperature.

For items assessing scientific reasoning ability, the following skills were assessed:

- *Knowledge of scientific tools used in scientific inquiry.*

Closed-ended item: What is the name of the tool?

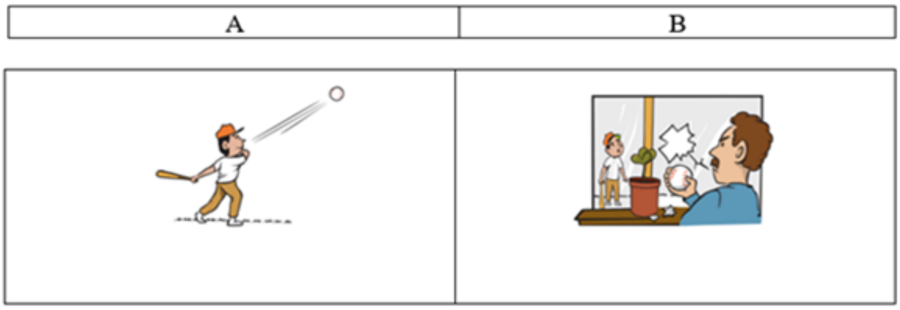
- Phone
- Thermometer
- I don't know

Open-ended item: What is the tool used for?

Figure 4. 10 Example of an item assessing the learner's knowledge of scientific tool used in scientific inquiry.

- *Making a conclusion*

Closed-ended item: Looking at picture A, what happened to the ball in picture B?



- The ball went into the sky
- I don't know
- The ball broke the window

Open-ended item: What is your reason for choosing this answer?

Figure 4. 11 Example of an item assessing the learner's ability to make a conclusion.

- *Logical reasoning*

Close-ended item: Circle/choose the two objects that can be used together.

1

2

Open-ended items: What is your reason for choosing this answer?

Figure 4. 12 Example of an item assessing the learner's logical reasoning.

- *Application of knowledge*

Closed-ended item: Looking at the picture, who will most win the rope tug?

- Parents
- Kids
- I don't know

Open-ended item: What is your reason for choosing this answer?

Figure 4. 13 Example of an item assessing the learner's ability to apply knowledge.

- *Making sense of observations*

Closed-ended item: Looking at the picture, what is that I can eat?

I can eat an apple

It is good for me

- Yellow banana
- Red apple
- I don't know

Open-ended item: Why should I eat the apple?

Figure 4. 14 Example of items assessing the learner's understanding of what is observed.

- *Analysis of data*

Closed-ended items: Here are Wavhudi's favourite things to do. What does he like to do the most?

- Reading
- Painting
- I don't know

Open-ended item: What is your reason for choosing this answer?

Figure 4. 15 Example of an item assessing the learner's ability to analyze data.

The structure of the questionnaire

The questionnaire consisted of two parts, and it was in English. The first part of the questionnaire was denoted as Section A. Section A was based on retrieving learners' demographics, such as age, gender, and mother tongue. The second part of the questionnaire consisted of closed-ended items. The closed-ended items consisted of Sections B, C, and D. Section B was a psychometric test and was aimed at assessing the learners' level of VL. While Section C was a content knowledge test and was aimed at assessing the learners' level of SL. Lastly, Section D was a psychometric test and was aimed at assessing the learners' level of SRA.

The third part of the questionnaire consisted of open-ended items, where the open-ended items were designed in such a way as to solicit responses that have a qualitative character. This means that more elaborate responses would make it possible for me to have insight into the learners' reasoning something which cannot be done by merely pigeon holding the learners' responses. Therefore, open-ended items consisted of Sections E, F, and G. Section E which corresponds to Section B, was aimed at assessing the learners' level of VL. While Section F which corresponds to Section C was aimed at assessing the learners' level of SL. Lastly, Section G which corresponds to Section D was aimed at assessing the learners' level of SRA. The open-ended items were guided by the closed-ended items in the quantitative part of assessing the level of VL, SL, and SRA among learners. In the next section, I will then be discussing how the developed questionnaire was validated through a panel of experts.

Validating the questionnaire through a panel of experts

The validation of the instrument was conducted using a combination of expert judgment and various forms of validity. Initially, the instrument's face validity, which refers to its appearance as a valid measure of the construct being assessed, was evaluated. This assessment provided the researcher with confidence in the instrument and its results. Although face validity is considered superficial, it serves as a preliminary measure of validity.

Content validity, on the other hand, examines the relevance and representativeness of the items in relation to the construct being measured. It ensures that the instrument covers all aspects of the content it intends to measure. Content validity was deemed crucial in this research, as it establishes whether the desired construct is adequately measured. However, it should be acknowledged that content validity can be subjective.

Construct validity, a more advanced form of validation, evaluates the extent to which the instrument tests the intended hypothesis or theory. It takes into account various factors that may affect the validity of the construct, such as definitions, measurement levels, and potential biases. Several threats to construct validity need to be considered and addressed to ensure the instrument accurately measures the desired construct.

Criterion validity estimates the agreement between the instrument and an external criterion, often referred to as the *gold standard.* However, the lack of readily available gold standards can be a challenge when assessing criterion validity for questionnaires.

Ecological validity, the final form of validation, measures how well the instrument predicts behavior in real-world settings and the generalizability of research findings. While research with high ecological validity is desirable, maintaining control in natural settings can be difficult.

For the current research, content validity was deemed most appropriate, as it is established during the initial stages of instrument construction. Content validity is considered a prerequisite for criterion validity and ensures that the instrument adequately covers the content being measured. Face validity was also considered valuable as a supplemental form of validity, increasing the researcher's confidence in the instrument. The face index (FVI) and content validity index (CVI) were calculated for the closed-ended items to provide evidence of face and content validity.

It is important to note that open-ended items in qualitative research often have their validity limited to grammar and appropriate word usage, as they are developed to correspond to the closed-ended items, as observed by experts.

Calculating FVI of the questionnaire items

To establish face validity, a rating scale was developed based on Yusoff's (2019) recommendations (Table 4.3). Similar to Lau et al. (2018), the questionnaire, along with the rating scale, was given to 10 parents of pre-primary school learners. The parents were asked to rate the questionnaire in terms of language use, clarity, and understandability of the items, following the guidelines provided in Table 4.3. Fraenkel and Wallen (2003) highlight the importance of obtaining feedback from potential respondents during the face validity process.

Yusoff (2019) suggests that a minimum of 10 raters is acceptable for face validity assessment. The validation process involved face-to-face interactions with the 10 parents in their homes, as this approach is considered more efficient than online or telephone methods, according to Yusoff's (2019) experience. The parents were encouraged to provide feedback on how to improve the clarity and comprehension of the items.

To calculate the Face Validity Index (FVI), the responses from the raters were scored. Using the formula recommended by Ozair et al. (2017), ratings of 3 or 4 were assigned a score of 1, while ratings of 1 or 2 were assigned a score of 0. The scores for each item were then summed across all raters and divided by the number of raters. Marzuki et al. (2018) consider an FVI value of .83 or higher to be acceptable. In this study, all 15 items had FVI values above .80, indicating good face validity. Additionally, no recommendations were made by the raters to rephrase the items, further supporting their clarity and comprehension.

Table 4. 3

A rating scale for establishing face validity

Item				Explanation	Scale
1	2	3	4	The item is very clear and understandable	4
5	6	7	8	The item is clear and understandable	3
9	10	11	12	The item is somewhat clear and understandable	2
13	14	15		The item is not clear and understandable	1

Calculating the CVI of the questionnaire items

The instrument, consisting of 30 items (15 closed-ended and 15 open-ended), underwent validation by a panel of experts (n = 5). Research suggests that a panel of five to eight experts is appropriate for content validation (Yusoff, 2019). The experts selected for the panel possessed expertise related to the constructs being measured in the questionnaire (Architha & Sreeamana, 2020). The panel consisted of one Natural Science Lecturer, two Grade R educators, one Grade 3 English language educator, and one Grade 4 Natural Science educator. The inclusion of experts from different fields aimed to ensure comprehensive coverage of the constructs and minimize potential bias among the experts (Bai, 2018). Additionally, the diverse expertise of the panel members would contribute valuable insights to the current research (Mnguni et al., 2016).

The panel of experts was provided with the questionnaire and tasked with evaluating the extent to which the instrument measures what it is intended to measure (Robson, 2011). They carefully examined each item to assess its validity and appropriateness for the research. To guide the content validation process, the panel of experts was presented with fundamental questions known as probes (Mnguni, 2012). These probes served to evaluate the content validity of the questionnaire:

- *Do the items test what they ought to?*
- *Are the items clear and suitable for Grade R learners?*
- *Are the text and visuals used in the item simple to follow?*
- *Are the item questions ambiguous?*

Like Yaghmale (2003), a modified 4-point Likert scale with items from Mnguni (2007) was given to the panel of experts to rate each item based on its relevance, clarity, simplicity, and ambiguity and indicate why the item had to be included, removed or changed. According to Vagias (2006), a Likert-type scale involves a series of statements that respondents can choose from to rate their responses to evaluative questions, as shown in Table 4. 3. A 4-point Likert scale is a forced Likert scale, whereby there is no safe 'neutral' option for the panel of experts as their opinion is essential. The scale ranges from 1 to 4, starting with strongly disagree at 1 point and strongly agree at 4 (Mcleod, 2008).

Table 4. 4

A modified 4-point Likert scale for establishing content validity

	Question	Item				Explanation	Point
Relevance	Does the item measure what it ought to?	1	2	3	4	Strongly Agree	4
		5	6	7	8	Agree	3
		9	10	11	12	Disagree	2
		13	14	15		Strongly Disagree	1
Clarity	Are the items clear and suitable for Grade R learners?	1	2	3	4	Strongly Agree	4
		5	6	7	8	Agree	3
		9	10	11	12	Disagree	2
		13	14	15		Strongly Disagree	1
Simplicity	Are the text and visuals used in the item simple to follow?	1	2	3	4	Strongly Agree	4
		5	6	7	8	Agree	3
		9	10	11	12	Disagree	2
		13	14	15		Strongly Disagree	1
Ambiguity	Is the item ambiguous?	1	2	3	4	Strongly Agree	4
		5	6	7	8	Agree	3
		9	10	11	12	Disagree	2
		13	14	15		Strongly Disagree	1

The experts scrutinized each item and commented on its legitimacy and appropriateness in answering the research questions. Experts' responses and feedback to the questionnaire were used to calculate the questionnaire's CVI, which was determined to support the validity of the questionnaire (Yuosoff, 2019). CVI is primarily determined in quantitative studies (Shi, Mo & Sun, 2012). The current research followed the content validation procedure by Yuosoff (2019). Several studies, such as that of Hardie et al. (2017); Ozair et al. (2017), support the use of the system in quantifying the content validity of an instrument's instruments. According to Yuosoff (2019), the acceptable CVI values depend on the number of experts on the panel and their item of 2 or 3‘(that is, strongly agree or agree, respectively) on the 4-point rating scale. The CVI for each item was calculated using the following formula (4.1):

$$\text{CVI} = \frac{\text{Number of experts giving rathing of 2 or 3}}{\text{Total number of panel experts}} \qquad \textit{Equation } 4.1$$

According to Hyrkäs et al. (2003) a CVI above .79 for an item is regarded as acceptable. CVI scores between .7 and .78 need attention and those below .69 as require revision or should be eliminated. The general feedback from the 4-point rating scale by the experts for the questionnaire items was:

- *Relevance - the experts indicated the item measures what it ought to measure, and the terminology used in the item was relevant for Grade R learners.*
- *Clarity - the experts indicated that the items were clear and easy to understand. Modifications were made to items with spelling errors.*
- *Simplicity - the items are short, simple, easy to follow, and to the point.*
- *Ambiguity - Some consisted of spelling errors that rendered the question ambiguous or meaningless. Adjustments were made in line with the recommendations by the panel of experts.*

Data from the CVIs (Figure 4.16) indicated that the panel of experts had concerns with items 5, 7, 13, and 14, as the items received CVIs lower than .69 and needed to be revised or removed.

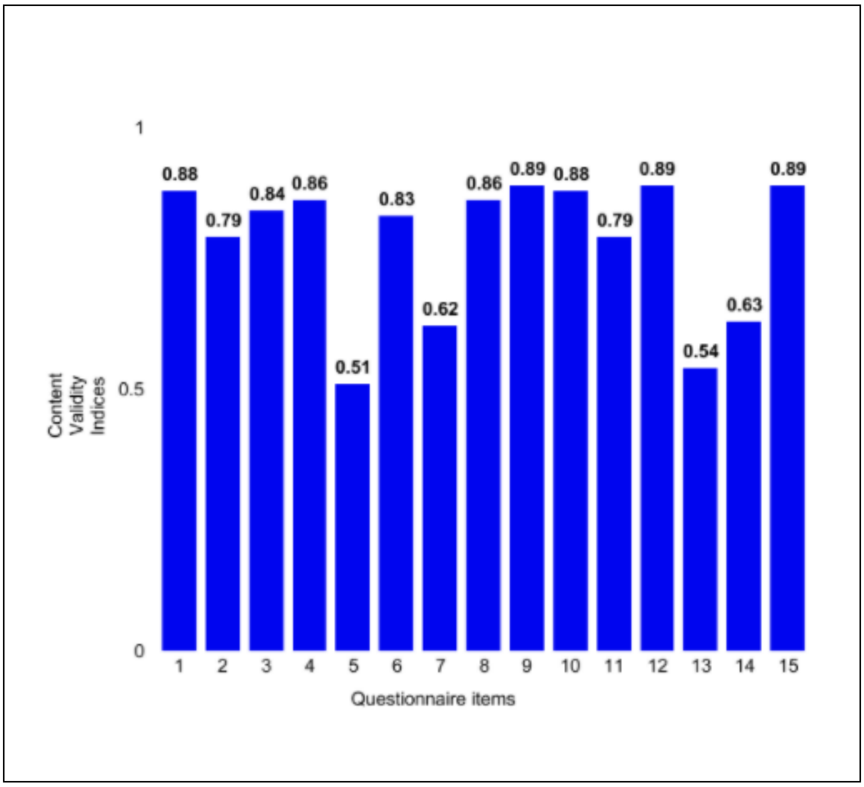


Figure 4. 16 Content validity indices obtained from the panel of experts.

The experts in the field identified items 5 and 7 as ambiguous and recommended that these items be revised. Additionally, they observed that item 13 duplicated item 12 and suggested its removal from the questionnaire. Moreover, concerns were raised by some experts regarding the age-appropriateness of item 14, as they felt that the language and terms used might be too advanced for Grade R learners. Consequently, revisions were made to item 14 to enhance its clarity and ensure better understanding among the target participants. Overall, the panel of experts found the questionnaire to be satisfactory and appropriate for the intended participants.

Taking into account the recommendations provided by the expert panel, adjustments were made to the questionnaire. These adjustments involved shortening the questionnaire and providing clarification for complex items. As a result, the final version of the questionnaire comprised 28 items, including 14 open-ended and 14 closed-ended questions. Whenever a closed-ended item was revised or removed, corresponding adjustments were made to the corresponding item in the open-ended section, ensuring consistency between the two sets of questions.

Determining the reliability of the questionnaire

To ensure the reliability of quantitative questionnaires, it is important to calculate the internal consistency reliability of the instrument. Reliability, as defined by Ali and Yusof (2011), pertains to the extent to which the results obtained through specific procedures and measurements can be replicated by multiple researchers. Assessing the reliability of an instrument helps ensure that the data collected is free from researcher bias and that consistent methods are employed.

An ideal method for calculating internal consistency reliability is using Cronbach's alpha. Cronbach's alpha not only calculates the correlation between items within an instrument but also computes the average intercorrelation among the items. In this research, the reliability of the questionnaire was determined using SPSS. Based on the content validity index (CVI) provided by the panel of experts and the learners' ability to complete the questionnaire (which will be further addressed during administration), I was confident in the validity of the instrument.

Following a similar approach to Bujang (2018), the Cronbach's alpha coefficient was calculated using a sample of 208 Grade R learners from STEM and non-STEM schools. The Cronbach's alpha value for the 14 closed-ended questions was found to be .72. This falls within an acceptable range, as recommended by Maree (2008), which suggests a range between .70 and 1.0 for acceptable reliability. Thus, the instrument demonstrated statistical reliability.

According to McCrae (2011), a rule of thumb is that a Cronbach's alpha below .70 indicates low reliability and warrants careful review of the items. Therefore, in the current research, the instrument was deemed both reliable and valid, making it ready for data collection.

Collecting data from the participants using a questionnaire

According to Kabir (2016), the concept of data collection involves gathering and measuring information based on the variables of research interest to answer the research question/s. While methods of data collection may differ across disciplines, the goal for all forms of data collection methods is to "capture quality evidence that then translates to rich data analysis and allows the building of convincing and credible answer/s to question/s that have been posed" (Kabir, 2016, p. 202).

A quantitative questionnaire with closed-ended items was used to collect data from all Grade R learners. The questionnaire was designed to measure pre-primary school learners' (Grade Rs) level of VL, SL, and SRA (Rittle-Johnson & Zippert, 2018; Kinzie et al., 2015; Brown et al., 2010). According to Kazi and Khalid (2012), "closed-ended items ask the respondents to make choices among a set of answers in a given question. The response could be mutually exclusive or may select more than one option" (p.515). All Grade R learners were assessed using the same questionnaire to benchmark the Grade R learners' VL, SL, and SRA (Figure 4.17).

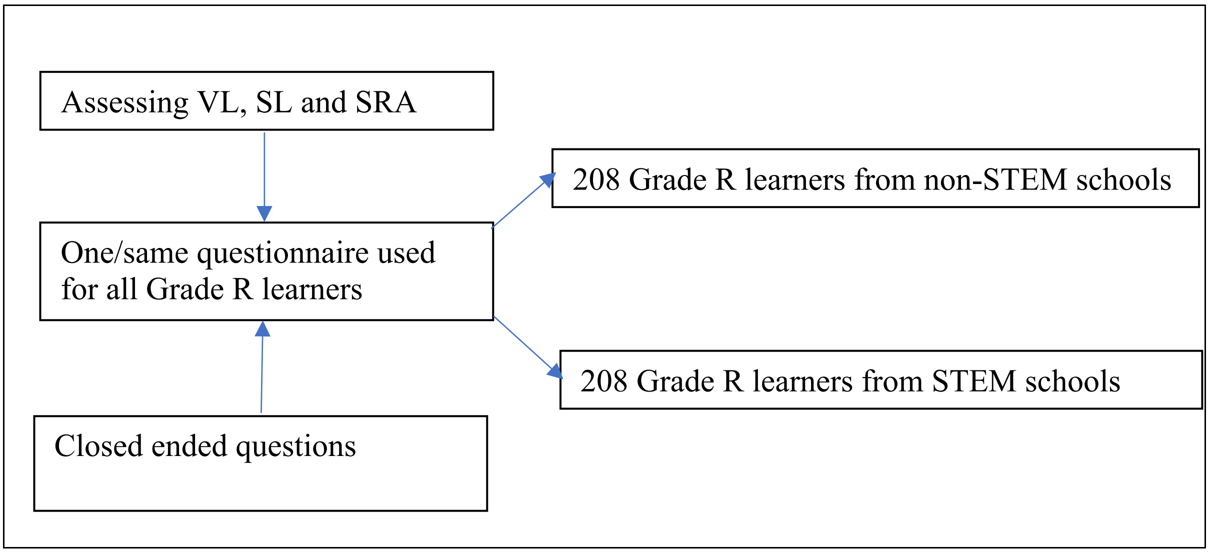


Figure 4. 17 Data collection procedure for the quantitative part of assessing the level of VL, SL, and SRA among pre-primary school learners in response to research sub-question 1.

Administering the questionnaire to the participants

As indicated in the sampling procedures, the target sample had 208 Grade R learners from three STEM and three non-STEM schools in the Free State Province, Bloemfontein region. The questionnaire aimed to assess the level of VL, SL, and SRA among Grade R learners. The following methods were used to distribute, administer and collect the questionnaires:

The questionnaires were prepared and organized according to the six schools involved in the study. To minimize disruption to the learners and educators during school hours, the questionnaires were administered by the class educators during aftercare. This approach allowed for a convenient and uninterrupted data collection process. The administration of the questionnaire took place within a two-week period in March 2022.

Considering that the target participants were very young learners between the ages of five and six, it was important to address any potential discomfort or anxiety they might experience when interacting with a stranger during the research process. To mitigate these concerns, the school's psychologist was present throughout the data collection process to provide emotional support and assistance to the learners as needed.

Furthermore, due to the ongoing COVID-19 pandemic, strict adherence to health protocols was followed during the data collection sessions. This included wearing masks and practicing frequent sanitization to ensure the safety and well-being of all participants involved.

The educators played a crucial role in administering the questionnaire to the learners. They ensured that the learners understood the instructions clearly before they began completing the questionnaire. All the questions were read aloud to the learners to ensure comprehension.

While the learners were encouraged to work independently, assistant educators were available to provide support to those who required assistance. In such cases, the assistant educators conducted semi-interviews with the learners to gather their responses and recorded them accordingly.

All the learners successfully completed the questionnaire, and there was no time limit imposed for its completion. However, it is noteworthy that all the learners were able to conclude answering the questions within a 30-minute timeframe. Once the learners had completed the questionnaires, the educators collected them and handed them over to the researcher for further data analysis.

Analyzing the data collected through the questionnaire

Scoring the questionnaire items

The scoring of learners' responses to the closed-ended items was conducted by myself, using a set of correct answers that I developed (refer to APPENDIX D). To ensure the accuracy of the scoring tool, it was validated by the Grade 4 Natural Science educator who was part of the panel of experts involved in the quantitative assessment of the level of VL, SL, and SRA among pre-primary school learners, specifically in response to research sub-question 1. The panel member confirmed the suitability of the scoring tool and indicated that all answers marked as correct were fair. Additionally, the panel member suggested a scoring approach for items with multiple correct answers, such as item 5 (refer to APPENDIX C), which had four correct and four incorrect choices. The suggestion was to award learners a full mark if they selected at least 50% of the correct options, considering that most items only had one correct answer.

Following Mnguni's (2012) approach, learners' responses to the closed-ended items were scored as either correct, receiving a score of 1 point, or incorrect, receiving a score of 0 points. In cases where no response was provided or when multiple answers were given for items with only one correct answer, a score of zero was assigned. However, in line with the panel member's suggestion, for items with multiple correct options, learners were allocated a score of 1 point if they selected at least 50% of the correct options.

Scales for levels of visual literacy, science literacy, and scientific reasoning ability

Like Reddy et al. (2022), the theoretical framework (Chapter 3) and the questionnaire were used to develop the scales for the level of VL, SL, and SRA. To determine the learners' level of each competency, e.g VL, SL, and SRA, learners' scores were aggregated for each section, and the same score description interpretation (Table 4.4) used by Reddy et al. (2022) was used in the current research.

Table 4. 5

The scale used for measuring the level of visual literacy, science literacy, and scientific reasoning ability among the Grade R learners.

Levels	Total score (%)	Description
L1	0-20	Very low levels
L2	21-40	Low levels
L3	41-60	Average levels
L4	61-80	High levels
L5	81-100	Very high (expert) levels

Analyzing the questionnaire scores

The collected percentage scores were used to compare the performance of Grade R learners from non-STEM schools and Grade R learners from STEM schools. The data analysis was conducted on all six schools participating in the research. All statistical analyses were performed using SPSS, which allowed for the calculation of descriptive and inferential statistics.

Initially, the collected data were analyzed descriptively to measure the frequency distribution, mean, and standard deviation of the Grade R learners from non-STEM schools and Grade R learners from STEM schools. Descriptive statistics aim to provide an understanding of the data by presenting estimates and summaries through graphs and tables, allowing the researcher to gain insights into the data's distribution.

In addition to descriptive analysis, inferential analysis was conducted to examine the learners' performances. An independent (unpaired) t-test analysis was employed to determine significant differences between the observed average scores of Grade R learners from STEM and non-STEM schools per construct. This analysis aimed to confirm that any differences observed were not due to chance. The unpaired t-test is a parametric statistical test used to assess if there is a significant difference between the means or averages of two independent samples from different populations.

Furthermore, the study also utilized paired t-test analysis, which examines the means or averages of two sample groups. However, unlike the unpaired t-test, the paired t-test calculates the difference in scores between two sets of observations from two sample groups selected from the same population.

It is important to note that the unpaired t-test is the parametric equivalent of the nonparametric Mann-Whitney test. Both tests assess whether there is a significant difference between two independently sampled groups based on a single continuous variable. However, the tests differ in terms of the assumed distribution. The Mann-Whitney test is nonparametric and assumes no specific distribution, while the unpaired t-test assumes a particular distribution.

Mnguni (2012) highlights that nonparametric test, such as the Mann-Whitney test, can only compare the medians rather than the means of sampled populations that do not follow a normal distribution. In contrast, the unpaired t-test is not suitable for use with ordinal data, as ordinal data lack a central tendency and do not assume a normal distribution. Ordinal data have evenly distributed values, rather than being grouped around a midpoint. Consequently, conducting an unpaired t-test analysis on ordinal data would lack statistical meaning.

Similar to the approach taken by Nkosi and Mnguni (2020), the present study utilized an unpaired t-test to examine significant differences in learners' performance between the experimental and control groups. This statistical test was deemed appropriate due to the study's sample composition, which comprised two distinct and independent groups: Grade R learners from non-STEM schools and Grade R learners from STEM schools. Moreover, the data collected from these groups exhibited a normal distribution, and it was assumed that the data met the requirements for parametric analysis.

In summary, the quantitative analysis involved using percentage scores to compare learners' performance, employing descriptive and inferential statistics, including the unpaired t-test. The qualitative analysis focused on collecting data to provide reasons for the learners' responses in the closed-ended items, complementing the quantitative findings.

II. Phase two - providing reasons for the learners' responses in closed-ended items

Determining the sample size of the sample population

The selection of the 12 learners for the qualitative portion of the research was guided by several criteria. Firstly, participants were chosen from the same group of learners who had previously participated in the quantitative analysis, ensuring consistency and a comprehensive understanding of the research question.

Random selection was employed to promote fairness and minimize bias. By randomly selecting 12 learners, the sample represented a diverse range of perspectives and experiences, thereby enhancing the validity and generalizability of the findings. Additionally, the sample included 6 Grade R learners from a STEM School and 6 Grade R learners from a non-STEM School, enabling a balanced representation and facilitating a comparison between the two groups.

The purpose of the semi-structured interviews was to delve deeper into the underlying reasons behind the learners' responses to the closed-ended items. Following the approach outlined by Elden (2013), the interviews provided an opportunity for the learners to express their perspectives, insights, and experiences in their own words. This qualitative data complemented the quantitative data and contributed richness and depth to the overall analysis.

The selection of 12 learners was determined based on recommendations from established scholars in childhood research, including Elden (2013), Clarke and Braun (2013), Fugard and Potts (2015), and Vasileiou (2018). Although there is no consensus on an optimal sample size for qualitative studies, a sample size of 12 was deemed sufficient for this research, considering the aim of achieving data saturation and practical considerations.

Moreover, the recognition that children are capable of offering valuable perspectives and opinions (Dayan & Ziv, 2007; Clark, 2004) supported the inclusion of children between the ages of five and six in the study. Their articulate responses during the interview process demonstrated their ability to provide meaningful insights.

The selection of 12 learners was considered adequate given the nature of the research, recommendations from prior studies, the comprehensive responses obtained during the interviews, and the achievement of data saturation. Data saturation ensures that the researcher has gained a thorough understanding of the phenomenon being investigated. Based on the analysis and interpretation of the collected data, the sample size of 12 learners was deemed sufficient to achieve this objective.

Collecting data from the participants through interviews

Data collection was conducted using an interview protocol that incorporated open-ended items, as recommended by Allen (2017). The purpose of utilizing open-ended items in the interview protocol was to enable a thorough and comprehensive investigation of the research question. Open-ended items provide participants with the opportunity to express their thoughts, experiences, and perspectives in their own words, allowing for a more nuanced understanding of the research topic. Therefore, by employing open-ended items in the interview protocol, the researchers aimed to gather rich and detailed data that would contribute to a comprehensive analysis of the research question.

The use of open-ended items in the interview protocol also aligns with the qualitative research approach. Qualitative research focuses on understanding the complexities of human experiences and seeks to capture rich and detailed data. Open-ended items provide the flexibility and depth required to gather comprehensive qualitative data that can shed light on the research question (O'Cathain, 2004). Furthermore, qualitative research aims to describe and interpret participants' feelings, opinions, and experiences in detail. Therefore, by using open-ended items, researchers can delve into the participants' thoughts and emotions, capturing the nuances and subtleties of their responses (Rahman, 2017). This approach facilitates a more thorough exploration of the research topic and allows for a more nuanced analysis of the data.

Moreover, the use of an interview-based approach enables direct interaction between the researcher and the participants (Teherani et al., 2015). This direct engagement fosters a deeper level of understanding and enables the researcher to probe further, seek clarifications, and explore unanticipated avenues during the interview process. The dynamic nature of the interview allows for a more interactive and in-depth exploration of the research question.

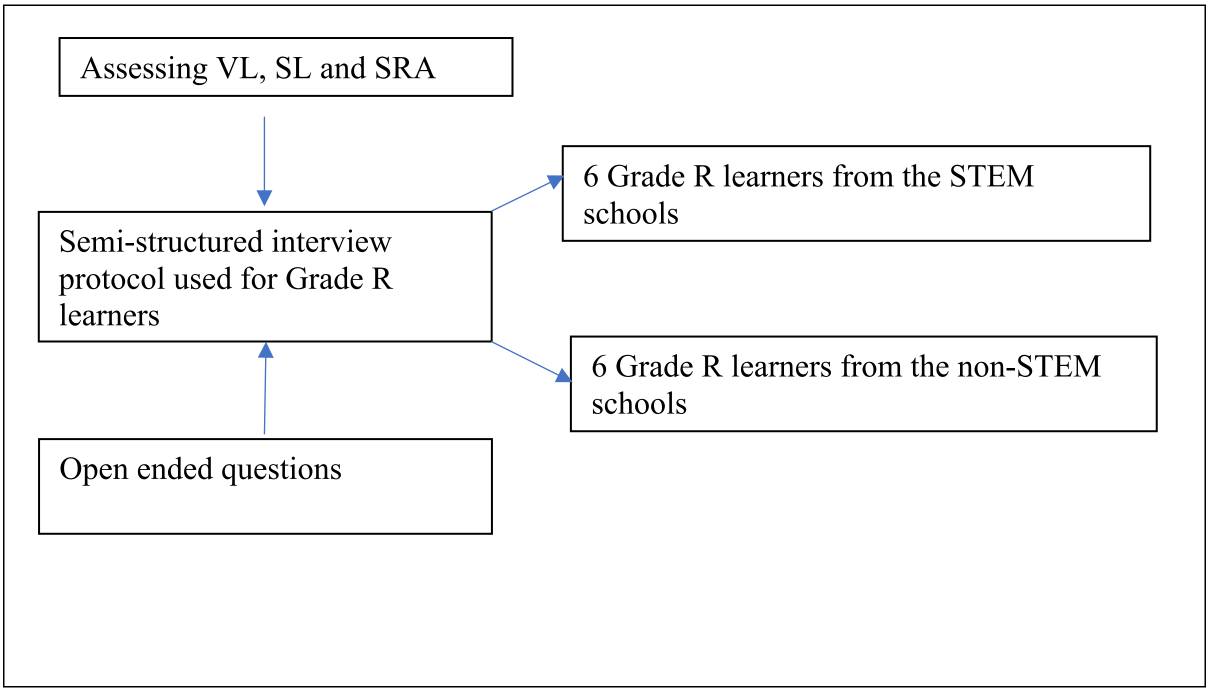


Figure 4. 18 Data collection procedure for the qualitative part of responding to research sub-question 1 by providing reasons for the learners' responses in the closed-ended items in phase one.

Administrating the interview protocol to the participants

The qualitative aspect of responding to research sub-question 1 involved the administration of interview protocol to Grade R learners through semi-structured focus group interviews, during which their responses were meticulously recorded. Focus group interviews were chosen for their advantages over individual interviews, as noted by Wooten and Reed (2000). These interviews facilitate the generation of richer responses by allowing participants to challenge one another's views, creating a dynamic interaction that cannot be captured in individual interviews. Moreover, focus groups help mitigate power imbalances between researchers and participants, particularly when adults interview children (Shaw et al., 2011). It is worth mentioning that children as young as four to five years old have been found capable of participating in focus group interviews (Adler et al., 2019), making them suitable for the current research.

To make the interview discussions more interactive and playful, in line with Cammisa et al. (2011) recommendations, visual aids were used in the form of flash cards. Flashcards were created for the 14 items, with the item number on one side and the corresponding visual on the other side. The use of flashcards in the focus group interviews was justified based on several reasons. Firstly, as suggested by Cammisa et al. (2011), incorporating visual aids, such as flashcards, makes the interview discussions more interactive and playful. The visual representation of the items on the flashcards adds a visual stimulus that can engage the participants and enhance their understanding of the content being discussed.

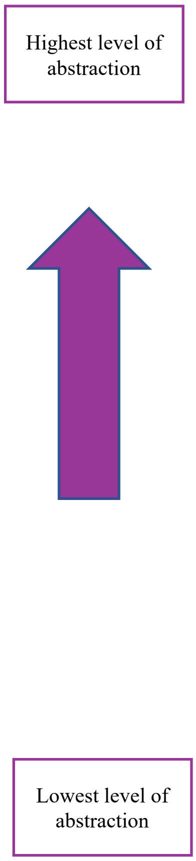
Moreover, the presence of flashcards with the item number on one side and the corresponding visual on the other side provides a structured and organized approach to the interviews. Each learner having their set of flashcards allows them to actively participate in the interview process by searching for the correct item number and associating it with the corresponding visual. This not only encourages engagement but also facilitates better recall and expression of their thoughts. Additionally, setting up the session with small groups of four to six children, as recommended by Heary and Hennessy (2012), creates a conducive environment for effective group interactions. This group dynamic allows the participants to benefit from the collective insights and perspectives shared during the discussions. The presence of an educator in the session, as suggested by Cammisa et al. (2011), further contributes to establishing a comfortable and familiar atmosphere, which can help alleviate any shyness or hesitation among the children.

Furthermore, incorporating a game-like approach into the interviews, where the learners search for the corresponding item number in their pack of flashcards and engage in item-by-item discussions, adds an element of fun and excitement. This approach taps into the natural inclination of children to be more attentive and serious in school-like settings (Kennedy et al., 2001), thereby enhancing their involvement and focus during the interviews. Overall, the use of flashcards in the focus group interviews serves to create an interactive and engaging environment, aids in structuring the discussions, promotes collaboration among the participants, and leverages the children's natural inclination to be attentive in school-like settings. These factors contribute to maximizing the quality of data obtained and ensuring a positive and productive research experience for the participants.

Analyzing the data obtained through the interviews

Qualitative content analysis was employed to analyze the data gathered from the open-ended items. Hsieh and Shannon (2005) define qualitative content analysis as a research method used for subjectively interpreting the content of textual data through a systematic process of coding and identifying themes. In line with Elo et al. (2014), successful content analysis requires the reduction of data into concepts that describe the research phenomenon, thereby creating themes or sub-themes.

The analysis process commenced by initially reading through the learners' responses obtained from the semi-structured interviews. This initial reading aimed to develop a general understanding of the main points expressed by the learners. Subsequently, the text responses were divided into meaningful units, as depicted in Figure 4.19.



Theme	Assessing SRA
Sub-theme	Application of knowledge
Code	More kids pull more rope
Condensed meaning units	"*Kids win, two parents and four kids*"
Meaning units	"*We must get 4 parents, kids going to win because there are two parents and four kids*"

Figure 4. 19 Example of analysis leading to higher levels of abstraction. The figure demonstrates an example of analysis leading to higher levels of abstraction (Ellingson and Brysiewicz, 2017).

The meaning units were further condensed by formulating code frameworks, which were grouped into their respective themes and sub-themes (Table 4.6). Like Erlingsson and Brysiewicz (2017), the themes were created at the highest level of abstraction and were extracted from the constructs measured in the research sub-question 1, which were removed from the literature as indicated in the theoretical framework (Section 3.2.2; 3.3.2; 3.4.1).

Table 4. 6

Theme and sub-themes created for content data analysis

Themes	Sub-themes
Assessing visual literacy	Patterning skills
	Spatial visualization skills
Assessing science literacy	Knowledge Living and non-living
	Knowledge of the Weather
	Understanding of Mass
Assessing Scientific reasoning ability	Knowledge of scientific tools used in scientific inquiry
	Making a conclusion
	Logical reasoning
	Following rules
	Application of knowledge

Note: The themes and sub-themes created for data analysis were extracted from the following literature sources (Rittle-Johnson et al., 2018; Kinzie et al., 2015; Furtak et al., 2008).

After extracting sub-themes from the questionnaire items that corresponded to each construct (as depicted in Table 4.4), coding was employed to categorize the data and facilitate thematic analysis. Thematic analysis enables the researcher to identify patterns in the learners' responses and gain a comprehensive understanding of their perspectives. The learners' answers often consisted of clusters of words, which were then transformed into codes (as shown in Figure 4.18). The analysis and presentation of the data will be presented in Chapter 5.

To ensure the trustworthiness and credibility of the findings, the process of member checking was employed. Member checking involves presenting the analyzed data and interpretations to the participants to verify the accuracy and authenticity of the information. In this study, the member-checking process involved engaging with the learners (as a group) who participated in the research. Following Yin's (2014) guideline, the researcher read out the findings of each question to the learners, seeking their confirmation and validation. In cases where discrepancies arose between the researcher's interpretation and the learners' perspectives, probing questions were utilized to gain deeper insights into their reasoning. The member checking process was crucial in establishing the trustworthiness and credibility of the findings.

Establishing trustworthiness and credibility of the qualitative part of the current research

The integration of qualitative and quantitative methods, as mentioned in Section 4.3.4, serves to enhance the validity, reliability, trustworthiness, and credibility of the research. In order to establish trustworthiness and credibility specifically for the qualitative component of addressing research sub-question 1, member checking was employed. Member checking, also known as participant or respondent validation, is a technique used to verify the interpretation of participants' responses and is often employed to assess the credibility of qualitative results (Birt et al., 2016; Doyle, 2007).

In qualitative research, the researcher's personal beliefs and interests can potentially influence the research process, leading to a dominant voice of the researcher over that of the participants (Mason, 2002). Hence, member checking becomes crucial in the current research. Additionally, considering the adoption of the post-positivism paradigm, which is known for its subjectivity, member checking was utilized to mitigate potential biases by actively involving the participants in the research process (Creswell & Miller, 2000).

After conducting the semi-structured interviews and recording the participants' responses, the member-checking process was initiated with each group of learners. Following Yin's guideline (2014), the researcher presented the findings of each question to the learners and sought their confirmation regarding the accuracy of the interpretation. In cases where the learners provided different responses, probing questions were employed to gain a deeper understanding of their reasoning behind the new replies. This process allowed for an iterative validation of the qualitative data (Candela, 2019). Subsequently, the qualitative data was prepared for further analysis.

To address the research question concerning the relationship between VL, SL, and SRA, the correlation between the levels of VL, SL, and SRA among Grade R learners was examined.

B. Determining the relationship between visual literacy, science literacy, and scientific reasoning ability

I. Analyzing the data obtained through the questionnaires

To respond to research sub-question 2 (Section 1.9), the same data obtained from the questionnaires (from the quantitative part of responding to research sub-question 1) were analyzed inferentially to determine the correlations between VL, SL, and SRA of Grade R learners from both the STEM and non-STEM schools (Table 4.1). According to Hon (2010), inferential statistics is used to make predictions or comparisons about a population using information gathered from the sample. Therefore, inferential statistics involves generalizing beyond the data, something those descriptive statistics cannot do.

The correlation coefficient *r* is a statistical measure that calculates the strength of the relationship between variables. In the current research, the *r* will be used to tell us about the strength and direction of the relationship between VL and SL; VL and SRA; and SL and SRA. However, according to Illowsky et al. (2013), because the reliability of the linear relationship also depends on how many observed data points are in the sample, I then had to look at both the value of *r* and the sample size *n* together. I used SPSS to calculate Pearson's *r*. Pearson's *r* is a parametric measure used to measure the strength and direction of association between two variables.

For the Pearson correlation, an absolute value of 1 indicates a perfect linear relationship. A correlation close to 0 indicates no linear relationship between the variables. The generated *r* value can range from -1 to + 1. The larger the absolute value of *r*, the stronger the real relationship between the variables. If $r = 0$, there is no correlation between the variables. An *r* value of 1, indicates a perfect linear relationship, meaning there is a 100% correlation such that the two variables are directly proportional. Furthermore, "an *r*-value of -1 is as strong as that which is 1. The difference is an inverse relation" (Mnguni, 2012, p.130). Lastly, an r value close to 0 indicates no linear relationship between the variables.

Therefore, suppose the results indicate sufficient evidence, meaning there is a significant linear relationship between VL and SL, VL and SRA, and SL and SRA because the r would be significantly different from zero. This will mean that a regression line can be used to model the linear relationship between the two independent samples. The results will be presented in chapter 5.

Table 4. 7

An outline of the research methodology used to respond to the research sub-question 2

Research sub-question	Research sub-question 2
Methodological approach	Quantitative
Data source	Participants sampled from the quantitative part of responding to research sub-question 2: 208 Grade R learners (87 Grade R learners from the STEM schools and 121 Grade R learners from the non-STEM schools)
Data collection method	Data obtained from the quantitative part of responding to research sub-question 2
Data analysis approach	The questionnaire was analyzed during the quantitative part of responding to research sub-question 2
Analysis procedure	Inferential statistics - to determine correlations or regression

4.6 Summary

This section summaries the types of methods and instruments used in the current research to collect data from the sampled participants and highlights the methods used to analyze the collected data to answer the research questions (Figure 4.20):

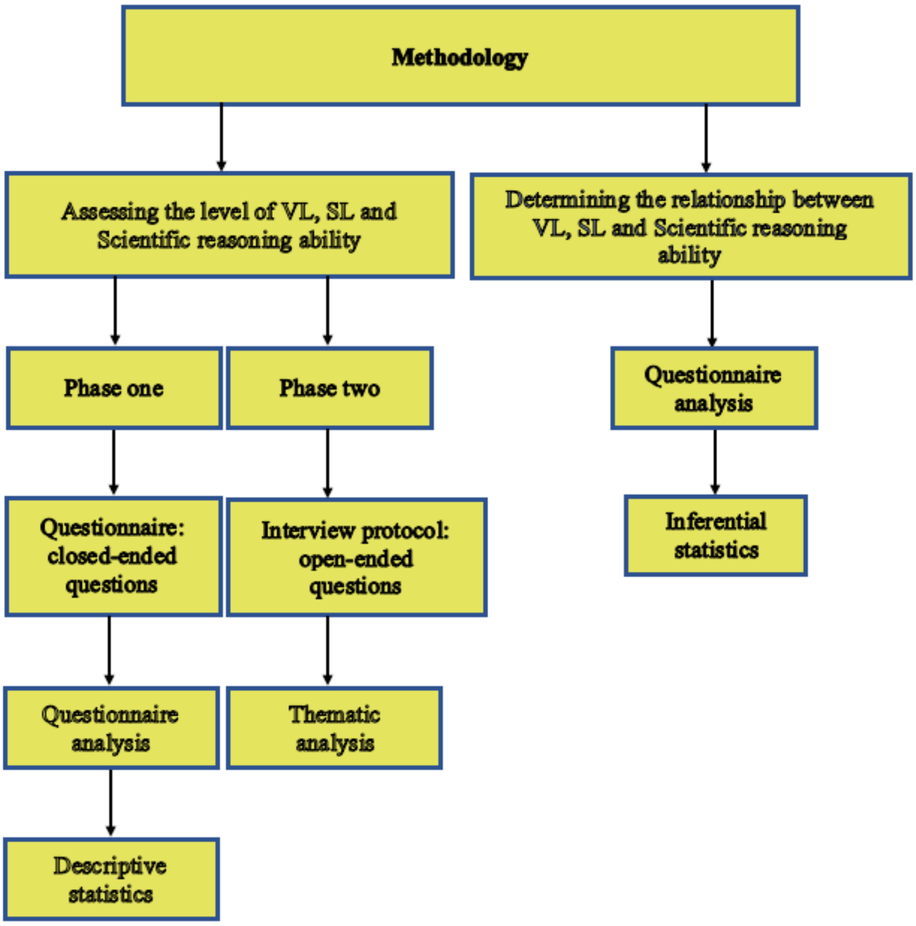


Figure 4.20. A summary of the research design followed in the current research

CHAPTER 5: CORROBORATING EVIDENCE ON THE IMPORTANCE OF STEM EDUCATION IN PRE-PRIMARY SCHOOL

“Creativity is the secret to science, technology, engineering, and mathematics.”

Ainisaa Ramirez

5.1. The outcome of the proposed hypothesis in the current research

Chapter 5 presents results in response to the hypothesis (stated in Section 1.10), that Grade R learners from STEM schools will be more likely to be competent in VL, SL, and SRA as compared to learners from non-STEM schools. In particular, the current study focused on the following skills:

- *Understanding of scientific concepts, processes, laws, theories, or phenomena (science literacy) to learn science in pre-primary school.*
- *Skills to evaluate, apply, or create conceptual visual representations (visual literacy) to learn science in pre-primary school.*
- *Conceptual understanding of science and inquiry skills (scientific reasoning ability) to learn science in pre-primary school.*

The hypothesis tested in the current research was derived from literature which suggested that learners’ exposure to science education in earlier years would have higher levels of VL, SL and SRA compared to those who have not been exposed (e.g., Kusumastuti et al., 2019; Ribeiro et al., 2021). This hypothesis was based on literature such as that of Kusumastuti et al. (2019); Ribeiro et al. (2021) who found that the integration of STEM education in pre-primary schools improves the learners’ level of SL and SRA. Furthermore, as I have already argued in Chapter one, VL and SRA form the subsets of SL. In this chapter, I present results that show that learners’ level of SL is largely dependent on the level of VL and SRA. The results corroborate with Colleta et al. (2008) who found that the development of SRA largely affects the learners' understanding of science. Furthermore, to support the above conjecture, Mnguni et al. (2016) argue that low levels of VL among learners may result in difficulty in understanding science as a result translating into low levels of SL.

The current research was further justified on the assumption that the use of VL could be an effective teaching strategy for introducing science education in pre-primary school. This assumption is supported by Flaum (2018) who argues that VL skills can be fostered through STEM education. Furthermore, to support my hypothesis on the importance of VL in early childhood science education, Milovanska-Farrington (2021) investigated the benefits of incorporating VL in science education and found that learners can easily find their working memory overloaded if they are not prepared for the demands of VL in science education, and so recommends that VL be introduced in science the earlier the better. Therefore, in the current chapter, my principal argument is that it is important to engage children in STEM education from an early age, through the use of VL to develop their SL and SRA (Dilek et al., 2020; Yaki et al., 2019).

While the literature has argued that science education could enhance learners' SL, VL, and SRA, it was important to explore this phenomenon in the South African context. In this regard, in the current research, I sought to respond to two research questions, i.e.:

- *What is the level of visual literacy, science literacy, and scientific reasoning ability among pre-primary school (Grade R) learners to effectively learn science through visual aid and establish their readiness to learn science?*
- *What is the relationship between visual literacy and science literacy for educators and curriculum designers to make the necessary changes to the curriculum to cater to 21st-century learners?*

In the next section, I will first present the reliability of the questionnaire which was used to collect data in chapter 4. This will give me confidence that the results I present in the current chapter are sound, replicable, and accurate.

5.2 Determining the reliability of the data collection instruments

As discussed in Chapter 4, I calculated the reliability of the questionnaire used in the research using Statistical Package for the Social Sciences. The results indicated a Cronbach alpha coefficient of .72, for the questionnaire, which is an acceptable level for statistical analyses (Reddy et al. 2022), thus suggesting that the instrument was statistically reliable. This is in line with Taber (2018) who stipulates that a Cronbach alpha coefficient of .7 or higher indicates an acceptable for internal consistency, even though a coefficient between .81 and .90 would be considered very good, while .91 and higher would be regarded as excellent. While the reliability in the current research is 72%, Tavakol (2011) argues that a high Cronbach alpha coefficient does not always mean high internal consistency. This is mainly because the Cronbach alpha coefficient is also sensitive to the number of items in a questionnaire, and thus a questionnaire with a large number of items would most probably result in a large Cronbach alpha coefficient. However, that does not mean that a lot of the items have a relationship with each other. On the contrary, the items might be so highly related to each other that they would most probably be considered redundant as they prevent the richness and complexity of the construct.

Therefore, in light of the observed Cronbach alpha coefficient, the instrument was deemed reliable in the current research. Below (Section 5.3) I present the results obtained from the completed questionnaires by using frequency tables. Thereafter, I will present the results from the correlation analysis of the questionnaires and the semi-structured interviews in Sections 5.4 and 5.5, respectively.

5.3 The outcome of the questionnaire analysis

This section focuses on the analysis of the questionnaires which were completed by the Grade R learners from both the STEM and non-STEM schools who participated in the current research, using frequency tables. The sample size of the Grade R learners who completed the questionnaire was 208 (n=208) and the questionnaire consisted of 14 items.

5.3.1 Demographic profile of the Grade R learners

In line with the current research's theoretical framework (Chapter 3) and the rationale (Section 1.9), it was necessary to profile the ages of participants (in Section A of the questionnaire) to support my argument, which is underpinned by the Post-Piagetian Theory of Cognitive Development, that children between the age of four and six years have the sufficient cognitive ability and motivation to learn and understand the science in Grade R. In accordance with the Department of Basic Education, a Grade R learner must be at least five years old and turning six or older by 30 June in the current year (The Department of Basic Education, 2015). This is in line with the age groups profiled in the current research, as presented in Table 5.1. Table 5.1 shows the age categories of the Grade R learners who participated in the research to range from five to six years, with the age category five years having the highest frequency count of 69%. This confirms that the sampled participants in the current research were representative of appropriate ages for Grade R learners to answer the research questions.

Table 5. 1

Biographical information of the grade R learners in all schools

Variables		**Frequency**	**Percentage (%)**
Age	5 years	144	69
	6 years	64	31
	Total	**208**	**100**
Self-reported gender	Male	107	51
	Female	101	49
	Other	0	0
	Total	**208**	**100**
Home language	Sesotho	98	47
	IsiXhosa	44	21
	IsiZulu	27	13
	Setswana	27	13
	Xitsonga	4	2
	Afrikaans	4	2
	Tshivenda	4	2
	Total	**208**	**100**

As discussed in Chapter four, the data for this study were collected from two independent sample groups of Grade R pre-primary school learners. The gender distribution of the learners was presented to provide an understanding of the sampled population's gender composition, which can be valuable for making predictions about the larger population and gaining insights into the underrepresentation of female learners in STEM education and careers (Makarova, 2019). Table 5.1 illustrates the gender distribution of the learners, indicating a relatively balanced distribution with 51% male learners and 49% female learners. None of the learners identified themselves as belonging to another gender category.

In addition, as mentioned in Chapter four, the data were collected from a purposively selected group of Grade R learners from six non-government English Medium Language pre-primary schools in the Motheo district, Bloemfontein, South Africa. The learners' home languages were also examined and presented in Table 5.1. The results demonstrate an uneven distribution, with Sesotho being the most prominent home language, representing 47% of the learners. isiXhosa followed with a percentage of 21%, while isiZulu and Setswana each accounted for 13%. Xitsonga, Afrikaans, and Tshivenda were represented at 2%, indicating the least common home languages among the learners. It is important to note that other official South African languages such as Sepedi, isiSwati, isiNdebele, and English were not represented among the learners.

Notably, it is worth mentioning that none of the learners in this research had English as their mother tongue, indicating that all participants were English second language learners. This composition of English second language learners aligns with the ideal sample population for the current research. This information is important to acknowledge because it indicates that the learners may have different language backgrounds and varying levels of proficiency in English. In the context of the current research, which focuses on assessing the level of VL, SL, and SRA among pre-primary school learners, the learners' home language becomes relevant in terms of potential language barriers or variations in language comprehension.

With these demographic characteristics established, the focus will now shift to exploring the levels of VL, SL, and SRA among Grade R learners from both STEM and non-STEM schools.

5.3.2 Level of visual literacy, science literacy, and scientific reasoning ability of Grade R learners

As discussed in Chapters 1 and 2, the rationale of the current research lies in the assumption that exposing children to science in early childhood directly translates into their level of SL. Furthermore, as indicated in the conceptual framework guiding the current research (Section 1.6), VL and SRA form subsets of SL. This means that for a learner to have adequate levels of SL, they require some level of VL and SRA. Therefore, by comparing the level of VL, SL, and SRA among Grade R learners from both STEM and non-STEM schools, the results will help determine whether the Grade R learners from STEM schools possess higher levels of SL, VL, and SRA due to their curriculum set to expose them to science related activities.

Looking at the items of the quantitative part of responding to research sub-question 1 (Section 1.8), which aimed to assess the level of VL, SL, and SRA among pre-primary school learners, the results indicate that the Grade R learners from the STEM schools performed generally better than the Grade R learners from the non-STEM schools for all the items. It is important at this stage to indicate that the mean scores of Grade R learners from both STEM and non-STEM schools will be presented separately in order to establish whether STEM or not STEM education has an impact on each construct.

A. Evidence of learners' level of visual literacy skills

In Chapter 4, I discussed that Section B of the questionnaire included closed-ended items designed as a psychometric test to evaluate the learners' level of VL. The VL assessment encompassed various skills, including patterning skills, spatial visualization skills, visual-spatial working memory skills, and visual perception skills.

The item assessing patterning skills aimed to measure the learners' capability to identify repeating visual patterns or units. Spatial visualization skills were evaluated to determine the learners' ability to mentally imagine and manipulate 2D and 3D spatial information. Assessing visual-spatial working memory involved examining the learners' capacity to retain and recall the locations of different objects and landmarks in their working memory, thus assessing their ability to remember visual stimuli. Lastly, the item related to visual perception evaluated the learners' capacity to comprehend and make sense of the structures and patterns presented in their surroundings.

Table 5.2 presents the scores obtained by the learners in the psychometric test assessing their level of visual literacy.

Table 5. 2

The summary of the psychometric test scores obtained by Grade R learners on visual literacy

Construct assessed	Skills assessed	Group	*N*	*M*	*SD*	*SEM*
Visual literacy	Patterns	Grade R learners in non-STEM schools	121	70	35.31	3.21
		Grade R learners in STEM schools	87	81	28.91	3.10
	Spatial visualization	Grade R learners in non-STEM schools	121	31	52.58	4.78
		Grade R learners in STEM schools	87	39	43.93	4.71
	Visual-spatial working memory	Grade R learners in non-STEM schools	121	35	50.93	4.63
		Grade R learners in STEM schools	87	49	41.88	4.49
	Visual perception	Grade R learners in non-STEM schools	121	67	53.24	4.84
		Grade R learners in STEM schools	87	73	44.58	4.78

Looking at the items assessing VL, the results showed that the Grade R learners from the STEM schools performed better than the Grade R learners from the non-STEM schools. For the item assessing the learners' patterning skills, the performance of the Grade R learners from the STEM schools was *M*=81, *SD*=28.91, while the Grade R learners from the non-STEM schools lagged behind with a score performance of *M*=70, *SD*=35.31. In contrast, to the above performance, the performance scores for spatial visualization were almost half the scores that the learners obtained for the item assessing patterning skills. The Grade R learners from the STEM schools had a score of *M*=39, *SD*=43.93, while the Grade R learners from the non-

STEM schools were behind with a score performance of *M*=31, *SD*=52.58. Furthermore, similar results as the item assessing spatial visualization were seen for the item assessing visual-spatial working memory, with the Grade R learners from the STEM schools obtaining a score of *M*=49, *SD*=41.88, while the Grade R learners from the non-STEM schools seemed to lag with a score performance of *M*=35, *SD*=50.93. Lastly, for the item assessing visual perception the Grade R learners from the STEM schools obtained a score of *M*=73, *SD*=44.58 while the Grade R learners from the non-STEM schools lagged behind with a score performance of *M*=67, *SD*=53.24.

Based on the results presented in Table 5.2, it can be inferred that science education has a positive impact on the development of VL skills among learners. The Grade R learners from STEM schools performed better than those from non-STEM schools in all the items assessing VL. This inference will be further supported by the correlation analysis results, which will be presented in Section 5.8.

It is worth noting that this finding contradicts the literature review discussed in Chapter 2, which primarily focuses on the impact of VL on science education rather than the other way around. This highlights a gap in the literature regarding the potential use of the science curriculum to enhance learners' VL skills, similar to how language educators scaffold the language curriculum to develop VL skills in language education (Baz, 2020).

Another inference that can be drawn from the Grade R learners in STEM schools outperforming those in non-STEM schools is that STEM schools may allow learners to engage in their preferred learning style. According to Shaaidi (2012), the most preferred learning style among learners is visual, and personalized learning in STEM schools, tailored to each learner's needs, interests, and abilities, enables them to learn in their preferred style. Additionally, the visual learning style has been found to significantly enhance VL skills (Aisami, 2015).

Furthermore, it can be inferred that the observed differences in VL performance between Grade R learners in STEM and non-STEM schools may be attributed to the extensive use of technology in STEM schools. The utilization of technology, such as watching science experiment videos, can promote VL skills, particularly in schools with limited science resources and facilities for conducting experiments.

In Chapter 4, a t-test was employed to determine the significance of the differences between the mean scores of Grade R learners from STEM and non-STEM schools for each construct. Considering the average scores presented in Table 5.2 for VL items (SL and SRA items will be presented in Tables 5.4 and 5.6, respectively), it is acknowledged that various factors could have influenced the learners' performance in these items. While it is not feasible to control all factors, Rusticus and Lovato (2014) point out that unequal sample sizes can lead to unequal variances between sample groups, which can significantly impact statistical power and Type I error rates.

To mitigate Type I errors, the significance values (p-values) of the two data sets were calculated at a 99% confidence level. Although p-values can be calculated at any confidence level, increasing the confidence level to 99% results in a wider confidence interval, thus reducing the Type I error to 0.1% (0.001). This provides a stronger level of significance compared to .1, .05, or .01. The results of the t-test analysis for each construct are presented separately in Table 5.3 (VL), Table 5.5 (SL), and Table 5.7 (SRA).

Table 5. 3

A comparison between the Grade R learners from STEM and non-STEM schools' level of visual literacy

		t-test for equality of means						
Construct assessed	**Items assessed**	***T***	***Df***	***P***	***MD***	**Std. Error Difference**	**99% Confidence Interval of the Difference**	
							Lower	Upper
Visual literacy	Patterns	2.465	105	*p*<.001	11	4.4622	-.98	22.98
	Spatial visualisation	1.192	105	*p*<.001	8	6.7105	-9.96	25.96
	Visual-spatial working memory	2.171	105	*p*<.001	14	6.4496	-.3.31	31.31
	Visual perception	.882	105	*p*<.001	6	6.8021	-12.2	24.2

I. A reflection on the positive impact of STEM education on patterning skills

Results reported in Table 5.3 indicate the statistical differences between the level of VL among the Grade R learners from the STEM and non-STEM schools. A *p*-value of less than 1% (*p* <.001), indicated that the difference between the core values of the Grade R learners from the STEM and the non-STEM schools was statistically significant, whereas a p-value higher than .1% (*p* >.001), indicated that difference between the core values of the Grade R learners from the STEM and the non-STEM school to be statistically insignificant. Furthermore, a p-value of .1% (*p*<.001) in the case that Grade R learners from the STEM schools performed better than the Grade R learners from the non-STEM school, indicates that I reject the null hypothesis (H_0). This is because the hypothesis underpinning the current research has been proven to be true, that Grade R learners from STEM schools will possess higher levels of VL, SL, and SRA compared to Grade R learners from non-STEM schools.

On the contrary, a *p*-value greater than .1% (p>.001) in the case Grade R learners from the non-STEM schools performed better than the Grade R learners from the STEM schools, indicates that I accept the null hypothesis (H_0), as the hypothesis underpinning the current research has been proven to be untrue. This means that Grade R learners from non-STEM schools will possess higher levels of VL, SL, and SRA compared to the Grade R learners from STEM schools.

Furthermore, as discussed in chapter four, I used the same score description interpretation (Table 4.4) used by Reddy et al. (2022) to rate the learners' mean scores of VL, SL, and SRA, whereby a range score of 0-20% indicated very low levels, 21-40% indicating low levels, 41-60% indicating average levels, 61-80% indicating high levels and 81-100% indicating very high (expert) levels.

In light of the hypothesis that I presented in Chapter one, that Grade R learners who have been exposed to science education as part of their curriculum in pre-primary school as those from the STEM schools will possess higher levels of VL, SL, and SRA as compared to those from the non-STEM schools. With regards to the level of VL skills presented in Table 5.2, the results corroborate my argument that STEM education has a positive impact on the development of VL skills as 81% of the Grade R learners from the STEM schools and only 70% from the non-STEM schools were able to correctly identify the missing shape in the pattern (Table 5.3). Furthermore, the t-test analysis showed there was a significant difference between the two groups, as (t (105) = 2.465, p < .001) (Table 5.3).

The analysis of the data presented in Table 5.2 demonstrates that Grade R learners from non-STEM schools displayed proficient levels of patterning skills, while Grade R learners from STEM schools showcased expert levels, achieving an attainment rate of 81%. These findings provide empirical support for the effectiveness of the current Grade R syllabus in fostering the development of learners' patterning skills, regardless of the emphasis on STEM subjects in the educational setting.

The results indicate that learners in non-STEM schools, where STEM education is not the primary focus, still exhibit commendable proficiency in patterning skills. This suggests that the existing curriculum implemented in these schools adequately addresses the learning needs of learners in terms of recognizing and manipulating patterns. It can be inferred that the Grade R syllabus, regardless of its non-STEM orientation, establishes a solid foundation for learners to acquire proficiency in patterning skills.

Moreover, the findings highlight the notable advantage observed among Grade R learners from STEM schools, who demonstrate expert levels of patterning skills. This implies that the additional emphasis on STEM education in these schools may contribute to the learners' enhanced mastery of patterning concepts. The inclusion of STEM subjects and related activities likely provides learners with increased opportunities to engage with various patterns, stimulating their cognitive abilities and fostering a deeper understanding of pattern recognition and manipulation.

Furthermore, considering that science education is not the primary focus in non-STEM schools, it can be further inferred that the exposure of Grade R learners from STEM schools to science education plays a role in their attainment of expert levels of patterning skills. In the context of science education, learners are encouraged to go beyond recognizing predictable repetitions and to identify similarities and differences among objects for the purpose of classification. This additional complexity in their understanding of patterns may contribute to their higher levels of proficiency in patterning skills.

II. A reflection on the deficiency of spatial visualization skills among the learners

Looking at the item assessing spatial visualization, results (Table 5.2) showed a deficiency of spatial visualization skills among the learners. The average number of Grade R learners from the non-STEM schools who correctly answered the item lagged behind the Grade R learners from the STEM schools by a mean difference of 8% (Table 5.3), with both groups showing very low levels of spatial visualization. The t-test analysis showed there was a significant difference between the two groups, as ($t(105) = 1.192$, $p < .001$) (Table 5.3).

The obtained results in Table 5.2 reveal low levels of spatial visualization skills among Grade R learners from both STEM schools (39%) and non-STEM schools (31%). This finding raises concerns as spatial reasoning is recognized as a crucial skill for mathematics learning, enabling learners to mentally visualize and manipulate objects and shapes. Previous studies have demonstrated a positive association between spatial reasoning skills and mathematical proficiency (Gilligan et al., 2019).

Based on the above evidence, it can be inferred that, despite mathematics being a part of the curriculum in both STEM and non-STEM schools, Grade R learners from both school types may not be adequately challenged with activities that require them to mentally manipulate 2D and 3D spatial representations. This deficiency in challenging spatial tasks could include activities involving the interpretation of pictures, graphs, or charts.

To foster the development of spatial visualization skills, it is crucial for educators and curriculum designers to provide learners with appropriate learning opportunities that engage their spatial reasoning abilities. Such activities may involve tasks that require learners to mentally rotate objects, visualize spatial relationships, and interpret visual representations commonly encountered in mathematics.

By incorporating more spatially oriented activities into the curriculum, both STEM and non-STEM schools can enhance learners' spatial visualization skills, thereby facilitating their mathematical learning and overall cognitive development. Addressing this deficit in spatial reasoning skills can contribute to promoting a deeper understanding of mathematical concepts and improved problem-solving abilities among Grade R learners.

III. A reflection on the underdevelopment of the visual-spatial working memory skill

Furthermore, similar to the item assessing spatial visualization the results (Table 5.2) showed a deficiency in the visual-spatial working memory among the Grade R learners from both the STEM and non-STEM schools. Nonetheless, the Grade R learners from the STEM schools performed better than the Grade R learners from the non-STEM schools, as the average number of Grade R learners from the non-STEM schools who were able to remember how many apples, I had shown them in the picture, lagged behind by a mean difference of 6% (Table 5.3). The t-test analysis for these results presented (t (105) = 2.171, $p < .001$) (Table 5.3), indicating that the difference between the average scores was statistically significant.

The visual-spatial working memory skill plays a crucial role in learners' ability to remember patterns and sequences, which is highly relevant for reading proficiency. Research by Pham et al. (2014) has established that deficits in visual-spatial working memory are associated with learning disabilities, particularly in reading and spelling.

Analyzing the results presented in Table 5.2 for the item assessing visual-spatial working memory, it is observed that Grade R learners from STEM schools displayed average levels of this skill (41%), whereas Grade R learners from non-STEM schools demonstrated lower levels with a score of 35%. These findings suggest that there may be a deficit in visual-spatial working memory among Grade R learners, which could contribute to the poor reading fluency observed among South African learners. It is widely acknowledged that South Africa faces a significant reading crisis among its learners (Spaull, 2013).

Drawing inferences from these results, it can be speculated that addressing the deficit in visual-spatial working memory among Grade R learners may have a positive impact on their reading abilities, particularly as they progress to higher grade levels. By focusing on the development of visual-spatial working memory skills, especially during the crucial Grade R phase, there is an increased likelihood of improving learners' reading proficiency and potentially mitigating the reading crisis prevalent in South Africa.

Targeted interventions aimed at enhancing visual-spatial working memory skills could contribute to improving reading fluency, comprehension, and overall literacy outcomes among South African learners. By recognizing and addressing the link between visual-spatial working memory and reading ability, educators and policymakers can implement strategies that support the development of this important cognitive skill, ultimately benefiting learners' academic achievements and future educational success.

IV. A reflection on the development of the visual perception skill

Lastly, the Grade R learners from both the STEM and non-STEM schools performed generally better for the item assessing visual perception than for the item assessing visual-spatial working memory as 73% of the Grade R learners from the STEM schools correctly identified the number of Christmas trees that look the same and 67% of the Grade R learners from the non-STEM schools also correctly responded to the item (Table 5.3). The mean difference of 6%, between the Grade R learners from the STEM and the non-STEM schools, was supported by the t-test analysis indicating that the difference in the means was statistically significant ($t\,(105) = .882$, $p < .001$) (Table 5.3).

Based on the results presented in Table 5.2, it is evident that both Grade R learners from STEM schools (73%) and non-STEM schools (67%) displayed high levels of visual perception skills. These findings suggest that both types of schools invest in activities that promote the development of learners' sensory and motor skills, such as painting, water play, and playing with play dough. Wuang (2020) emphasizes the importance of sensory integration, visual perceptual skills, and motor functioning as foundational elements for a child's overall development and adaptive social interactions.

The observed high levels of visual perception skills among Grade R learners indicate that educators in both STEM and non-STEM schools prioritize the development of sensory, motor, and visual perceptual abilities. This is significant because the dysfunction of these developmental abilities can potentially lead to developmental disabilities, including conditions such as autism spectrum disorder (Wuang, 2020).

The implications of these findings underscore the importance of educators paying close attention to fostering the development of learners' sensory, motor, and visual perception skills. By prioritizing these aspects of early childhood education, educators can contribute to the overall well-being and optimal development of learners. Additionally, it highlights the need for early identification and intervention in cases where there may be potential developmental challenges, ensuring that appropriate support is provided to learners who may require it.

By understanding the significance of sensory, motor, and visual perceptual development in early childhood education, educators can create a nurturing environment that supports learners' overall growth and facilitates their successful social interactions. This knowledge can inform educational practices and interventions aimed at promoting the well-rounded development of young learners.

B. Evidence of the Grade R learners' level of science literacy

As mentioned in Chapter 4, Section C of the questionnaire was a content knowledge test and was aimed at assessing the learners' level of SL. To assess the Life Science Literacy component of SL, the item was designed to assess the learner's ability to differentiate between living and non-living. To assess the Earth Science Literacy domain, the developed item was designed to assess the learner's conceptual knowledge of concepts of weather. Furthermore, for assessing the Physical Science Literacy content, the item was designed to assess learners' understanding of concepts such as the mass of objects and balancing of objects, and temperature. Table 5.4 presents the scores obtained by the learners in the content knowledge test assessing the learners' level of SL.

Table 5. 4

The summary of the content knowledge test scores obtained by Grade R learners on visual literacy

Construct assessed	**Item assessed**	**Group**	***N***	***M***	***SD***	***SEM***
Science literacy	Living and non-living things	Grade R learners in non-STEM schools	121	81	10.01	.91
		Grade R learners in STEM schools	87	89	7.74	.83
	Weather	Grade R learners in non-STEM schools	121	87	10.67	.97
		Grade R learners in STEM schools	87	91	8.86	.95
	Mass	Grade R learners in non-STEM schools	121	85	10.01	.91
		Grade R learners in STEM schools	87	93	7.74	.83
	Temperature	Grade R learners in non-STEM schools	121	83	8.48	.68
		Grade R learners in STEM schools	87	90	5.69	.61

I. A reflection on the Grade R learners' readiness to learn science

Looking at the items assessing SL, the results (Table 5.4) showed that the Grade R learners from the STEM schools performed significantly better than the Grade R learners from the non-STEM schools. The Grade R learners from the STEM schools obtained a score of M=89, SD=7.74 in the item assessing the learners' ability to differentiate between living and non-living things, while the Grade R learners from the non-STEM schools lagged behind with a score of M=81, SD= 10.67. Furthermore, for items assessing the learners' conceptual knowledge of the weather, the Grade R learners from the STEM schools further performed better with a score of M=91, SD=8.86, than the Grade R learners from the non-STEM schools who had a score of M=87, SD= 10.01. When comparing the results for the item assessing the learners' understanding of the mass of objects, the Grade R learners from the STEM schools performed better with a score of M=93, SD=7.74, while the Grade R learners from the non-STEM schools lagged behind with a score of M=85, SD= 10.01. Lastly, for the item assessing the learners' understanding of temperature, the Grade R learners from the STEM schools performed better with a score of M=90, SD=5.69, while the Grade R learners from the non-STEM schools lagged behind with a score of M=83, SD= 8.48.

The analysis of the data presented in Table 5.4 reveals that Grade R learners from both STEM and non-STEM schools attained significantly high scores for the items assessing SL skills. These scores demonstrate a commendable level of science content knowledge among Grade R learners in both types of schools. Specifically, the significantly high scores achieved by Grade R learners from non-STEM schools highlight their substantial understanding and proficiency in SL, comparable to that of their counterparts in STEM schools. This suggests that the non-STEM educational setting is effective in fostering SL skills among Grade R learners, despite its emphasis on non-STEM subjects. However, it is important to note that despite the high scores, there are notable differences between the two groups.

The findings suggest that Grade R learners from STEM schools outperformed their counterparts from non-STEM schools in terms of SL skills. This highlights the positive impact of the STEM approach in the curriculum of STEM schools, which emphasizes science learning. The integration of STEM subjects in these schools likely provides learners with more exposure to exciting science content, leading to a deeper understanding and higher levels of SL skills.

On the other hand, the results also suggest that the science content covered in the current curriculum for Grade R learners, both in STEM and non-STEM schools, may not be sufficient to develop SL skills to an expert level. As a result, there is a need for the Department of Basic Education to reconsider the science content included in the current curriculum. By incorporating more exciting and comprehensive science topics, Grade R learners from non-STEM schools can have increased opportunities to develop their SL skills to a higher level. This adjustment would help to bridge the gap between the SL skills of Grade R learners from STEM and non-STEM schools.

The results of the t-test analysis for items assessing SL skills (Table 5.5) provide statistical evidence of the observed differences in performance between the two groups. These findings reinforce the significance of integrating STEM education and expanding the science content in the curriculum to enhance SL skills among Grade R learners.

Table 5. 5

A comparison between the Grade R learners from STEM and non-STEM schools' level of science literacy

		t-test for equality of means						
Construct assessed	**Items assessed**	***T***	***Df***	***P***	***MD***	**Std. Error Difference**	**99% Confidence Interval of the Difference**	
							Lower	Upper
Science literacy	Living and non-living things	6.496	105	*p*<.001	8	6.4959	4.66	11.34
	Weather	2.946	105	*p*<.001	4	1.3576	.36	7.64
	Mass	6.495	105	*p*<.001	8	1.2315	4.66	11.34
	Temperature	3.917	105	*p*<.001	7	1.7873	1.67	12.33

II. A reflection on the acquisition of science literacy through transformative learning

Looking at the overall scores of SL, the Grade R learners from the STEM schools scored higher than the Grade R learners from the non-STEM school in all the items assessing SL. For the item that required the learners to differentiate between the living and non-living things, the mean scores of Grade R learners from the non-STEM schools lagged slightly behind the Grade R learners from STEM schools with a mean difference of 8% (Table 5.5). Furthermore, the analysis of the t-test showed that the difference between the means was statistically significant (t (105) = 6.496, p<.001) (Table 5.5).

Moreover, for the items that required the learners to differentiate between the different weather conditions, the Grade R learners from the STEM schools outperformed the Grade R learners from the non-STEM schools by a mean difference of 4% (Table 5.5). The results of the t-test analysis of the learners' performance showed that there was a significant difference in the learners' average scores (t(105= 2.946, p< .001)(Table 5.5) when comparing the Grade R learners from the STEM and non-STEM schools.

With regards to the item assessing the learners' ability to differentiate between objects with different masses, the Grade R learners from the non-STEM schools were outperformed by the Grade R learners from the STEM schools by a mean difference of 8% (Table 5.5). The t-test analysis further showed a significant difference between the two sample groups' scores for the item assessing the learners' ability to differentiate between items/objects with different masses, (t(105= 6.495, p< .001) (Table 5.3).

Lastly, with regards to the items assessing the learners' ability to differentiate between items/objects with different temperatures, Grade R learners from non-STEM schools lagged slightly behind Grade R learners from the STEM schools with a mean difference of 7% (Table 5.5). Furthermore, the t-test analysis showed statistical significance between the scores of the two sample groups on the item assessing learners' ability to differentiate between items/objects with different temperatures (t(105)= 3.917, p< .001)(Table 5.5).

Based on the analysis of the overall performance of Grade R learners from STEM and non-STEM schools (Table 5.4 and 5.5), it can be inferred that the pedagogical approach employed by educators in teaching science significantly influences the learners' level of SL. This inference aligns with the observed differences in performance between the two groups and highlights the importance of pedagogy in science education.

In non-STEM schools, the use of a transmissive model of pedagogy is commonly employed by educators. This approach involves the educator maintaining strict control over the knowledge delivery process, while learners passively absorb the information through recall, repetition, or summarization of facts. The limitations of this pedagogical model may contribute to the comparatively lower performance of Grade R learners from non-STEM schools in terms of SL skills.

In contrast, STEM educators often employ a transformative pedagogical approach to enhance learners' STEM literacy. This approach focuses on creating meaningful and engaging learning experiences for learners. STEM education encourages learners to follow their natural curiosity and interests, providing them with opportunities to explore a wide range of fascinating activities across various topics. By making science fun and engaging, STEM educators aim to provide learners with a more meaningful and impactful learning experience.

The observed higher performance of Grade R learners from STEM schools in SL skills suggests that the transformative pedagogical approach employed by STEM educators may contribute to their enhanced SL. By fostering curiosity, encouraging active participation, and offering hands-on learning experiences, STEM educators create a more conducive environment for learners to develop their SL skills.

C. Evidence of the Grade R learners' level of scientific reasoning ability

Lastly, as previously discussed in chapter 4, for items assessing SRA, I focused on the learners' ability to: (1) recognize the scientific tool used in scientific inquiry, (2) make a conclusion, (3) apply logical reasoning, (4) apply science knowledge, (5) make sense of observations and (6) analyze of data. Table 5.6 presents the scores obtained by the learners in the psychometric test assessing the learners' level of SRA.

Table 5. 6

The summary of the psychometric test scores obtained by Grade R learners on scientific reasoning ability

Construct assessed	**Skills assessed**	**Group**	***N***	***M***	***SD***	***SEM***
Scientific reasoning ability	Scientific tools	Grade R learners in non-STEM schools	121	77	8.8	.80
		Grade R learners in STEM schools	87	78	7.36	.79
	Making a conclusion	Grade R learners in non-STEM schools	121	85	50.38	4.58
		Grade R learners in STEM schools	87	97	41.60	4.46
	Logical reasoning	Grade R learners in non-STEM schools	121	97	40.18	3. 65
		Grade R learners in STEM schools	87	98	42.30	3.45
	Application of knowledge	Grade R learners in non-STEM schools	121	81	28.49	2.59
		Grade R learners in STEM schools	87	88	23.50	2.52
	Understanding of evidence	Grade R learners in non-STEM schools	121	88	37.18	3.38
		Grade R learners in STEM schools	87	96	30.78	3.30
	Analyzing data	Grade R learners in non-STEM schools	121	80	43.78	3.98
		Grade R learners in STEM schools	87	90	36.19	3.88

Lastly, when looking at the items assessing the learners' SRA, the results (Table 5.6) showed that the Grade R learners from the STEM schools performed better than the Grade R learners from the non-STEM schools. The Grade R learners from the STEM schools obtained a score of *M* =78, *SD*=7.36 in the item assessing the learners’ ability to recognize the scientific tool used in scientific inquiry, while the Grade R learners from the non-STEM schools lagged behind with a score of *M*=77, *SD*= 8.8. Furthermore, for items assessing the learners’ ability to conclude, the Grade R learners from the STEM schools performed relatively better with a score of *M*=97, *SD*=41.60, than the Grade R learners from the non-STEM schools who had a score of *M*=85, *SD*= 50.38. When comparing the results for the item assessing the learners’ ability to apply logical reasoning, the Grade R learners from the STEM schools performed better with a score of *M*=98, *SD*=42.30, while the Grade R learners from the non-STEM schools lagged behind with a score of *M*=97, *SD*=42.18.

Furthermore, for the item assessing the learners’ ability to apply scientific knowledge, the Grade R learners from the STEM schools performed better with a score of *M*=88, *SD*=23.50, while the Grade R learners from the non-STEM schools lagged behind with a score of *M*=81, *SD*=28.49. Additionally, when comparing the results (Table 5.6) for the item assessing the learner’s ability to make sense of observations, the Grade R learners from the STEM schools performed better with a score of *M*=96, *SD*=30.78, while the Grade R learners from the non-STEM schools lagged behind with a score of *M*=88, *SD*= 37.18. Lastly, for the item assessing the learners’ ability to analyze data, the Grade R learners from the STEM schools performed better with a score of *M*=90, *SD*=36.19, while the Grade R learners from the non-STEM schools lagged behind with a score of *M*=80, *SD*= 43.78.

I. A reflection on developing scientific reasoning through inquiry

The analysis of the results (Table 5.6) supports the hypothesis that Grade R learners from STEM schools would outperform Grade R learners from non-STEM schools in terms of SRA. STEM education, characterized by hands-on learning experiences and real-world applications, is believed to foster the development of SRAs. SRA encompasses hypothesizing, experimenting, inferencing, evaluating data, and drawing conclusions, which are crucial skills for learners to possess.

Children exhibit a natural inclination towards scientific reasoning from an early age, as they demonstrate curiosity, exploration, and a desire to understand the world around them. This innate curiosity is often expressed through asking questions, which forms the foundation of science learning. The results presented in Table 5.6, indicating high levels of scientific tool recognition and expert levels of skills related to making conclusions, logical reasoning, knowledge application, understanding observed evidence, and data analysis, support the notion that there is no age restriction for the initiation of science learning. Inquiry-based learning in science education is centered around asking *why* questions, and we should tap into children's existing curiosity and embrace their natural inclination for exploration.

Unfortunately, when science education is introduced to children, it often takes place in a formal setting and emphasizes rote memorization of scientific vocabulary and concepts. This approach, along with other factors, has contributed to learners finding science difficult to comprehend. Introducing science education in Grade 4, as commonly done in the Intermediate Phase, is considered relatively late, as learners have already formed attitudes towards science, positive or negative, which can persist. Moreover, science education is often presented as an abstract subject, which further hampers learners' engagement and interest in pursuing science careers.

To address these challenges, we should leverage children's innate curiosity and their drive to understand *how and why things work*. This can be achieved by introducing more playful and interactive science experiments that allow children to discover scientific principles on their own. Such self-discovery activities provide opportunities for developing various skills, including communication, collaboration, teamwork, perseverance, analytical thinking, scientific reasoning, and problem-solving.

The results presented in Tables 5.4 and 5.5 demonstrate that Grade R learners from STEM schools outperformed their counterparts from non-STEM schools in all items assessing SRA. This suggests that STEM schools have moved away from formal classroom-based science learning and embraced a more experiential approach that exposes learners to firsthand experiences of science in the real world. By providing novel and exciting learning experiences, STEM schools extensively develop learners' SRAs and create a positive and engaging environment for science education.

Table 5. 7

A comparison between the Grade R learners from STEM and non-STEM schools' level of scientific reasoning ability

t-test for equality of means								
Construct assessed	**Items assessed**	***T***	***Df***	***P***	***MD***	**Std. Error Difference**	**99% Confidence Interval of the Difference**	
							Lower	Upper
Scientific reasoning ability	Scientific tools	.890	105	p<.001	1	1.1237	-2.01	14.01
	Making a conclusion	1.877	105	p<.001	12	6.3928	-5.15	29.15
	Logical reasoning	.713	105	p<.001	1	1.823	-2.40	12.49
	Application of knowledge	1.937	105	p<.001	7	3.6133	-2.69	16.69
	Understanding of evidence	1.693	105	p<.001	8	4.7238	-4.66	20.66
	Analyzing data	1.799	105	p<.001	10	5.5583	-4.90	24.9

II. A reflection on the importance of STEM for scientific reasoning ability development

When comparing the Grade R learners from the STEM and non-STEM schools' scores for the item assessing the learners' ability to correctly identify the scientific tool that was presented in the questionnaire, the results show that almost equal numbers of Grade R learners from both the STEM (78%) and non-STEM (77%) schools were able to correctly respond to the item (Table 5.6). With the mean difference of 1% (Table 5.7), the results of the t-test analysis show that the difference in means was statically significant (t (105) = .890, p<.001) (Table 5.7) on the item assessing the learners' knowledge of the scientific tool in the questionnaire.

Additionally, for items assessing the learners' ability to make conclusions, the mean scores of Grade R learners from the non-STEM schools (85%) lagged slightly behind the average number of Grade R learners from the STEM schools (97%) (Table 5.6), who correctly answered the item by a mean difference of 12% (Table 5.7). The t-test analysis showed a significant difference between the two sample groups for the item assessing the learners' ability to make conclusions (t (105) = 1.877, p<.001) (Table 5.7).

Furthermore, for the item assessing logical reasoning, the Grade R learners from the STEM and non-STEM almost performed equally, with 98% of Grade R learners from the STEM schools and 77% of the Grade R learners from non-STEM schools correctly to the item (Table 5.5). Additionally, the t-test analysis showed a significant difference between the two sample groups for the item assessing the learners' logical reasoning (t (105) = .713, p<.001) (Table 5.7).

Moreover, for the item assessing the learners' ability to apply their knowledge, the average number of Grade R learners from the non-STEM schools who correctly responded to the item was less than the average number of Grade R learners from the STEM who correctly responded to the item by 7% (table 5.5). However, the t-test analysis indicates that the difference between the average scores of the two sample groups was statistically not significant (t (105) = 1.937, p<.001) (Table 5.7).

Lastly, with the items assessing the learner's ability to: (1) understand the evidence and (2) analyze data, the results presented in 5.7, show that the Grade R learners from the STEM schools performed better than the Grade R learners from the non-STEM schools, as the mean difference was 8 % and 10% for the items assessing learner's ability to understand evidence and learner's ability to analyze data, respectively. Nevertheless, the t-test analysis results showed that there was a significant difference in the learners' average scores when comparing the Grade R learners from the STEM and non-STEM schools scores for the item assessing learners' ability to understand evidence (t (105) = 1.693, p<.001) (Table 5.7) and learners' ability understand to analyze data (t (105) = 1.799, p<.001) (Table 5.7).

Therefore, based on the overall average scores of Grade R learners from both STEM and non-STEM schools, it can be concluded that the learners demonstrate relatively high levels of SRA, as indicated in Tables 5.6 and 5.7. This supports the argument that Grade R learners possess sufficient levels of SRA to actively engage in science-related activities. However, a closer examination of the results reveals that Grade R learners from STEM schools outperformed their counterparts from non-STEM schools in all items assessing SRA.

This leads to the inference that the development of SRA, which encompasses critical thinking and problem-solving skills, is influenced by the type of curriculum to which learners are exposed. Therefore, learners with higher levels of essential 21st-century skills, including critical thinking and problem-solving, are more likely to engage in inquiry-based activities that require the use of SRA. As previously discussed, STEM education plays a crucial role in the development of SRA, enabling learners with high levels of SRA to master complex and abstract scientific concepts.

Furthermore, the results presented in Tables 5.6 and 5.7 highlight the significance of STEM education in the development of SRA. It can be inferred that SRA is a product of STEM education, which not only fosters the acquisition of science content knowledge but also nurtures SRAs. The superior performance of Grade R learners from STEM schools in all items assessing SRA underscores the interdependence between STEM education and the development of SRA.

Lastly, considering that Grade R learners from STEM schools outperformed their counterparts from non-STEM schools in all items assessing SRA, another inference can be made regarding the importance of SRA in 21st-century education. The exceptional performance of Grade R learners from STEM schools, which is attributed to both their exposure to the STEM curriculum and their pre-existing levels of SRA, suggests a mutually dependent relationship between STEM education and SRA. Furthermore, a deficiency in SRAs implies a lack of 21st-century skills such as problem-solving and critical thinking. Consequently, learners lacking

SRA may struggle to effectively engage in STEM-related activities that require skills such as data analysis, problem-solving, experimental planning and execution, drawing conclusions, generalization, and evaluation.

5.4 Correlation analysis of the questionnaires

As presented in the title of the research, the fundamental question for the research was whether the level of VL correlates with the level of SL, whether the level of VL correlates with the level of SRA and whether the level of SL correlates with the level of SRA among Grade R learners. Having determined the average scores of Grade R learners from both the STEM and non-STEM schools who correctly responded correctly to the items (Table 5.2, 5.4, and 5.6), I investigated the correlation between the level of VL, SL, and SRA and the results are presented in Table 5.8.

Table 5. 8

Pearson's correlations between the level of visual literacy, science literacy, and scientific reasoning ability

	Group		Visual literacy	Science literacy	Scientific reasoning ability
non-STEM schools	Visual literacy	Pearson r			
		Sig. (2-tailed)			
	Science literacy	Pearson r	-.934		
		Sig. (2 tailed)	*p*>.01		
	Scientific reasoning ability	Pearson r	-.764	.898**	
		Sig. (2 tailed)	*p*>.001	*p*<.001	
STEM schools	Visual literacy	Pearson r			
		Sig. (2 tailed)			
	Science literacy	Pearson r	-.929		
		Sig. (2 tailed)	*p*>.001		
	Scientific reasoning ability	Pearson r	-.756	.885**	
		Sig. (2 tailed)	*p*>.001	*p*<.001	

Note: **Significant at 99%

In the non-STEM school group, the results of the Pearson correlation indicated there is an insignificant negative relationship between the learners' level of SL and VL ($r(2)= -.934$, $p>.001$) (Table 5.8). Similarly, the results indicated that there was an insignificant negative relationship between the learners' level of SRA and VL, however, the relationship was statistically not significant ($r(2)= -.764$, $p >.001$) (Table 5.8). Lastly, in contrast to the above-indicated results, the correlation analysis indicated that there was a statistically significant positive correlation between the learners' level of SL and SRA ($r(2)= .898$, $p <.001$) (Table 5.8).

Similar to the results indicated in the non-STEM schools' group, in the STEM schools group, the results of the Pearson correlation indicated there is an insignificant negative relationship between the learners' level of SL and VL ($r(2)= -.929$, $p>.001$) (Table 5.8). Furthermore, the results also indicated an insignificant negative relationship between the learners' level of SRA and VL, ($r(2)= -.756$, $p >.001$) (Table 5.8). However, much like in the non-STEM schools' group, the Pearson correlation analysis in the STEM schools group indicated that there was a positive correlation between the learners' level of SL and SRA, which was considered to be statistically significant ($r(2)= .885$, $p <.001$) (Table 5.8). Below (Section 5.5), I present the results obtained from the semi-structured interviews.

5.5 Making sense of the semi-structured interviews data analysis

In accordance with the chosen research design, which is an embedded mixed methods approach as discussed in Chapter 4, I deemed it necessary to employ an explanatory mixed method format to provide a deeper understanding of the quantitative data presented in Section 5.3.3. The purpose of this format was to elucidate the underlying reasons behind the observed levels of VL, SL, and SRA among the learners.

In this section, I present qualitative insights gained from conducting interviews with six Grade R learners from a STEM school and six Grade R learners from a non-STEM school. Through these interviews, I sought to explore and unpack the learners' self-reported rationales for their choices in the closed-ended items that assessed VL, SL, and SRA. As previously mentioned in Chapter 4, the three identified themes (VL, SL, and SRA) were derived from the relevant literature, as outlined in the theoretical framework (Section 3.2.2, 3.3.2, and 3.4.1), and were validated by the data presented in this section.

It is important to note that the identified themes align with the constructs measured in the closed-ended items, which constitute the quantitative component of the analysis related to research sub-question 1. By revisiting these themes in the qualitative analysis, I aim to provide insights into the underlying factors influencing the Grade R learners' choices and responses in the psychometric test assessing VL and SRA, as well as the content knowledge test assessing SL. This qualitative exploration will help provide a comprehensive understanding of the learners' perspectives and shed light on the reasons behind their performance in the quantitative assessments.

A. Assigning participants pseudonyms

As indicated in section 4.5.2, where I discussed obtaining ethical clearance to conduct the research, I indicated that in order to protect the confidentiality of the learners, the data obtained in the current research were collected anonymously without having the participants give personal information such as their names. Therefore, to protect the learners' identities, I assigned pseudonyms to each participant, which are described in Table 5.9.

Table 5. 9

Pseudonyms of Grade R learners from both the STEM and non-STEM schools

Grade R learners from the STEM school	Pseudonym	Grade R learners from the non-STEM school	Pseudonym
STEM learner 1	Rethabile	non-STEM learner 1	Neo
STEM learner 2	Warona	non-STEM learner 2	Amo
STEM learner 3	Baldwin	non-STEM learner 3	Letlotlo
STEM learner 4	Kenneth	non-STEM learner 4	Bothlale
STEM learner 5	Victoria	non-STEM learner 5	Nolusindiso
STEM learner 6	Peter	non-STEM learner 6	Palesa

In this section, I will present the results pertaining to the three identified themes: assessing VL, SL, and SRA. These themes were derived from relevant literature, as outlined in the theoretical framework presented in Sections 3.2.2, 3.3.2, and 3.4.1. The purpose of the interviews conducted was to gain insights into the reasons behind the Grade R learners' specific choices and responses in the psychometric or content knowledge test items used to assess their levels of VL, SL, and SRA.

The interview protocol was designed to explore and elucidate the factors influencing the learners' decision-making processes and their rationale for selecting certain answers in the assessment tests. By analyzing their responses, we aim to gain a deeper understanding of their perspectives and motivations.

The results will be presented in table format, providing a concise summary of the findings. However, it should be noted that only a selection of learners' responses will be shared in the tables, as they represent the overall patterns and trends observed in the data. The remaining responses from other learners were found to align with the presented data and thus support the conclusions drawn from the analysis.

B. Theme 1: Assessing visual literacy

For assessing VL, the open-ended items of the questionnaire were formulated to address different dimensions of VL, which constituted four sub-themes, namely: patterns, spatial visualization, visual-spatial working memory, and visual perception. In this section, the Grade R learners from both the STEM and non-STEM schools were interviewed, with the aim of understanding why the Grade R learners from the STEM schools outperformed the Grade R learners from the non-STEM schools in the psychrometric test items assessing VL as presented in Table 5.2. Furthermore, the results presented in this section will give a clear view of the learners' levels of VL skills.

I. Patterning skills

For the purpose of understanding the learners' levels of patterning skills presented in Table 5.2, whereby the item assessed the learners' ability to identify units of repeating visual patterns by indicating the correct missing shape in the pattern presented in Figure 5.1. I probed the learners to explain to me their reasons for the choice of the missing shape.

Figure 5. 1 Item assessing the learners' patterning skills.

The results presented in Table 5.10 demonstrate the learners varied reasons as to why they think the circle is the correct missing shape. As seen in Table 5.10, learners like Rethabile (STEM school) suggested that the circle is the missing shape "*Because the circle and the triangle were exchanging places".* In the same question, Amo (non-STEM school), explained her reasoning by stating that "*the circle*" is the missing shape by saying "*Because it is a pattern*".

Table 5. 10

The examples of learners' responses to the item assessing patterning skill

Learner	The learners' school	The missing shape	The learners' justification for their responses to the item
Rethabile	STEM	*"The red circle"*	*"Because it is a pattern since the shapes are exchanging between a circle and a triangle"*
Amo	non-STEM	*"The Circle"*	*"Because it is a pattern"*

Upon closer examination of the learners' reasoning for their choices regarding the missing shape in Figure 5.1, it is noteworthy that both Rethabile from the STEM school and Amo from the non-STEM school demonstrated the ability to make logical connections and employ visual reasoning skills in identifying the pattern. This aligns with the theoretical framework discussed in section 3.2.3, which outlines the three stages of visualization: internalization, conceptualization, and externalization of ERs. According to Mnguni et al. (2016), recognizing patterns is a manifestation of visual perception, wherein an ER is internalized through sensory organs. Furthermore, making logical connections can be attributed to the conceptualization stage of visualization, where meaning is derived from observations (Mnguni et al., 2016). As outlined in section 3.2.3 of the theoretical framework, learners need to organize the visualized information in their working memory as new knowledge, integrating it with prior knowledge stored in their long-term memory in order to make meaning. This suggests that learners require prior knowledge to operate at the conceptualization stage of visualization. Learners who have not previously been exposed to identifying and completing patterns may only operate at the internalization stage.

Based on the aforementioned insights, it can be inferred that Grade R learners from both STEM and non-STEM schools operate at the internalization and conceptualization stages of visualization, indicating a high level of patterning skill. Both groups were able to recognize the repeating shapes forming a pattern in Figure 5.1. However, some learners, such as Rethabile from the STEM school, exhibited more advanced distinctions by elucidating the characteristics of a pattern. This represents the externalization stage, wherein learners are capable of producing external visual models, written text, or verbal expressions of their cognitive mental schemes (Mnguni, 2014). Rethabile's response, stating that the pattern involves "*shapes that are exchanging between the circle and the triangle*" demonstrates that Grade R learners from the STEM school possess higher levels of patterning skill compared to their non-STEM counterparts. These STEM learners operate at all three stages of visualization, explaining the constituents of the pattern presented in Figure 5.1 a skill lacking in the Grade R learners from the non-STEM school.

Consequently, the results indicate that Grade R learners from the STEM school exhibit superior patterning skills compared to those from the non-STEM school. This finding aligns with the quantitative results presented in Table 5.2, which demonstrated that STEM learners outperformed their non-STEM counterparts in the corresponding item of the psychometric test, further corroborating the outcomes of this section.

Nonetheless, although colour was not explicitly mentioned in the responses provided by Rethabile from the STEM school "*The red circle*" and Amo from the non-STEM school "*The Circle*", it is crucial to acknowledge the potential influence of colour on the perception and interpretation of visual stimuli, particularly patterns.

Colour holds a substantial role in visual perception and cognition, as it can elicit different emotions, influence attention and focus, and even impact decision-making processes. When it comes to identifying patterns, the presence or absence of colour can affect learners' responses. Colour can serve as a visual cue that helps individuals distinguish and recognize patterns more effectively. For instance, using different colours for the elements within a pattern can enhance their visibility and make the pattern more apparent. Moreover, colour contrast can draw attention to specific elements within a pattern, facilitating pattern recognition. By leveraging colour effectively, educators and designers can potentially enhance learners' ability to identify and comprehend patterns. Taking into consideration the potential influence of colour in pattern recognition tasks can lead to the development of more effective instructional materials and optimize the learning experience for learners.

II. Spatial visualisation skill

In an effort to understand the levels of spatial visualization of the Grade R learners from both the STEM and non-STEM schools presented in Table 5.2. The learners were probed to explain their reason for their answer choice of a number of blocks they perceive in Figure 5.2.

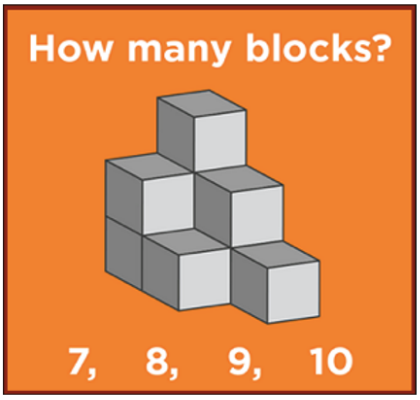


Figure 5. 2 Item assessing the learners' spatial visualization skills.

Table 5.11 presents the learners' explanations of the number of blocks they perceived in Figure 5.2. As it stands in Table 5.11, Bothlale (non-STEM school) explains that in Figure 5.2 there are "*6*" blocks present "*Because he counted them*". Warona's (STEM school) on the other hand indicated that there are "*9*" blocks present in Figure 5.2, "*Because some of the blocks are hiding behind the blocks I see in the picture*".

Table 5. 11

The learners' responses to the item assessing spatial visualization skill

Learner	**The learners' school**	**The number of blocks**	**The learners' justification for their responses to the item**
Warona	STEM	*"9"*	*"Because there are other blocks hiding behind the blocks I see in the picture"*
Bothlale	non-STEM	*"6"*	*"Because I counted them"*

From the quantitative analysis results presented in Table 5.2, it emerged that all Grade R learners from both the STEM and non-STEM schools were able to visually count the blocks. Visual counting refers to the basic visual capacity of counting the number of objects. This type of skill only requires the learners to operate at an internalization stage of visualization as it is a type of visual perception (Mnguni et al., 2016). However, my argument is that for a learner to be able to count the number of objects in the ER presented in Figure 5.2, the learner should have previously memorized how to count objects as prior knowledge. The ability to recall or retrieve memorized information implies that a learner operates at the conceptualization stage of visualization (Mnguni et al., 2016).

On the contrary, Warona's (STEM school) response that there are "*nine*" blocks present in Figure 5.2 because there are other blocks behind the ones, he sees demonstrates that Grade R learners from the STEM school possess some ability to complete the entire ER, even though they are only seeing a part of it, which is regarded as visual closure. Based on the Gestalt principles of closure, visual closure 'signifies our tendency to see complete ERs even when part of the information is missing' (Mnguni, 2007, p. 28). The Grade R learners from the STEM school's ability to complete an entire ER, even though they are only seeing a part of it, implies that they function at the externalization stage of visualization (Mnguni et al., 2016), which is the highest order of cognitive function.

Furthermore, considering that the Grade R learners from the STEM school were able to correctly perceive "*nine*" blocks, even though there were other blocks that were not visible in the ER, this demonstrates that Grade R learners from the STEM school can mentally manipulate the ER in such a way as to see the blocks that are situated behind the ones which are visible to the human eye in the 2-D image. The ability to mentally manipulate ER in order to make sense of the ER implies that Grade R learners from the STEM school operate at a conceptualization stage (Mnguni et al., 2016), which is a skill that Grade R learners from non-STEM schools lack.

Therefore, from the results presented in Table 5.11, it is evident that Grade R learners from STEM schools possess higher levels of spatial visualization skills and operate at a higher cognitive level than the Grade R learners from non-STEM schools. This distinction is evident as the Grade R learners from the STEM schools operated at both the internalization and conceptualization stage, while the Grade R learners from the non-STEM schools only operated at an internalization stage. Therefore, the results show that Grade R learners from the STEM schools possessed better visual-spatial skills than the Grade R learners from the non-STEM schools. Furthermore, the results corroborate the results presented in Table 5.2 of the corresponding item in the psychometric test.

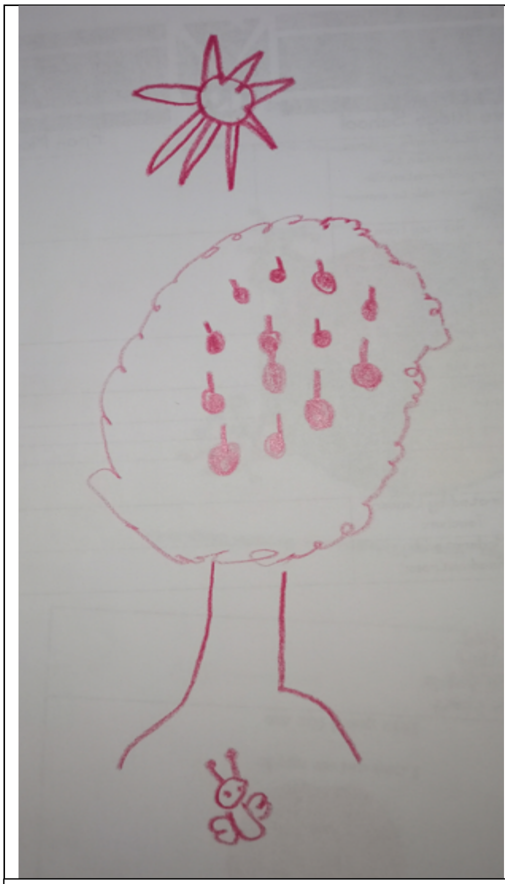
On the other hand, it is plausible that the learner from the STEM school may have been previously exposed to the same item and is responding based on prior knowledge. It is important to consider that prior knowledge and experiences can influence a learner's understanding and responses. Previous exposure to relevant concepts or materials related to the item in question can contribute to a learner's ability to provide accurate responses or demonstrate a deeper understanding. Therefore, it is worth acknowledging that the Grade R learner from the STEM school may have benefited from prior exposure to the topic, which could have influenced their response in the given context.

III. Visual-spatial working memory skill

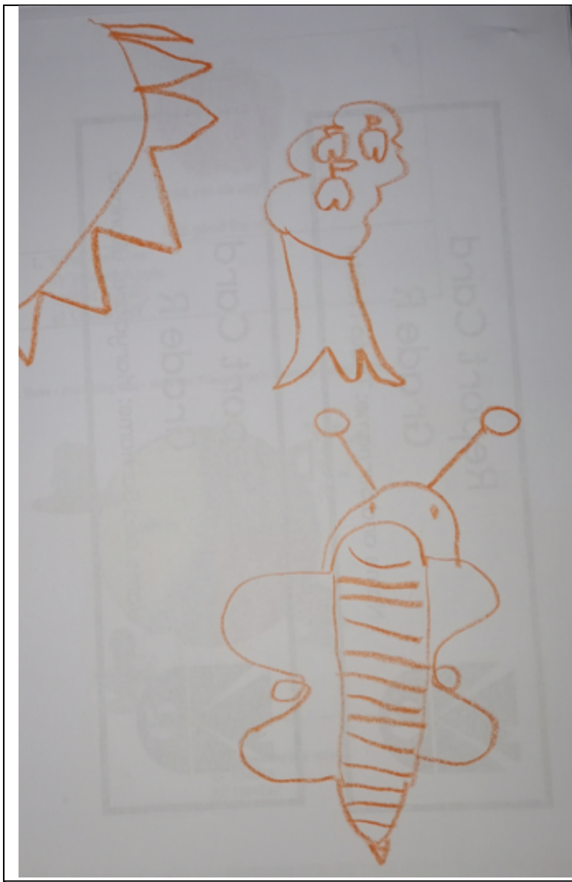
To understand the levels of visual-spatial working memory of the Grade R learners from both the STEM and non-STEM schools presented in Table 5.2, in the open-ended item, I asked the learners to look at the Figure. 5.3 and re-draw what is on the left side of the image, onto the folded side of the paper, based on what they can remember seeing. After drawing their pictures, I asked the learners "*How many apples were in the picture*?" (Figure 5.3) that I had shown them. I further probed the learners by asking them to explain why they had drawn that number of apples.

Figure 5. 3 Item assessing the learners' visual-spatial working memory skills.

Figure 5.4 exhibits two pictures that were drawn by Palesa (non-STEM school - who drew the picture on the left) and Baldwin (STEM school - who drew the picture on the right). As illustrated in Figure 5.4 Palesa (non-STEM school) drew 13 apples on the tree, while Baldwin (STEM school) only had three apples on the tree.



Palesa non-STEM school learner



Baldwin STEM school learner

Figure 5. 4 Pictures were drawn by learners assessing learners' visual-spatial working memory.

Furthermore, seeing that Palesa (non-STEM school) had drawn 13 apples on the tree as demonstrated in Figure 5.4, while Baldwin (STEM school) only had three apples on the tree. Table 5.12 demonstrates the reasons given by the learners as to why they had drawn either three or 13 apples on the tree. In Table 5.12, Palesa explained why she had 13 apples on her tree, by saying that "*There were many apples on the tree*". While Baldwin (STEM school) on the other hand, justified the three apples he had drawn by giving a reason such as: "*That is how many I remember seeing on the tree*".

Table 5. 12

The learners' responses to the item assessing visual-spatial working memory skill

Learner	The learners' school	Number of apples on the tree	The learners' justification for their responses to the item
Baldwin	STEM	*"3"*	*That is how many I remember seeing on the tree"*
Palesa	non-STEM	*"13"*	*"There were many apples on the tree"*

Based on the results presented in Table 5.2 of the corresponding item in the psychometric test, it was observed that both the Grade R learners from the STEM and non-STEM schools were able to detect the apples on the tree. The ability to detect part of an ER that is embedded in a visually complex background is known as ground perception, which is a visual perception skill that only requires learners to operate at an internalization stage of visualization (Mnguni et al., 2016).

However, as indicated in Table 5.12, only the Grade R learners from the STEM school were able to remember and accurately draw the number of apples present on the tree in Figure 5.4. As mentioned earlier, the ability to remember information from memory indicates that learners are operating at a conceptualization stage of visualization. Furthermore, the capability to correctly sketch or draw an ER from memory demonstrates that the Grade R learners from the STEM school function at an even higher cognitive level by operating at an externalization stage of visualization (Mnguni et al., 2016).

Nevertheless, when examining the number of apples drawn by Palesa (non-STEM school) in Figure 5.4, one may question why Palesa remembers seeing more apples when only three were presented in the image. Also, a possible response from the learner from the non-STEM school, perceiving more than three apples on the tree, could be based on their previous experiences of frequently observing trees bearing more than just three apples. It is important to consider that learners' prior experiences and observations can shape their perceptions and expectations. If the learner has frequently encountered trees with a higher number of apples, they may naturally assume that the tree in question also has more than three apples. These observations and experiences can influence their response, even if it does not align with the expected numerical count. Therefore, it is plausible that the learner's response is influenced by their familiarity with trees typically bearing a larger quantity of apples.

Additionally, considering that Palesa recalls the other elements of the image, such as the sun, tree, and bee, it raises the possibility that Palesa may have been distracted by the ER used in Figure 5.4. As discussed in Section 3.2 of the theoretical framework and Section 4.5.2 regarding the design of the data collection instrument, I made efforts to adhere to the Cognitive Theory of Multimedia Learning Principles, aiming to maximize learners' cognitive processing of multimedia elements while minimizing extraneous processing (Mayer, 2011, p.40), which can be distracting. However, despite these efforts, the presence of three objects/items in the ER may have resulted in overstimulation for Palesa (non-STEM school), as children have limited working memory capacity. Thus, I advocate for the use of Mayer's Redundancy Principle of Multimedia Learning, in conjunction with the Cognitive Theory of Multimedia Learning Principles, when designing learning materials for children. This principle suggests the removal of extraneous images, even if they are related to the learning process, as excessive visuals can distract children and lead to cognitive overload.

In conclusion, the results presented in this section indicate that Grade R learners from the STEM school possess better visual-spatial working memory than those from the non-STEM schools, as the STEM learners operated at all three stages of visualization, while the non-STEM learner only operated at the internalization stage. These findings are consistent with the quantitative results presented in Table 5.2, further supporting the conclusion.

IV. Visual perception skill

Lastly, under the theme of assessing VL, I engaged with the Grade R learners from both the STEM and non-STEM schools in order to understand the results presented in Table 5.2, illustrating their levels of visual perception, whereby the learners' ability to make sense of structures and shapes were assessed. In that regard, I probed the learners to explain to me their reasons for their choice of a number of trees they think match based on their shapes as presented in Figure 5.5, which illustrates the corresponding item in the psychometric test.

Figure 5. 5 Item assessing the learners' visual perception skills.

Table 5.13 presents the learners' explanations of the number of trees they think match Figure 5.5 based on their shapes. Kenneth (STEM school) explained why he correctly indicated that four tree matches based on their shapes by saying "*Because there are four trees at the top that has the same shape as four trees at the bottom*". Neo (non-STEM school) on the other hand simply responded to the item, by saying that "*Because there are five trees at the top and five trees at the bottom*".

Table 5. 13

The learners' responses to the item assessing visual perception skill

Learner	The learners' school	The number of Christmas trees matching	The learners' justification for their responses to the item
Kenneth	STEM	*"4"*	*"Because there are four trees at the top that has the same shape as four trees at the bottom"*
Neo	non-STEM	*"5"*	*"Because there are five trees at the top and five trees at the bottom"*

Based on the quantitative results presented in Table 5.2, it can be concluded that Grade R learners from STEM schools demonstrate superior visual perception skills compared to Grade R learners from non-STEM schools. This finding is further supported by the observations made in Table 5.12, where Kenneth (STEM school) correctly identifies that four trees at the top of Figure 5.5 have the same shape as four trees at the bottom. This indicates that Grade R learners from the STEM school possess VL skills, including visual-spatial working memory and pattern recognition. In the case of visual-spatial working memory and pattern recognition, Kenneth was able to recall visual details of various shapes to recognize matching trees based on their shapes (Mnguni et al., 2016). The ability to recognize shapes and match them to stimuli suggests that learners operate at an internalization stage of visualization (Mnguni et al., 2016). Moreover, when learners can recall specific visual details and use them to perceive and match stimuli, it indicates their operation at a conceptualization stage of visualization (Mnguni et al., 2016).

Contrarily, Neo's (non-STEM school) response that five trees match in Figure 5.5 "*Because there are five trees at the top and five trees at the bottom*" reveals her inability to sort objects based on their shape or patterns, a skill mastered by Grade R learners from the STEM school. The failure of Grade R learners from non-STEM schools to organize or classify objects based on their shapes or patterns implies their inability to even operate at the lowest level of visualization, which is the internalization stage (Mnguni et al., 2016), as there were two trees that did not match based on their shapes.

In conclusion, analyzing the responses provided by Grade R learners from both STEM and non-STEM schools, it is evident that Grade R learners from STEM schools exhibit better visual perception skills compared to Grade R learners from non-STEM schools, which aligns with the quantitative results presented in Table 5.2.

C. Theme 2: Assessing science literacy

For assessing SL, the quantitative part of the questionnaire aimed to assess various dimensions of SL constituted of four sub-themes, namely: knowledge of living and non-living, understanding of different weather conditions, understanding mass, and understanding temperature. In order to understand why the Grade R learners from the STEM schools outperformed the Grade R learners from the non-STEM schools in the content knowledge test items assessing SL as presented in Table 5.2. The learners were interviewed to establish the logic behind the choices made in the content knowledge test assessing SL skills, therefore giving a clear view of the learners' levels of SL skills.

I. Knowledge of living and non-living things

In the interest of understanding the learners' levels of knowledge of living and non-living things as presented in Table 5.2, whereby the learners were asked to choose which of the items shown in Figure 5.6 are living and which ones are non-living. I interviewed the Grade R learners from both the STEM and non-STEM school, in order to understand the reasoning behind the choices they made, by probing the learners to give a reason for their choices.

Figure 5. 6 Item assessing the learners' knowledge of living and non-living things.

The results presented in Table 5.14 demonstrate the reasons given by the Grade R learners from both the STEM and non-STEM schools, for the items they chose as living and non-living. As seen in Table 5.14, Rethabile (STEM school) justified his choices of the dog, the boy, and the chicken as living by saying that they "*Can breathe and move around*". While Amo (non-STEM school) explained why she thinks that the dog and the chicken are not living by saying that they "*cannot talk*". Warona (STEM school) on the other hand, explained why he thinks the boy and the dog are living, by indicating that it is because they "*Need water to grow*".

Table 5. 14

The learners' responses to the item assessing the learner's knowledge of living and non-living things

Learner	The learners' school	The thing/s that are living	The learner's justification for their responses to the item
Rethabile	STEM	*"It is the dog, the boy, the chicken"*	*"The dog, boy, and chicken can breathe and move around"*
Amo	non-STEM	*"It is the boy"*	*"The dog and chicken cannot talk"*
Warona	STEM	*"It is the dog and boy"*	*"The boy and dog need water to grow"*

In accordance with section 3.2.3 of the theoretical framework, the National Science Education Standards were employed to establish the specific knowledge expectations for Grade R learners in various science domains, including Life Science (such as distinguishing between living and non-living things and classifying plants and animals), Earth Science (e.g., understanding weather and seasonal changes), and Physical Science (comprehending forces, properties of matter like weight, balancing objects, and temperature measurement).

Examining the responses provided by the learners in Table 5.14, it becomes evident that Rethabile (STEM school) and Warona (STEM school) possess a clear understanding of the characteristics that define an item or thing as living or non-living. Warona's response highlighting that the boy and the dog are living because they require water to grow demonstrates the STEM school Grade R learners' knowledge of living things. The ability to grow is one of the distinguishing characteristics of living organisms. According to the National Science Education Standards, Grade R learners are taught to differentiate between living and non-living things based on the seven characteristics of life. Furthermore, Rethabile (STEM school) also identified another characteristic of living things, which is the ability to breathe. This understanding of metabolism and respiration implies that Grade R learners from STEM schools possess prior knowledge of the seven characteristics of life, while their counterparts from non-STEM schools do not.

Additionally, the quantitative results presented in Table 5.2 indicate that Grade R learners from non-STEM schools lack knowledge regarding the attributes that classify an item or thing as living or non-living. This is evident from Amo's (non-STEM school) response, claiming that the dog and the chicken are non-living because they cannot talk. Amo (non-STEM school) associates living items or things solely with the ability to talk, disregarding the fact that not all living organisms possess the capacity for verbal communication, such as plants and certain animals, despite exhibiting all seven characteristics of life.

Therefore, based on the outcomes depicted in Table 5.14, it is apparent that Grade R learners from STEM schools demonstrate a more comprehensive understanding of the characteristics that define a living item or thing compared to Grade R learners from non-STEM schools. This implies that Grade R learners from STEM schools possess greater knowledge regarding the characteristics of living things than their counterparts from non-STEM schools. Furthermore, these findings align with the quantitative results presented in Table 5.2, reinforcing the superior performance of Grade R learners from STEM schools over those from non-STEM schools.

II. Understanding of the weather

In order to make sense of the Grade R from both the STEM and non-STEM school's level of understanding of the weather presented in Table 5.2, I interviewed the learners by asking them to explain why the boy in Figure 5,7 needs to wear sunglasses when playing in the sun.

Figure 5. 7 Item assessing the learners' understanding of the weather.

Table 5.15 demonstrate the reasons given by the Grade R learners from both the STEM and non-STEM schools as to why the boy needs to wear sunglasses when playing in the sun. The explanation given by Baldwin (STEM school) as to why the boy needs to wear sunglasses when playing in the sun, was "*To protect his eyes from the heat of the sun*". While Letlotlo (non-STEM school) responded by saying, it is "*Because it is summer*".

Table 5. 15

The learners' responses to the item assessing understanding of the weather

Learner	The learners' school	The learners' responses to the item
Baldwin	STEM	*"To protect his eyes from the heat of the sun"*
Letlotlo	non-STEM	*"Because it is summer"*

The quantitative results presented in Table 5.2 indicate the varying levels of understanding among Grade R learners from STEM and non-STEM schools regarding weather. Specifically, it is evident that Grade R learners from STEM schools exhibit a better understanding compared to those from non-STEM schools. These findings align with the results presented in Table 5.14.

Although both STEM and non-STEM Grade R learners are capable of expressing why the boy needs to wear sunglasses when playing in the sun, Baldwin's (STEM school) responses demonstrate a superior understanding of the function of sunglasses as protective gear designed to shield the eyes from the sun's heat. Furthermore, Baldwin's (STEM school) mention of the need for protection from the sun's heat suggests that Grade R learners from STEM schools not only comprehend that the sun is a source of heat but also possess knowledge of the adverse effects of excessive heat, which can be acquired through the study of different seasons and weather conditions in Earth Science.

Conversely, Letlotlo's (non-STEM school) response that the boy needs to wear sunglasses when playing in the sun because "*it is summer*" illustrates the non-STEM Grade R learners' awareness of different seasons. However, upon closer examination of Letlotlo's (non-STEM school) response, it becomes apparent that Letlotlo failed to establish a logical connection between the presence of the sun and its impact regardless of the season. Thus, these results suggest that while non-STEM Grade R learners may have received exposure to learning about different seasons, they possess limited understanding of the sun's role in determining seasons on Earth. This understanding is rooted more in the tilt of the Earth and its orbit around the sun, rather than solely the presence of solar heat. Such comprehension can only be attained through exposure to the study of different seasons and weather conditions in Earth Science.

Therefore, the results presented in Table 5.15 demonstrate that Grade R learners from STEM schools possess a better understanding of weather compared to their counterparts from non-STEM schools. This is evidenced by the ability of STEM Grade R learners to articulate the reasons why sunglasses are necessary in hot weather conditions, a comprehension lacking among non-STEM Grade R learners. Furthermore, these findings in Table 5.15 align with the quantitative results presented in Table 5.2 regarding the corresponding item.

III. Understanding of mass

To try to understand the Grade R learners from both the STEM and non-STEM schools' levels of understanding of mass as presented in Table 5.2, the learners were asked in an interview to explain why they indicated the elephant to be heavier than the ant (as seen in Figure 5.8), in the corresponding item in the content knowledge test.

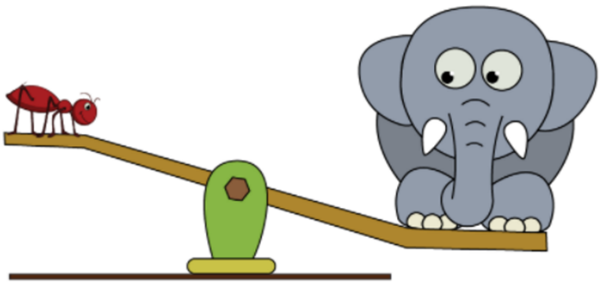


Figure 5. 8 Item assessing the learners' understanding of mass.

The results presented in Table 5.16 illustrate the explanations given by the Grade R learners from both the STEM and non-STEM schools as to why they indicated the elephant to be heavier than the ant in the corresponding item in the content knowledge test. Victoria (STEM school) indicated that the elephant was heavier than the ant "*Because the elephant has more kilograms".* While Nolusindiso (non-STEM school) on the other hand seems to think that the elephant is heavier than the ant, "*Because the elephant is big*".

Table 5. 16

The learners' responses to the item assessing understanding of mass

Learner	**The learners' school**	**The learners' justification for their responses to the item**
Victoria	STEM	*"Because the elephant has more kilograms"*
Nolusindiso	non-STEM	*"Because the elephant is big"*

The results presented in Table 5.16, similar to the quantitative findings in Table 5.2, highlight that Grade R learners from STEM schools possess a superior understanding of the concept of mass compared to Grade R learners from non-STEM schools. This is exemplified by Nolusindiso's (non-STEM school) response, stating that the elephant is heavier than the ant "*Because the elephant is a big giant*" The use of the adjective "*big*" to describe the elephant suggests that non-STEM Grade R learners associate heaviness with the size of an object. However, it is important to note that size refers to the magnitude or dimension of an object and is measured linearly using metric units such as kilometer, meter, centimeter, and millimeter. Length, however, is not a measure of mass.

In contrast, Grade R learners from STEM schools were able to demonstrate an understanding that the weight of an elephant is measured in units of mass, such as kilograms. This understanding aligns with the National Science Education Standards, which emphasize the need for Grade R learners to engage in activities related to weight and mass in physical science. Additionally, the standards highlight the distinction between size and mass/weight, emphasizing that large objects can sometimes be light and small objects can sometimes be heavy.

Therefore, the results presented in Table 5.16 suggest that Grade R learners from STEM schools possess a better grasp of the factors that contribute to an object's heaviness when measured on a scale, compared to Grade R learners from non-STEM schools. Furthermore, these findings align with the quantitative results of the corresponding item presented in Table 5.2.

IV. Understanding of temperature

Lastly, as a means to understand the quantitative results of the corresponding item in the content knowledge test presented in Table 5.2, whereby the learners were asked to choose between the ice and the sun presented in Figure 5.9 and indicate which of the two had higher temperatures. In this section, I present the results obtained from interviews with the Grade R learners from both the STEM and non-STEM schools, whereby the learners were asked to explain why they chose either the ice or sun as the item with the higher temperature, in order to understand their level of understanding of temperature.

Figure 5. 9 Item assessing the learners' understanding of temperature.

The data presented in Table 5.17, demonstrate the varied explanations given by the Grade R learners from both the STEM and non-STEM schools as to why they chose the sun as the item with a higher temperature than the ice. Rethabile's (STEM school) responded by saying because "*The sun is hot, and the ice is cold*". While Nolusindiso's (non-STEM school) explanation as to why the sun has a higher temperature than ice is because "*The sun is hot*".

Table 5. 17

The learners' responses to the item assessing understanding of temperature

Learner	The learners' school	The item/thing with a higher temperature	The learners' justification for their responses to the item
Rethabile	STEM	*"The Sun"*	*"The sun is hot, and the ice is cold"*
Nolusindiso	non-STEM	*"The Sun"*	*"The sun is hot"*

The responses presented in Table 5.17 indicate that Grade R learners from STEM schools possess a better understanding of temperature compared to Grade R learners from non-STEM schools. Nolusindiso's (non-STEM school) response that the sun has a higher temperature than ice because "*The sun is hot*" suggests her understanding that hot objects emit heat or have high temperatures. This implies that Grade R learners from non-STEM schools have been exposed to learning about heat and objects that generate heat, such as the sun.

On the other hand, Rethabile's (STEM school) response that the sun has a higher temperature than ice because "*The sun is hot, and the ice is cold*" demonstrates that Grade R learners from STEM schools not only understand heat and objects that emit heat, but they can also differentiate between cold and hot objects based on the presence or absence of heat. Furthermore, Rethabile's response aligns with the expectations outlined in the National Science Education Standards for Grade R learners. These standards emphasize the ability to differentiate between cold and hot objects based on the presence or absence of heat. Objects with low temperatures would imply the absence of heat, while objects with high temperatures would imply the presence of heat.

Therefore, the results presented in Table 5.17 illustrate that Grade R learners from STEM schools possess a deeper understanding of temperature compared to Grade R learners from non-STEM schools. This is evident in their knowledge of temperature and the ability to differentiate between objects with high and low temperatures based on the presence or absence of heat. Additionally, these findings align with the quantitative results of the corresponding item in the content knowledge test presented in Table 5.2.

D. Theme 3: Assessing scientific reasoning ability

For assessing SRA, the psychometric test items were formulated to assess different dimensions of SRA, which constituted six sub-themes, namely: knowledge of scientific tools, ability to make conclusions, logical reasoning, application of knowledge, making meaning of what is observed, and ability to analyze data. In the interest of understanding the levels of SRA of both Grade R learners from the STEM and non-STEM schools presented in Table 5.2. The learners participated in an interview that aimed at understanding why the Grade R learners from the STEM schools outperformed the Grade R learners from the non-STEM schools in the psychometric test items assessing SRA.

I. Knowledge of scientific tools used in scientific inquiry

Table 5.2 presents the results obtained from the psychometric test item assessing the learners' knowledge about scientific tools used in scientific inquiry. The learners were asked to identify the scientific tool presented in Figure 5.10, in order to establish their level of knowledge of scientific tools used in scientific inquiry. In this section, the Grade R learners from both the STEM and non-STEM schools were interviewed and asked to explain what they think the scientific tool they identified in Figure 5.10 is used for.

Figure 5. 10 Item assessing the learners' knowledge of scientific tools used in scientific inquiry.

Table 5.18 presents the responses given by the Grade R learners from both the STEM and non-STEM schools as to what the thermometer is used for. Warona (STEM school) responded by saying that a thermometer is "*Used to check your temperature".* While Amo (non-STEM school) responded by saying that "*It is what the security guard uses the machine at the mall to see if you have coronavirus*". This is because Amo (non-STEM school) referred to the thermometer as a "*Coronavirus machine*".

Table 5. 18

The learners' responses to the item assessing knowledge of scientific tools used in scientific inquiry

Learner	The learners' school	The name of the scientific tool	The learners' justification for their responses to the item
Warona	STEM	*"thermometer"*	*"It used to check your temperature"*
Amo	non-STEM	*"Coronavirus machine"*	*"It is what the security guard uses at the mall to see if you have coronavirus"*

Taking a closer look at Amo's (non-STEM school) response, referring to the thermometer as the "*Coronavirus machine*" and stating that "*It is what the security guard uses at the mall to see if you have coronavirus*" it is evident that Amo's logic is influenced by her observations during the Covid-19 pandemic, particularly during her visits to the mall. During this time, the World Health Organization recommended the use of face masks and hand sanitization when entering public spaces. Additionally, temperature screening was often conducted by security guards using a thermometer in various public locations. Amo's response suggests that Grade R learners from non-STEM schools may associate the thermometer with what they observed security guards using for temperature screening at schools or malls.

As mentioned in section 3.4.2 of the theoretical framework, the Evidence-Based Reasoning Framework was utilized to evaluate the specific components of the scientific method, including premise, claim, rule, data, and evidence, which are crucial for assessing the level of SRA.

Furthermore, as indicated in section 3.4.1 of the theoretical framework, a claim is considered a prediction or observation. In this context, although the Grade R learners from non-STEM schools were unable to correctly identify the thermometer, their observations led them to associate a high temperature as one of the symptoms of the coronavirus disease. Therefore, the results in this section imply that Grade R learners from non-STEM schools possess some basic knowledge of scientific tools used in scientific inquiry.

On the other hand, Warona's (STEM school) response that a thermometer "*is used to check your temperature*" suggests that Grade R learners from STEM schools have already been exposed to using a thermometer, as they correctly identified the scientific tool and stated its function accurately.

Hence, the results presented in Table 5.18 indicate that Grade R learners from STEM schools have a better understanding of scientific tools compared to Grade R learners from non-STEM schools, which aligns with the psychometric test results presented in Table 5.18.

II. Ability to make a conclusion

In order to understand the results (presented in Table 5.2) of the corresponding item in the psychometric test, whereby the Grade R learners from both the STEM and non-STEM schools' ability to make a conclusion were assessed. In this section, I present the results from the interviews in which the Grade R learners from both the STEM and non-STEM schools participated. The learners were asked to study pictures A and B in Figure 5.11 and explain what they think happened to the ball in picture B.

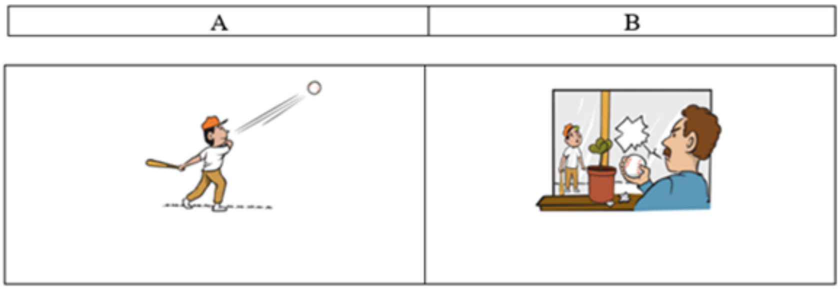


Figure 5. 11 Item assessing the learners' ability to make a conclusion.

Table 5.19 demonstrates the learners varied explanations as to what they think happened in picture B of Figure 5.11. Victoria (STEM school) responded to the item by saying that "*The man is holding the ball inside the house because the boy hit the ball, and it broke the window going inside the house*". While Palesa responded by saying (non-STEM school) "*The window is broken*".

Table 5. 19

The learners' responses to the item assessing their ability to make a conclusion

Learner	The learners' school	The learners' justification for their responses to the item
Victoria	STEM	*"The man is holding the ball inside the house because the boy hit the ball, and the ball broke the window going inside the house"*
Palesa	non-STEM	*"The window is broken"*

By carefully analyzing Victoria's (STEM school) response, which states, "*The man is holding the ball inside the house because the boy hit the ball, and it broke the window going inside the house*" it is evident that Victoria demonstrates her ability to observe, analyze, interpret, and draw a conclusion. This type of response highlights her proficiency in the Evidence-Based

Reasoning Framework, as outlined in section 3.4.1 of the theoretical framework, where data is considered as reports of past or present observations. Victoria's response includes observations such as "*The man is holding the ball inside the house*" "*because the boy hit the ball*" and "*the ball broke the window going inside the house.*"

Furthermore, Victoria showcases her ability to draw a conclusion by stating, "*The man is holding the ball inside the house because the boy hit the ball and the ball broke the window going inside the house*." This conclusion demonstrates her analytical skills in examining both picture A and picture B of Figure 5.11. Victoria's capability to analyze both pictures A and B exemplifies her aptitude for closely examining the images to identify any similarities or differences, thus understanding the nature and relationship between the pictures. Moreover, her ability to draw a conclusion reflects her proficiency in interpreting the analyzed observations and transforming the evidence into a generalized statement that outlines her judgment or decision based on the reasoning process.

Therefore, the results presented in Table 5.19 indicate that Grade R learners from STEM schools exhibit high levels of SRAs required for scientific inquiry. In contrast, Palesa's (non-STEM school) response, "*The window is broken*" only demonstrates her ability to make an observation rather than a conclusion. Her statement is solely based on the current observation in picture B without making any connections to the events depicted in picture A.

In conclusion, the results in Table 5.19 illustrate that Grade R learners from STEM schools possess better SRAs compared to Grade R learners from non-STEM schools. These findings are consistent with the quantitative results presented in 5.2 of the corresponding item in the psychometric test.

III. Ability to reason logically

Considering that Table 5.2 revealed that the Grade R learners from the STEM schools outperformed the Grade R learners from the non-STEM schools in the psychometric test item assessing the learners' logical reasoning. In this section, I present the results obtained by interviewing the Grade R learners from both the STEM school and non-STEM schools, in order to get a clear view of their level of logical reasoning ability presented in Table 5.2. During the interviews, the learners were shown Figure 5.12 and asked to explain why they chose either the cup of tea/coffee and the spoon or the colouring pencils/crayons, and the books as the two items together in the psychometric test item assessing the learners' logical reasoning.

Figure 5. 12 Item assessing the learners' ability to logically reason.

Table 5.20 illustrate the two varied responses given by the learners as to why the spoon can be used together with the cup of tea/coffee, while the colouring pencils/crayons would be used together with the books. Baldwin's (STEM school) response was that "*The teacup and teaspoon go together because we use the teaspoon to stir the tea in the teacup and not crayons*". While Letlotlo (non-STEM school) indicated that "*The crayons and the books go together because you use the crayons to colour in the book*".

Table 5. 20

The learners' responses to the item assessing the ability to reason logically

Learner	The learners' school	The learners' justification for their responses to the item
Baldwin	STEM	*"The teacup and teaspoon go together because we use the teaspoon to stir the tea in the teacup and not crayons"*
Letlotlo	non-STEM	*"The crayons and the books go together because you use the crayons to colour in the book"*

Taking a closer look at the level of logical reasoning ability among the learners, as presented in Table 5.2, it becomes evident that Grade R learners from both STEM and non-STEM schools performed at a similar level, although the STEM learners slightly outperformed the non-STEM learners. This observation is supported by the responses given by Baldwin (STEM school) and Letlolo (non-STEM school), who both demonstrated the ability to determine why certain items should be used together. For instance, Baldwin correctly identified that the spoon should be used to stir the teacup, while Letlolo recognized that the coloring pencils/crayons would be best suited for use with the book.

Referring to the Evidence-Based Reasoning Framework outlined in section 3.4.1 of the theoretical framework, this ability to logically deduce that the spoon should be used with the cup of tea/coffee and the coloring pencils/crayons should be used with the book exemplifies the application of logical reasoning.

On the other hand, Baldwin's response that the spoon should be used to stir the teacup and not the crayons represents an example of a premise, where a conclusion is drawn based on at least two true statements. This indicates that the claims made by STEM learners about the premise were supported by their logical deduction that the spoon should be used with the cup of tea/coffee, while the coloring pencils/crayons are better suited for use with the book.

Therefore, the results presented in Table 5.20 illustrate that Grade R learners from both STEM and non-STEM schools were able to make distinctions regarding which items should be used together. However, STEM learners also demonstrated the ability to discern which items do not work together. This suggests that STEM learners exhibit better logical reasoning skills compared to their non-STEM counterparts. These findings are consistent with the quantitative results presented in Table 5.2 of the corresponding item in the psychometric test.

IV. Ability to apply knowledge

In light of the results presented in Table 5.2 demonstrating the learners' level of ability to apply knowledge, whereby the learners were asked to choose between the four children and the two parents (as seen in Figure 5.3) who they think would win the pull rope challenge. In this section, I present the results obtained from interviewing the Grade R learners from both the STEM and non- STEM schools, as to why they chose either the four children or the two parents as possible winners of the pull rope challenge.

Figure 5. 13 Item assessing the learners' ability to apply knowledge.

The results presented in Table 5.21, demonstrates the responses given by the learners from both the STEM and non-STEM school as to why they chose either the four children or the two parents as possible winners of the pull rope challenge. Peter (STEM school) indicated that "*The parents will win*" the pull rope challenge "*Because the parents have more power*". While Neo's (non-STEM school) response suggests that the children will win, "*Because the children are more than the parents".*

Table 5.21

The learner s' responses to the item assessing the ability to apply knowledge

Learner	**The learners' school**	**Who will win the pull rope challenge?**	**The learners' justification for their responses to the item**
Peter	STEM	*"The parents will win"*	*"Because the parents have more power"*
Neo	non-STEM	*"The children will win"*	*"Because the children are more than the parents"*

Analyzing Peter's (STEM school) response that "*The parents will win*" the pull rope challenge "*Because the parents have more power*" provides insight into the Grade R learners' knowledge of power. In this context, power refers to the rate at which work is done. It suggests that parents can accomplish more work by pulling more rope than the children over a short distance, as the force of an object increases with its weight or mass. Therefore, considering that parents are likely to weigh more than children, they would exert more force, do more work, and possess more power. Consequently, these results demonstrate that Grade R learners from STEM schools were able to apply their prior knowledge about power, work, and forces to determine the outcome of the pull rope challenge.

Referring to the Evidence-Based Reasoning Framework presented in section 3.4.1 of the theoretical framework, the application of prior knowledge serves as a foundation for generating new knowledge as learners follow the steps of the scientific method to reach scientific conclusions.

On the other hand, Neo's (non-STEM school) response that "*The children will win because the children are more than the parents*" suggests that Grade R learners from non-STEM schools base their prediction on the number of children participating. If we estimate the combined weight of the children, it would likely be less than that of the two parents combined. This implies that the children would exert less force and do less work, thus failing to pull enough rope in a short period to win the challenge.

Therefore, the results presented in Table 5.21 demonstrate that Grade R learners from STEM schools were able to apply their prior knowledge of power, forces, and work, whereas non-STEM learners lacked this understanding. Additionally, these results align with the quantitative findings presented in Table 5.2 of the corresponding item in the psychometric test, indicating that Grade R learners from STEM schools are more proficient at applying their knowledge to problem-solving than their non-STEM counterparts.

V. Making meaning of observations

With the aim of understanding the results (presented in Table 5.2) of the corresponding item in the psychometric test, whereby the Grade R learners from both the STEM and non-STEM schools' ability to make meaning of what they observe. In this section, I present results obtained from the interviews with the learners, whereby the learners were asked to look at the ER in

Figure 5.14, while I read the text "*I can eat an apple. It is good for me*", out loud for them. The learners were then asked based on what they are observing, why should I eat an apple?

I can eat an apple

It is good for me

Figure 5. 14 Item assessing the learners' ability to make meaning of what they observe.

Table 5.22 presents the varied responses given by the learners as to why I should eat an apple based on their observations. Rethabile (STEM school) responded by saying that "*Apples are good for us because apples have vitamins*". While Amo's (non-STEM school) response to why I should eat an apple, is because "*Apples are good for us*".

Table 5. 21

The learners' responses to the item assessing their ability to make meaning of what is observed

Learner	**The learners' school**	**The learners' justification for their responses to the item**
Rethabile	STEM	*"Apples are good for us because apples have vitamins"*
Amo	non-STEM	*"Apples are good for us*

Examining the learners' responses regarding why one should eat an apple based on their observations, we can gain valuable insights. Amo's (non-STEM school) response illustrates the ability of Grade R learners from non-STEM schools to evaluate an ER and selectively choose relevant information based on their observations. As mentioned earlier, making observations involves using our senses to receive external information and construct new knowledge. This process requires VL skills to make sense of what is being observed. Therefore, the results suggest that Grade R learners from STEM schools possess sufficient VL skills to make sense of the information in ERs.

Analyzing Rethabile's (STEM school) response to why one should eat an apple, Rethabile stated that "*Apples are good for us because apples have vitamins*". Similar to Grade R learners from non-STEM schools, Grade R learners from STEM schools also possess sufficient VL skills to make sense of the information in ERs, as indicated by their correct response that one should eat an apple because it is good for them. However, Rethabile's response further demonstrates the ability of Grade R learners from STEM schools to logically rationalize that apples are good for us due to their nutritional value, specifically the presence of vitamins.

Therefore, the results presented in Table 5.22 indicate that Grade R learners from STEM schools have a better ability to derive meaning from observed ERs compared to Grade R learners from non-STEM schools. These findings align with the quantitative results presented in Table 5.2 of the corresponding item in the psychometric test.

VI. Ability to analyze data

Lastly, to try and understand the results presented in Table 5.2 of the corresponding item in the psychometric test, whereby the Grade R learners from both the STEM and non-STEM schools had to analyze a pie chart of all Wavhudi's favourite things to do, as shown in Figure 5.15. In this section, I present the results obtained by interviewing the learners to explain as to "*why would reading be Wavhudi's favourite thing to do*?".

Figure 5. 15 Item assessing the learners' ability to analyze data.

Table 5.23 demonstrate the various responses given by the Grade R learners from both the STEM and non-STEM schools as to why reading would be Wavhudi's favourite thing to do. Victoria (STEM school) responded by saying that reading is Wavhudi's favourite thing to do "*Because reading has more space*". While Bothlale (non-STEM school) responded by saying "*Because reading is fun*".

Table 5. 22

The learners' responses to the item assessing ability to analyze data

Learner	The learners' school	The learners' responses to the item
Victoria	STEM	*"Because reading has more space"*
Bothlale	non-STEM	*"Because reading is fun"*

Upon examining the learners' responses regarding why reading would be Wavhudi's favorite thing to do, we can gain valuable insights. Victoria's (STEM school) response suggests that the yellow portion of the pie chart, representing reading, is the largest compared to the other segments. As mentioned earlier, the ability to analyze data involves evaluating and interpreting a substantial amount of information and identifying relevant patterns. In this regard, Grade R learners from STEM schools not only evaluated the ER presented in Figure 5.23 but also interpreted the data it contained. These results indicate that Grade R learners from STEM schools possess the ability to analyze data presented in visual form and have sufficient VL skills to distinguish colours in the pie chart based on their sizes.

On the other hand, Bothlale's (non-STEM school) response that reading would be Wavhudi's favourite thing to do because it is fun implies that Bothlale recognized that reading is what Wavhudi enjoys the most. However, his reasoning does not demonstrate the ability to evaluate and interpret the presented data to draw a conclusion that reading is Wavhudi's favourite activity based on the pie chart.

Therefore, the results presented in Table 5.23 indicate that Grade R learners from STEM schools possess better data analytic skills compared to Grade R learners from non-STEM schools. These findings are consistent with the results presented in Table 5.2 of the corresponding item in the psychometric test.

5.6 Take-home message

This chapter presents the results that aimed to address the two research sub-questions of the current study. By examining the learners' levels of VL, SL, and SRA, it can be inferred that the introduction of STEM education in pre-primary schools significantly improved the Grade R learners' ability to answer SL-related questions. The findings indicate a significant difference in the levels of VL, SL, and SRA between the Grade R learners from STEM schools and non-STEM schools, with the STEM school learners demonstrating significantly higher levels of VL, SL, and SRA compared to their non-STEM school counterparts. However, it is important to note that despite the significant improvement in SL skills among the STEM school learners, both groups of Grade R learners generally exhibited poor levels of VL skills.

Additionally, concerning the relationship between VL, SL, and SRA, the results revealed a significant correlation between the learners' levels of SL and SRA in both sample groups. Thus, introducing STEM education in pre-primary school can be considered beneficial for learners, as it has been shown to enhance SL skills in Grade R learners. Therefore, it can be asserted that by improving learners' SL levels through the introduction of science education in pre-primary school, their SRA levels can also be enhanced, particularly if science is presented in an engaging and enjoyable manner. In Chapter 6, a concise discussion of the key findings and their implications for introducing science education in pre-primary school through VL will be provided, along with recommendations for further research. This will involve reflecting on the research questions posed at the beginning of the study.

CHAPTER 6: DISCUSSION OF THE CURRENT RESEARCH'S FINDINGS

"If a child can't learn the way we teach, maybe we should teach the way they learn."

Ignacio Estrada

6.1. The gist of the chapter

According to Mnguni et al. (2016), there is a recognized necessity for further research to enhance our understanding of VL in the context of science education. Existing research indicates that science learners often lack the requisite VL skills necessary for effective science education, resulting in a negative impact on their academic performance. As a result, my research focuses on the introduction of science education through VL in pre-primary schools. The central argument of this study revolves around how VL can be leveraged to improve learners' SL and SRA.

In this chapter, I present the findings, implications, and recommendations derived from the results presented in Chapter five. To accomplish this, I integrate the existing knowledge available in the literature review chapter to articulate the new insights generated from the current research. Additionally, I address the research question posed in Chapter 1 and reflect upon the extent to which the research objectives have been achieved.

6.2. The findings from the research

As mentioned, the findings presented in this chapter aim to answer the main research question (Section 1.8) which was broken down into two research sub-questions (Section 1.8), and the findings for each sub-question are presented below.

The first research sub-question asked, "*What is the level of visual literacy, science literacy, and scientific reasoning ability among pre-primary school learners to effectively learn science through visual aid and establish their readiness to learn science*?" In response to this sub-question, I have organized the findings according to the objectives of the research:

- *To determine the level of visual literacy, science literacy, and scientific reasoning ability among pre-primary school learners.*

- *To determine the relationship between visual literacy, science literacy, and scientific reasoning ability.*

6.2.1 To determine the level of visual literacy, science literacy, and scientific reasoning ability among pre-primary school learners.

A. The levels of visual literacy among the Grade R learners

Upon reviewing the quantitative (Section 5.3.3) and qualitative (Section 5.5.2) results presented in Chapter five, it becomes apparent that the Grade R learners from both STEM and non-STEM schools encountered difficulties in interpreting ERs used in science education. The current research findings indicate that these learners primarily operated at the conceptualization stage of visualization, as they struggled with the interpretation of ERs. Nkosi and Mnguni (2020) suggest that the challenges in correctly interpreting ERs may stem from the learners' need for a complex interplay between prior knowledge and relevant experiences. While Grade R learners from STEM schools may possess prior knowledge associated with STEM-related content, they still require representational competence to effectively reason with ERs used in the curriculum. Nonetheless, the current research demonstrates that Grade R learners possess certain VL skills, including visual reasoning, organizing/classifying, ground perception, mental manipulation, outlining patterns, visual counting, sketching, recognizing patterns, recalling from memory, and visual perception, with visual perception being the most frequently utilized skill.

The findings of the present research align with Fernandezn and Ruiz-Gallardo's (2017) study, which examined VL skills among primary school learners in a biology classroom. Similar to the current research, Fernandezn and Ruiz-Gallardo (2017) found limited VL skills among primary school learners. Likewise, Matusiak (2019) discovered that children lack essential skills in selecting, evaluating, and using ERs accurately. These findings imply that science learners are not explicitly taught how to interpret ERs correctly, leading to poor VL skills. Moreover, as discussed in Chapters one and two, Mnguni et al. (2016) argue that learners' inability to visualize and interpret ERs in science education may result in poor performance in the subject.

Comparing the levels of VL skills between Grade R learners from STEM and non-STEM schools, the current research indicates that in some items assessing VL, only Grade R learners from STEM schools demonstrated the ability to retrieve information from long-term memory and express it externally as ERs or verbally (Nkosi and Mnguni, 2020). This suggests that exposing learners to science education in early childhood can contribute to the development of their VL skills. Nkosi and Mnguni (2020) propose that learners' interaction with relevant ERs in their curriculum can enhance their ability to interpret and create related ERs, thereby improving their representational competence. Additionally, the current research findings align with Flaum's (2018) affirmation that VL skills can be fostered through STEM education. Consequently, based on these findings, it is postulated that introducing STEM education in pre-primary schools may be beneficial. Previous research (as discussed in Chapters 1 and 2) has demonstrated that children who engage in STEM activities frequently exhibit increased levels of 21st-century skills such as critical thinking, creativity, cultural awareness, collaboration, problem-solving skills, and VL skills.

I. The levels of patterning skills among Grade R learners about literature

The analysis of the quantitative results (Section 5.3.3) reveals that both Grade R learners from STEM and non-STEM schools displayed the ability to recognize repeating shapes that form patterns. These findings align with a similar study conducted by Rittle-Johnson et al. (2013), which assessed the pattern knowledge of pre-primary school learners. The study demonstrated that learners were capable of duplicating and extending patterns. Additionally, the Grade R learners from STEM schools in the current research exhibited a deeper understanding of patterns by abstracting them. These findings indicate that pre-primary school learners develop an understanding of repeating patterns even before entering school, highlighting their preparedness for STEM education (as discussed in Chapter 2). Importantly, these findings emphasize the significance of introducing STEM education during early childhood.

II. The levels of spatial visualization skills among Grade R learners

Furthermore, the analysis of the quantitative results (presented in Section 5.3.3) reveals that Grade R learners from STEM schools exhibited the ability to accurately perceive objects in an ER, even when they were partially obscured. This finding suggests that these learners possess adequate visual closure perceptual skills, which were lacking in Grade R learners from non-STEM schools. This finding aligns with a study conducted by Sorby (2019), in which Grade 9 learners who received STEM training in Grade 7 outperformed a control group in both state-wide mathematics assessments and local placement tests for Grade 9 mathematics. These findings underscore the importance of STEM education in the development of visual-spatial skills within educational settings.

Sorby and Veurink (2019) argue that the ability to visualize in three dimensions is crucial for success in STEM education. This viewpoint is supported by Uttal and Cohen (2012), who emphasize that neglecting the development of spatial visualization skills may impede learners' progress in subjects such as science and mathematics. Therefore, incorporating spatial skill training within STEM education can enhance learners' VL and SL levels.

III. The levels of visual-spatial working memory skills among Grade R learners

The interviews conducted in the current research (presented in Section 5.5) with Grade R learners from both STEM and non-STEM schools yielded findings regarding their ground perception skills. It was observed that both groups possessed this visual perception skill, which only required them to operate at the internalization stage of visualization (Mnguni et al., 2016). However, Grade R learners from STEM schools demonstrated an additional ability to accurately externalize stored memory, indicating their proficiency in operating at the externalization stage of visualization (Mnguni et al., 2016). As far as I am aware, there is no existing research that directly aligns with these specific findings, as much of the research has primarily focused on the impact of visual-spatial working memory training on enhancing academic performance in STEM education, rather than the reverse.

Nevertheless, a closely related study conducted by Kyttälä (2008) examined the visual-spatial working memory of learners, with the aim of investigating whether learners with mathematics difficulties differed from their normally achieving peers in terms of visual-spatial working memory. The findings from Kyttälä's study indicated that learners with poor performance in mathematics exhibited lower performance on visual-spatial working memory tasks. This emphasizes the significance of prioritizing the development of visual-spatial working memory skills within the context of STEM education.

IV. The levels of visual perception skills among Grade R learners

The analysis of both the quantitative results (presented in Section 5.3.3) and qualitative results (presented in Section 5.3.2) revealed the existence of visual perception skills among Grade R learners from both STEM and non-STEM schools. These skills encompassed the ability to recall information from memory, recognize objects based on their shapes or patterns, and classify objects based on their shapes or patterns. Notably, Grade R learners from STEM schools demonstrated a higher proficiency in the classification of objects based on their shapes or patterns. These findings align with the results of a study conducted by Jaafar (2021), which aimed to investigate the visual perception skills of children between the ages of four and six. The findings of Jaafar's study indicated the presence of similar visual perception skills, as observed in the current research, among six-year-old children who are typically in Grade R. Therefore, these findings further support the notion of Grade R learners' readiness to engage in science and mathematics education, as discussed by Cui (2017).

B. The levels of science literacy among the Grade R learners

The findings presented in this section were derived from the content knowledge test (Section 5.3.3) and the interview results (Section 5.5.3). The results of the current research revealed the level of science content knowledge among Grade R learners from both STEM and non-STEM schools in specific science domains. These domains included Life Science (Living vs. Non-living things and Classifications of plants and animals), Earth Science (Weather such as changes of seasons), and Physical Science (Forces, Properties of matter such as weight, Balancing of objects, and Measurement of temperature).

Regarding the aforementioned science domains, the findings demonstrated the existing prior knowledge among Grade R learners. Specifically, learners from STEM schools exhibited a higher level of content science knowledge in areas such as the seven characteristics of life, understanding different seasons, the role of the sun in determining seasons, various weather conditions, distinctions between size and mass, the concepts of weight and mass, the presence and absence of heat, forces, work, and power, as compared to learners from non-STEM schools.

The current research findings align with a study conducted by Kusumastuti et al. (2019), which aimed to assess the impact of integrating STEM education in primary schools on students' levels of scientific literacy. Kusumastuti et al. (2019) found that learners who studied integrated STEM curricula demonstrated higher levels of SL, as evidenced by their ability to answer questions and provide detailed explanations in science compared to learners following a common project-based study. However, in contrast to these findings, Hyacinth (2006) found no significant differences in science and mathematics performance between learners from

STEM and non-STEM schools. Nevertheless, similar to the current research, the study highlighted the importance of early STEM-based mathematics and science instruction in fostering active engagement in learning, inquiry, design, and reflection processes, while developing conceptual understanding of the science curriculum and 21st-century skills (Hyacinth, 2006).

C. The levels of scientific reasoning ability among the Grade R learners

Based on the quantitative results from the psychometric test (Section 5.3.3) and the qualitative findings from the interviews (Section 5.5.4), the current research identified the presence of systematic problem exploration and critical thinking skills among Grade R learners from both STEM and non-STEM schools. These skills enabled the learners to understand and interpret scientific information presented in visual form. The findings demonstrated a range of SRAs exhibited by the Grade R learners, including analysis, observation, logical reasoning, interpretation, conclusion-making, logical deduction, and evaluation of problems presented visually.

The results of the current research align with a study conducted by Ribeiro et al. (2019) that aimed to investigate the ideas of pre-primary school learners when it comes to collecting, organizing, and representing data, which are essential skills for scientific inquiry. The findings of Ribeiro et al.'s study indicated that Grade R learners, similar to those in the current research, were capable of evaluating and interpreting data presented in graphical form, demonstrating their ability to analyze data. Ribeiro and colleagues also observed that Grade R learners could translate a simple line graph into a pictogram, showcasing their understanding of information presented graphically. These findings suggest that by prioritizing skills such as data collection and analysis through inquiry-based methods, learners can develop logical reasoning and other related skills. Additionally, the findings of the current research are consistent with a study conducted by Samarapungavan et al. (2008) that examined the nature of science learning through inquiry-based methods in pre-primary school learners. The study revealed that intervention through inquiry-based learning in science resulted in a better understanding of scientific concepts, indicating that integrating STEM education through inquiry-based learning in early childhood may significantly enhance the development of SRAs among children.

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6.2.2 To determine the relationship between visual literacy, science literacy, and scientific reasoning ability

The second research sub-question asked, “*What is the relationship between visual literacy, science literacy, and scientific reasoning ability*?”.

The findings of the current research indicate a significant positive relationship between the learners' level of SL and their SRAs. The results demonstrate that as the use of scientific process skills increases in science education, the level of SL among learners also increases in a predictable manner. This supports the argument made in Chapter One that the understanding of scientific concepts, processes, laws, theories, or phenomena (SL) heavily relies on the learners' use of science process skills (SRA).

These findings are consistent with a study conducted by Aydoğdu et al. (2006), where researchers also found a positive relationship between scientific process skills and the learners' level of scientific knowledge. This suggests that when learners are exposed to a curriculum that emphasizes the development of science process skills, their ability to understand scientific principles and concepts, as well as their critical thinking and problem-solving skills, improves.

However, the current research did not find a significant relationship between the learners' level of VL and their SRAs. Additionally, there was no significant relationship between VL and SL. These findings suggest that the learners' levels of VL do not impact their ability to understand science and develop their science process skills.

Contrary to the findings of the current research, the central argument of this study posits that VL is an essential component in deepening the learners' understanding of scientific concepts and improving their critical thinking skills. This argument is supported by the findings of a study conducted by Afolasade and Nyong (2018), who found a significant effect of VL on the academic performance of learners in biology, indicating a positive relationship between VL and biology literacy.

Despite the current research findings, a substantial number of studies have consistently shown that VL is essential in science education. For instance, Lowe (2000) suggests that the level of SL heavily depends on the learners' level of VL. In this regard, if SL is highly reliant on the learners' level of VL and their use of science process skills (as observed in the current research findings), one might argue that as the learners' level of VL increases, their level of SL and science process skills also increase.

6.3 Conclusion of the research

In conclusion, this research advocates for educators to prioritize the development of VL skills among Grade R learners. As discussed in Chapters one and two, the neglect of VL skills in science education poses a concern as it hinders learners' ability to effectively utilize ERs (Mnguni et al., 2016), consequently impacting their acquisition of SL and SRAs. Extensive literature supports the notion that introducing science in early childhood through ERs not only enhances VL skills but also fosters the development of various literacies such as SL, information literacy, and digital literacy.

Although the findings of this study did not reveal a significant correlation between VL and SL, it is still inferred that pre-primary school learners may face difficulties comprehending scientific concepts due to their limited VL skills. Furthermore, as education progressively adopts digital learning models, visually illiterate learners risk falling behind, particularly in science subjects where digital resources are integrated into the curriculum.

Therefore, this research suggests that by incorporating VL learning in pre-primary education, Grade R learners are more likely to develop a genuine interest in science-related subjects. Moreover, considering the learners' existing SL levels, it is our responsibility as science educators to nurture their innate curiosity by introducing them to science at an early age, thereby stimulating their intellectual growth.

6.4 Recommendations for further research

While the findings of the research are important, I further argue that future research is needed to understand the following aspects:

- *The importance of VL to introduce science to pre-primary school learners*
- *The support required by pre-primary school educators to introduce science in Grade R*

This section will provide an array of recommendations that address:

- *Teaching and learning of science in pre-primary school*
- *Curriculum policy design of science education in pre-primary school*

- *Methodological issues in early-childhood research*
- *Challenges of educational theories in early childhood research*

6.4.1 Teaching and learning of science in pre-primary school

The research findings emphasize the significance of addressing the issue of VL among Grade R learners in the context of science education. Although the findings did not align with the initial ideologies regarding the relationship between VL and SL, it is evident that VL plays a crucial role not only in science education but across all disciplines for the development of 21st-century skills. Specifically, learners who face language barriers or have limited English proficiency can greatly benefit from the integration of visuals such as diagrams and images in educational settings. These visuals facilitate comprehension and effectively bridge the language gap, enabling learners to understand and engage with the subject matter more effectively.

The utilization of visual aids in educational settings, such as presenting information through visual representations, is particularly beneficial for learners with language barriers or limited English proficiency. By incorporating visuals, educators provide learners with alternative means to access and interpret information, making it easier for them to grasp and understand concepts. This enhances their overall learning experience and supports their academic progress. Furthermore, integrating VL strategies into education promotes inclusivity by catering to the diverse needs of learners. It equips learners with the skills to navigate and interpret visual representations, regardless of their language proficiency. Therefore, by developing VL skills, learners can effectively understand and derive meaning from visual materials, contributing to their overall learning and cognitive development.

Based on these findings, it is recommended to prioritize the integration of VL education into science instruction to enhance understanding and engagement among all learners. Further research should explore the introduction of explicit VL instruction in pre-primary schools, as previous studies highlight the importance of VL education in early childhood to prepare learners for the visual demands of subjects like science and prevent cognitive overload. Therefore, explicit VL instruction should be incorporated into the science curriculum to develop learners' VL skills and prepare them for future science-related careers. Moreover, the research findings support existing studies that emphasize the failure of educators to explicitly teach learners how to visualize and interpret ERs used in the science curriculum, resulting in a prevalence of VL. Future research should investigate ways to reinforce different levels of abstraction in science education and provide support for learners to enhance their VL skills.

To enhance learners' understanding of VL, instructional designers and educators should adapt their practices based on the research findings. Rather than assuming that learners will naturally acquire visual skills, explicit instruction should be provided on visualizing ERs used in the curriculum. Therefore, collaborative efforts among stakeholders are essential. The government should prioritize science education by establishing guidelines, frameworks, and providing teacher training opportunities. Pre-primary school administrators should create a supportive environment for science learning and facilitate professional development for teachers. Teachers, in turn, should incorporate hands-on and inquiry-based approaches to integrate science into the curriculum. Additionally, parents and caregivers can play a role in supporting science education at home. Through collaboration and support, stakeholders can effectively integrate science teaching and learning with VL in pre-primary schools, fostering SL and nurturing a genuine interest in science among young learners.

6.4.2 Curriculum policy design of science education in pre-primary school

The findings of the current research shed light on the readiness of Grade R learners to engage in science education. However, it is evident that the current curriculum, which draws content from Social Sciences, Natural Science, and Technology, does not adequately support the development of learners' science process skills (SRA). The research findings indicate that Grade R learners from non-STEM schools faced challenges in areas such as identifying scientific tools, analyzing data, and making meaning from observations, which are essential science process skills. In contrast, Grade R learners from STEM schools demonstrated proficiency in these areas.

As discussed in Chapter two, science education is not given sufficient emphasis in the South African foundation phase curriculum. This lack of emphasis, combined with educators' inadequate pedagogical science content knowledge, puts pre-primary school learners at a disadvantage in learning science. It is crucial to conduct further research to determine how foundation phase educators can be effectively supported in introducing science in pre-primary schools. This aligns with the argument made by James et al. (2019) that science should be foregrounded as a learning area in the foundation phase curriculum and be a compulsory component of educator education programs.

Moreover, as discussed in Chapter two, science is best learned through *doing* and engaging in scientific inquiry-based learning. This approach promotes the development of science process skills and enhances learners' enjoyment of science. The study by Ramnarain (2014) supports the use of inquiry-based learning as it promotes science learning and the development of science process skills among primary school learners in South Africa. Therefore, it is recommended to adopt inquiry-based learning as a pedagogical approach for introducing science in pre-primary schools. This approach not only develops learners' science process skills but also enhances their VL skills through the use of visual thinking strategies.

Building on the concept of visual thinking strategies discussed in Chapter two, combining VL and inquiry-based learning in science education can be highly effective. Therefore, investing in the training of pre-primary school educators in visual thinking strategies would address the challenge of learners' lack of interest in science and their perception of it being difficult and impractical. This training would help educators create engaging and meaningful science learning experiences, making science more accessible and enjoyable for South African learners.

6.4.3 Methodological issues in early-childhood research

The recommendations provided in this section are based on the challenges encountered during data collection from Grade R learners and the experiences gained throughout the research process. It is important to carefully consider the choice of research methods, regardless of the target population. In this study, the administration of open-ended items through semi-structured focus group interviews revealed certain challenges that may raise concerns about the validity of the obtained data.

One significant challenge was the level of anxiety among the learners, resulting in limited responses to the interview questions. Additionally, the learners easily became distracted and lost interest during the interviews. To address these challenges, Cammisa et al. (2011) suggested the use of flashcards containing the ERs found in the items to make the interview session more interactive and playful. This approach helped maintain the learners' focus and engagement, as they were captivated by the interactive nature of the interview. Therefore, I recommend incorporating multiple activities, particularly when interviewing young children in a focus group, to sustain their interest and attention due to their limited span of focus.

Another challenge encountered was the implementation of member checking with children. Member checking involves presenting the data and interpretations to the participants, allowing them to verify the credibility of the information and narrative accounts. According to Creswell and Miller (2000), this process can enhance a study's validity and trustworthiness. However, when attempting to confirm the interpretation of data with children as young as five years old, discrepancies in their responses during member checking arose, casting doubt on the validity of the findings. To address this issue, I recommend conducting repeated interviews, where the same interview is repeated at least three times with the same group of learners in the same settings. This approach not only increases the validity of the findings but also enhances the reliability of the results.

6.4.4 Challenges of educational theories in early childhood research

As discussed in Chapter three, Mayer's Cognitive Theory of Multimedia Learning emphasizes the processing of auditory and visual information through separate channels when learners are exposed to words and pictures in a multimedia presentation. However, a critical question arises regarding how visually impaired or auditory impaired learners engage with multimedia learning based on this theory.

For visually impaired learners, Tactison, a multimedia learning tool specifically designed for blind individuals, can be utilized. On the other hand, deaf learners access multimedia content through sign language interpreters or synchronized text captioning in video presentations. It is worth noting that Mayer's Cognitive Theory of Multimedia Learning does not account for inclusive education, as it fails to consider learners who cannot access multimedia learning through audio or visual channels.

Therefore, considering the limitations of Mayer's theory in addressing the needs of diverse learners, I recommend adopting an advanced, modern, inclusive, and smart theoretical perspective for multimedia learning. Liu et al. (2016) proposed a theoretical model for smart learning, which serves as an open-ended, intelligent, and integrated learning space based on constructivist learning theory, blended learning theory, and modern educational approaches. This model encompasses various devices, tools, techniques, media, teaching resources, teacher communities, and learner communities. Given its comprehensive nature, this model is well-suited for addressing the learning requirements of diverse learners typically found in inclusive classrooms.

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APPENDIX A

ETHICAL CLEARANCE FROM ETHICS REVIEW COMMITTEE

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2022/02/09

Ref: **2022/02/09/ 51915987/28/AM**
Name: Ms MM Ramulumo
Student No.: 51915987

Dear Ms MM Ramulumo

Decision: Ethics Approval from 2022/02/09 to 2027/02/09

Researcher(s): Name: Ms MM Ramulumo
E-mail address: Ramulmm@unisa.ac.za
Telephone: 0763185143

Supervisor(s): Name: Prof L.E. Mnguni
E-mail address: lindelani.mnguni@wits.ac.za
Telephone: 0117172764

Title of research:

The Relationship Between Visual Literacy and Science Literacy Among English Second Language Pre-Primary School Learners

Qualification: PhD Natural Science Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2022/02/09 to 2027/02/09.

*The **medium risk** application was reviewed by the Ethics Review Committee on 2022/02/09 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

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3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the UNISA College of Education Ethics Review Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing.
6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
8. No field work activities may continue after the expiry date **2027/02/09**. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number **2022/02/09/ 51915987/28/AM** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Kind regards,

Prof AT Motlhabane
CHAIRPERSON: CEDU RERC
motlhat@unisa.ac.za

Prof PL Mabunda
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APPENDIX B

PERMISSION TO CONDUCT RESEARCH IN THE FREE STATE DEPARTMENT OF EDUCATION: MOTHEO DISTRICT

Enquiries: M.Z. Thango
Ref: Research Permission: M.M. Ramulumo
Tel. 051 404 8808
Email: MZ.Thango@fseducation.gov.za

education
Department of Education
FREE STATE PROVINCE

2958 Makgasane Street
Rocklands
Bloemfontein
9323

Dear Ms. M.M. Ramulumo

PERMISSION TO CONDUCT RESEARCH IN THE FREE STATE DEPARTMENT OF EDUCATION: MOTHEO DISTRICT

This letter serves to inform you that you have been granted permission to conduct research in the Free State Department of Education within the Motheo Education District. The details in relation to your research project with the University of South Africa are as follows:

Topic: The relationship between visual literacy and Science Literacy among English Second language Pre-primary School Learners.

1. **List of schools involved:** Olive Ridge School.
2. **Target Population:** Ten Grade R learners, five Grade 1-3 learners (Foundation Phase) and five learners in Intermediate Phase at the selected school.
3. **Period of research**: From the date of signature of this letter until 30 September 2022. Please note that the department does not allow any research to be conducted during the fourth term (quarter) of the academic year. Should you fall behind your schedule by three months to complete your research project in the approved period, you will need to apply for an extension. The researcher is expected to request permission from the school principals to conduct research at schools.
4. The approval is subject to the following conditions:
   - 4.1 The collection of data should not interfere with the normal tuition time or teaching process.
   - 4.2 A bound copy of the research document should be submitted to the Free State Department of Education, Room 101, 1st Floor, Thuto House, St. Andrew Street, Bloemfontein or can be emailed to the above-mentioned email address.
   - 4.3 You will be expected, on completion of your research study to make a presentation to the relevant stakeholders in the Department.
   - 4.4 The ethics documents must be adhered to in the discourse of your study in our department.
5. Please note that costs relating to all the conditions mentioned above are your own responsibility.

Yours Sincerely,

Mr. MZAMO W. JACOBS
DIRECTOR: QUALITY ASSURANCE, M&E AND STRATEGIC PLANNING

DATE: 03/03/2022

RESEARCH APPLICATION BY M.M. RAMULUMO, PERMISSION LETTER 03 MARCH 2022. MOTHEO DISTRICT
Strategic Planning, Research & Policy Directorate Private Bag X20565, Bloemfontein, 9300 - Thuto House, Room 101, 1st Floor, St Andrew Street, Bloemfontein

Enquiries: M.Z. Thango
Ref: Notification of research: M.M. Ramulumo
Tel. 051 404 8808
Email: MZ.Thango@fseducation.gov.za

education
Department of Education
FREE STATE PROVINCE

District Director
Motheo District

Dear Mr. Moloi

NOTIFICATION OF RESEARCH: PERMISSION TO CONDUCT RESEARCH PROJECT IN MOTHEO DISTRICT

This letter serves to inform you that Ms. M.M. Ramulumo has been granted permission to conduct research in the Motheo District under the auspices of the University of South Africa. The details in relation to the research project are as follows:

Topic: The relationship between visual literacy and Science Literacy among English Second language Pre-primary School Learners.

1. **List of schools involved:** Olive Ridge School.
2. **Target Population:** Ten Grade R learners, five Grade 1-3 learners (Foundation Phase) and five learners in Intermediate Phase at the selected school.
3. **Period of research**: From the date of signature of this letter until 30 September 2022. Please note the department does not allow any research to be conducted during the fourth term (quarter) of the academic year nor during normal school hours. The researcher is expected to request permission from the school principals to conduct research at schools.
4. **Research benefits:** The study will benefit both private and the Free State Department of Education Schools by providing them with strategies to improve learners' visual literacy skills. Furthermore educators and curriculum designers will need to make the necessary changes by can exposing learners to a wide range of tasks containing a variety of visual representation with an array of levels of abstraction and great use of visual literacy skills.
5. Strategic Planning, Policy and Research Directorate will make the necessary arrangements for the researchers to present the findings and recommendations to the relevant officials in the Department.

Yours Sincerely,

Mr. MZAMO W. JACOBS
DIRECTOR: QUALITY ASSURANCE, M&E AND STRATEGIC PLANNING

DATE: 03/03/2022

APPENDIX C

DATA COLLECTION INSTRUMENT

Section A: Demographic information

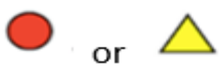
1. Age	3 years		4 years				5 years		6 years			
2. Gender	Female						Male					
3. Home language	Zulu	Xhosa	North Sotho	South Sotho	Ndebele	Venda	Tsonga	Swati	Afrikaans	English	Tswana	Other

Section B: Visual literacy

1. Patterning skill

1.1. Closed-ended item: Choose the correct missing shape in this pattern.

1

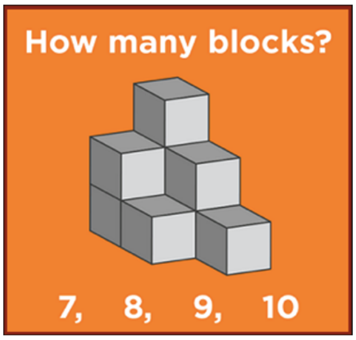


2

1.2. Open-ended item: What is your reason for choosing this answer?

2. Spatial visualization skill

2.1. Closed-ended item: How many blocks are in the picture?



1

2

2.2. Open-ended item: What is your reason for choosing this answer?

3. Visual-spatial working memory

3.1. Closed-ended item: Look at the picture on the left and redraw the picture on the folded side of the paper based on what you can remember seeing. How many apples were in the picture I showed you?

a. 2
b. 4
c. 3
d. I don't know

3.2 Open-ended item: What is your reason for choosing this answer?

4. Visual perception skill

4.1. Closed-ended item: Count how many trees at the top match with the trees at the bottom based on their shape.

a) 4

b) 5

c) 10

d) I don't know

4.2. Open-ended item: What is your reason for choosing this answer?

Section C: Science literacy

5. Life Science - Living and non-living things

5.1. Closed-ended item: Circle/choose a thing/things that are/are alive.

1

2

5.2. Open-ended item: What is your reason for choosing this answer?

6. Earth Science -Weather

6.1. Closed-ended item: Match the clothes to the weather.

1

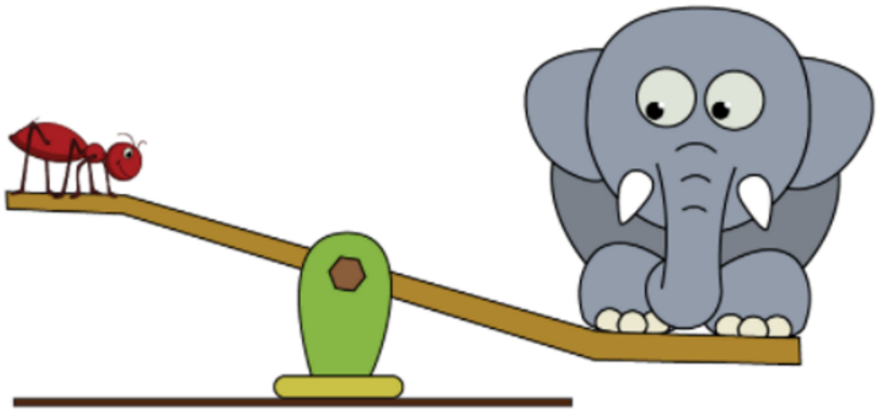
2

6.2. Open-ended item: Why does the boy need glasses and a hat when playing in the sun?

7. **Physical Science - Weight/Balance**

7.1. Closed-ended item: Circle/choose the heavier animal.

a) Ant
b) Elephant
c) I don't know



7.2. Open-ended item: What is your reason for choosing this answer?

8. Physical Science – Temperature

8.1. Closed-ended item: Circle/choose the item/thing that has a higher temperature?

1 2

3

8.2. Open-ended item: What is your reason for choosing this answer?

Section D: Scientific reasoning ability

9. Scientific tools – What is the name of the tool?

9.1. Closed-ended item: What is the name of the tool?

a) Phone

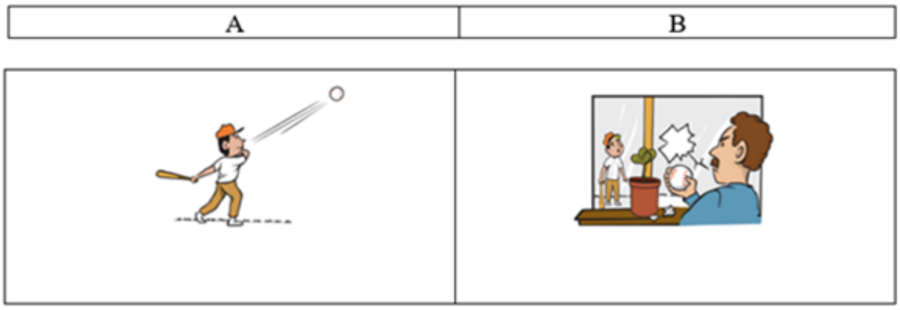
b) Thermometer

c) I don’t know

9.2. Open-ended item: What is the tool used for?

10. Claim -Making a conclusion

10.1. Closed-ended item: Looking at picture A, what happened to the ball in picture B?



a) The ball went into the sky
b) I don't know
c) The ball broke the window

10.2. Open-ended item: What is your reason for choosing this answer?

11. Premise - Logical reasoning

11.1. Close-ended item: Circle/choose the two objects that can be used together.

1

2

11.2. Open-ended items: What is your reason for choosing this answer?

12. Application of knowledge

12.1. Closed-ended item: Looking at the picture, who will most win the rope tug?

a) Parents

b) Kids

c) I don't know

12.2. Open-ended item: What is your reason for choosing this answer?

13. Evidence - Making sense of observations

13.1. Closed-ended item: Looking at the picture, what is that I can eat?

a) Yellow banana
b) Red apple
c) I don't know

13.2. Open-ended item: Why should I eat the apple?

14. Data – Analysis of data

14.1Closed-ended items: Here are Wavhudi's favourite things to do. What does he like to do the most?

a) Reading
b) Painting
c) I don't know

14.2 Open-ended item: What is your reason for choosing this answer?

APPENDIX D

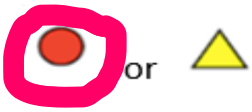
MEMORANDUM/SCORING TOOL

Section B: Visual literacy

1. Patterning skill

1.1. Closed-ended item: Choose the correct missing shape in this pattern.

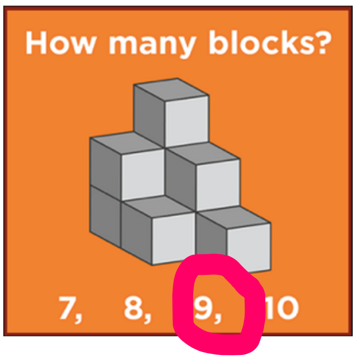
1



2

2. Spatial visualization skill

2.1. Closed-ended item: How many blocks are in the picture?



1

2

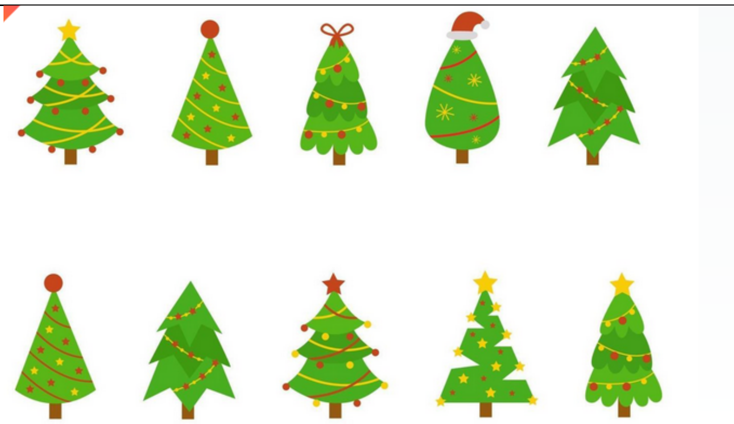
3. Visual-spatial working memory

3.1. Closed-ended item: Look at the picture on the left and redraw the picture on the folded side of the paper based on what you can remember seeing. How many apples were in the picture I showed you?

a. 2
b. 4
c. 3
d. I don't know

4. Visual perception skill

4.1. Closed-ended item: Count how many trees at the top match with the trees at the bottom based on their shape.

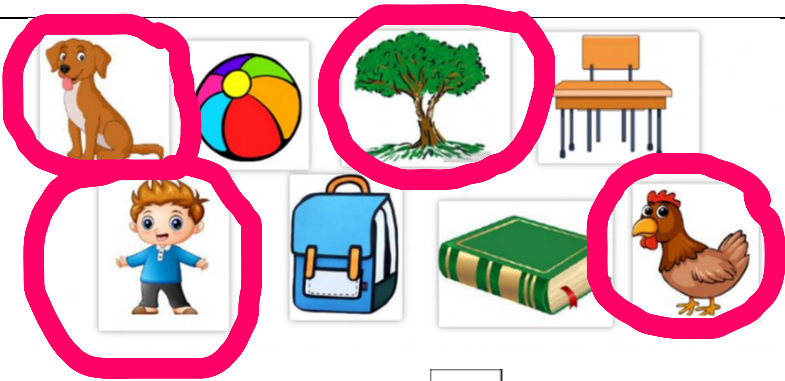


a) 4
b) 5
c) 10
d) I don't know

Section C: Science literacy

5. Life Science - Living and non-living things

5.1. Closed-ended item: Circle/choose a thing/things that are/are alive.

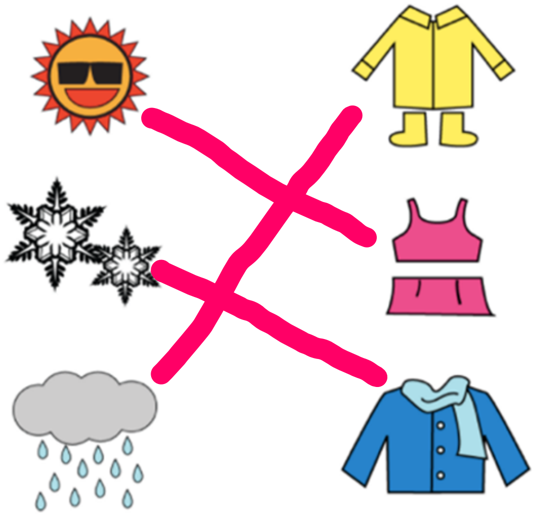


1

2

6. Earth Science -Weather

6.1. Closed-ended item: Match the clothes to the weather you would wear.



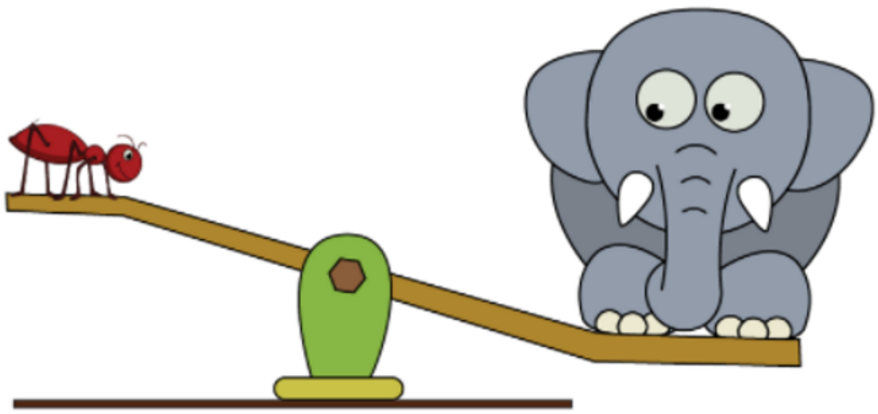
1

2

7. Physical Science - Weight/Balance

7.1. Closed-ended item: Circle/choose the heavier animal.

a) Ant
b) Elephant
c) I don't know



8. Physical Science – Temperature

8.1. Closed-ended item: Circle/choose the item/thing that has a higher temperature?

1

2

3

Section D: Scientific reasoning ability

9. Scientific tools – What is the name of the tool?

9.1. Closed-ended item: What is the name of the tool?

a) Phone

b) Thermometer

c) I don't know

10. Claim -Making a conclusion

10.1. Closed-ended item: Looking at picture A, what happened to the ball in picture B?

A	B
	

a) The ball went into the sky

b) I don't know

c) The ball broke the window

11. Premise - Logical reasoning

11.1. Close-ended item: Circle/choose the two objects that can be used together.

1

2

12. Application of knowledge

12.1. Closed-ended item: Looking at the picture, who will most win the rope tug?

a) Parents
b) Kids
c) I don't know

13. Evidence - Making sense of observations

13.1. Closed-ended item: Looking at the picture, what is that I can eat?

I can eat an apple

It is good for me

a) Yellow banana
b) Red apple
c) I don't know

***14.* Data – Analysis of data**

14.1. Closed-ended items: Here are Wavhudi's favourite things to do. What does he like to do the most?

a) Reading
b) Painting
c) I don't know