A Teacher-directed Approach to Teaching and Learning of Mathematics in Early Childhood Second Language Classrooms in South Africa

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Abstract

This article examines how a teacher-directed pedagogy applied during morning ring in early childhood classrooms (also known as morning circle time) may support the learning and teaching of mathematics to children who receive tuition in English as their second language. The study aimed to explore the impact of direct instruction on the teaching and learning of mathematics in early childhood second language classrooms through a systematic literature review, combining contextual and conceptual review methods. The literature was analysed according to three predetermined topics: 'Early childhood teaching and learning practices', 'Direct instruction', and 'Cognitive load theory.' Each topic was further examined by identifying sub-topics. This study suggests that combining teacher-directed activities using flashcards, toys, and games during the morning ring can be a dynamic and effective approach to introducing new mathematical concepts (in a second language) to children aged (3-6 years). This approach not only supports novice mathematical learning from a working memory perspective but also captures young children's attention and nurtures their early cognitive development. Due to its support of working memory, this approach provides a strong foundation for future mathematics learning in a second language while making the process enjoyable and engaging for young learners. Since morning ring time is integral to early childhood education, this article proposes strategies to bridge the gap between play-based learning and direct instruction when teaching concepts such as colors, numbers, and shapes to second-language early childhood learners. By following these guidelines, educators can better support second language learning in early childhood mathematics education.

Keywords: direct instruction, early childhood mathematics, early childhood second language classrooms, working memory, morning ring, play-based learning

1. Introduction

The teaching and learning of mathematics in early childhood is a foundational process that sets the stage for a child's mathematical development and later mathematical academic success at formal school level. At this crucial stage, teachers should use creative and practical methods to engage young minds in exploring fundamental mathematical concepts. Through activities such as counting, number recognition and exploring space, shape and colours, children begin to grasp the basic building blocks of mathematics. UNICEF Lego Foundation (2018) explains that young children are 'hands-on' learners and acquire knowledge through playful interactions with both objects and people. Teachers, therefore, play a pivotal role in introducing novice mathematical vocabulary and concepts to young learners, fostering a positive attitude towards mathematics through interactive activities and social collaboration.

Effective communication is paramount in transferring mathematical knowledge to young children, and thus, the role of language in mathematics is crucial (DG Murray Trust, 2014). It serves as the bridge that connects abstract mathematical concepts to children's developing minds (Henning, 2013; Craig & Morgan, 2015).

While the importance of using a child's first language (L1) in education has been recognised, many children in South Africa start their formal education at a disadvantage due to a mismatch between the language of teaching and learning (LoLT) and home language (Murris, 2023; Pretorius & Spaull, 2023; UNICEF Lego Foundation, 2018). According to the South African language in education policy, parents have the right to choose the language of instruction for their children (Government of South Africa, 1997). UNICEF (2016) explains while this policy has the advantage of providing space for L1 learning, it also allows for the choice of English over any of the mother tongues, a choice made frequently by parents which leads to the entrenchment of the achievement gap from the earliest years.

In particular, the transfer of mathematical concepts in early childhood is challenging when it occurs in the second language (L2) (Robertson & Graven, 2019), leading to comprehension difficulties, misinterpretation of mathematical terms, and limited vocabulary for expressing mathematical ideas accurately (Paciga, Hoffman, & Teale, 2011; Konishi, Kanero, Freeman, Golinkoff, & Hirsh-Pasek, 2014). This hinders the development of a strong mathematical foundation that persists through education (Espinas & Fuchs, 2022).

The methods teachers use in early childhood settings to support early childhood children who learn in L2 are crucial. Alisoy (2024) indicates that interactive play-based learning approaches increased learner engagement by 35%, with a notable improvement in second language comprehension. A more teacher-directed method (direct method or direct instruction) resulted in a 45% increase in overall second language proficiency among children aged 4-6 years. However, direct instruction in early childhood is often criticized for being the opposite learning pedagogy of play-based learning, the preferred pedagogy in early childhood settings (McMullen & Madelaine, 2014; Shammas, 2023). While the authors of this article acknowledge the importance of play for learning in early childhood, the value that direct instruction may add to supporting the teaching and learning of mathematics in early childhood second language classrooms in South Africa is emphasized.

In light of the foregoing, this article aims to unpack how direct instruction, combined with play-based learning, can enhance mathematics learning in early childhood settings, particularly for South Africa children engaged in learning mathematics in their second language.

2. Rationale for the Study

A specific opportunity in early childhood classrooms for learning through direct instruction is the morning ring (also called circle time) (Zaghlawan & Ostrosky, 2011). Morning ring extends beyond mere morning greetings and sharing news from home. It is a platform to foreground forthcoming lessons and convey essential information (Bustamante, Hindman, Champagne & Wasik 2018). However, the teacher's lack of structured planning for the morning ring often results in missed opportunities for meaningful engagement and skill development among young learners (Bustamante et al., 2018). This is especially prevalent where novice mathematical concepts are demonstrated to young learners during morning ring, for example, new L2 vocabulary (i.e., names of colours or shapes or counting activities).

To fully understand the value that direct instruction may add to the teaching and learning of mathematics to early childhood second language learners, the following methodology was followed.

3. Methodology

The study aimed to explore the impact of direct instruction on the teaching and learning of mathematics in early childhood second language classrooms through a systematic literature review, combining contextual and conceptual review methods. By thoroughly assessing relevant literature, the researchers positioned themselves within a framework of pertinent studies, evaluating material from a substantial body of completed work in relation to their own research concerns (Fraenkel & Wallen, 2010). As an ECD centre manager and a teacher trainer, the authors juxtaposed their concerns regarding play-based learning of mathematics in early childhood (which they acknowledge as the accepted standard for learning in early childhood) against the teaching and learning of mathematics in second language using direct instruction as teaching approach during morning ring. To fully understand the possibilities of direct instruction in second language early childhood learning and teaching of novice mathematical concepts, they used working memory (WM) and cognitive load theory as a guiding framework.

To gather the latest literature, commentaries, and current developments on the topic, the systematic review involved consulting seminal scholarly books, edited volumes and journal articles, accessed through databases such as EBSCOhost, Sabinet, Wiley, SAGE, and Taylor and Francis via the University of South Africa (UNISA) library web portal (http://www.unisa.ac.za/library). Additionally, the internet, including Google Scholar, was utilized to obtain current, diverse, and readily accessible materials. Keywords used in the search included early childhood practices, morning ring (or circle time) in early childhood classrooms, second language learning, mathematics, direct instruction, working memory (WM), phonological loop, visio-spatial sketchpad, executive functions, and cognitive load theory.

Inclusion and exclusion criteria were applied to journal articles by selecting only those published in English between 1990 and 2024. The review also included internationally published books, ensuring that older references (over 20 years old) were supported by more recent ones for verification, although some older references were seminal works on ‘working memory (WM)’ and ‘cognitive load theory’.

Hermeneutics, a philosophical approach suitable for both textual and social science research, was employed in data analysis. This interpretive method involves understanding textual materials, human behaviours, events, and circumstances. The analysis involved a dialectic process of interpreting individual elements and comprehending the text as a whole, termed the “cyclical process of ever deeper understanding” (Babbie, 2014). Hermeneutics requires detailed consideration of the texts' meanings, despite its subjective nature, which is a methodological limitation. Hermeneutics provides essential ontological insights for human interpretation and comprehension (Maree, 2016).

To achieve interpretation and comprehension, the literature was reviewed according to *contextual* and *conceptual* topics. The contextual review described ‘Early childhood teaching and learning’, ‘Teaching mathematics in second language’, and ‘Early childhood practices in the South African context’, while the conceptual review analysed ‘Direct instruction’, ‘Working memory’ and ‘Cognitive load theory’.

The keywords mentioned above were used as the main topics for analysis. These topics were examined individually, key elements were identified, and then integrated to understand how the contextual and conceptual reviews influenced each other (Walker & Avant, 2005).

The literature was analysed according to three predetermined topics: 1. ‘Early childhood teaching and learning practices’; 2. ‘Direct instruction’; and 3. ‘Cognitive load theory’. Each topic was further examined by identifying sub-topics.

For the first topic, ‘Early childhood teaching and learning practices’, sub-topics included: ‘Morning ring or circle time in early childhood classrooms’ and ‘second language mathematics education’.

The second topic namely, ‘Direct instruction’, was dissected into sub-topics, namely, ‘Working memory’ and ‘Phonological loop and visio-spatial sketchpad’.

The third topic, ‘Cognitive load theory’, focused on key elements of both direct instruction and teaching and learning of mathematics in early childhood second language.

The analysis proceeded in three phases. The *first phase* discussed the contextual topics namely ‘Early childhood teaching and learning practices’; The *second* phase considered the conceptual topics, ‘Direct instruction’ and ‘Cognitive load theory’. To complete the cyclical process for an ontological understanding of the teaching and learning of mathematics in early childhood second language classrooms using a teacher-directed approach for South African teachers, the *third* phase concluded with a discussion of and conclusion on the synergy between phase one and two. The setting of recommendations determined the end of the cyclical phase.

Permission for the study was granted by the College of Education Ethics Committee of the University of South Africa. The study, which is a literature review, did not involve human or animal participation.

4. Review findings

The findings of the review are discussed according to the three broad topics mentioned in the methodology section, namely ‘Early childhood teaching and learning practices, ‘Direct instruction’ and ‘Cognitive load theory’. This is followed by a discussion of the relationship between the topics.

4.1 Early Childhood Teaching and Learning Practices

Early childhood education emphasises the use of play-based and child-centred approaches to promote comprehensive development. These methods should establish a supportive and stimulating environment that enables children to actively explore, investigate, and participate in hands-on activities, promoting cognitive, social, physical and emotional development. Teachers play a crucial role in early childhood education by creating a supportive and dynamic learning environment, particularly in settings with linguistic diversity. Research emphasises the significance of play-based and social interactions in language acquisition, as these methods enable children to organically acquire and practise new language abilities (García & Kleifgen, 2023). Teachers have the responsibility of creating and executing curricula that are centred around play and children, while also addressing the cognitive, social, emotional, and physical requirements of young children. They serve as mentors and enablers, promoting investigation and questioning while offering the necessary support for children to develop new abilities and understanding (Melhuish, Tggart, & Siraj, 2023).

4.1.1 Second Language Mathematics Education in Early Childhood

In an ideal scenario, young children would attend early childhood programmes where the language used for teaching and learning is the child's L1. However, in South Africa, 11 officially recognised languages are spoken as a first language; English is the favoured medium of teaching in schooling. Most children are not fluent in English and are still in the process of acquiring the language when they start school (Heugh, 2023; Kotzé, Taylor & Fleisch, 2023).

Proficiency in oral language is a fundamental skill necessary for developing reading abilities, which, along with writing, are essential for all forms of learning. L1 education is widely proposed amongst researchers as the preferred language of instruction, especially at the beginning of schooling (Nishanti, 2020). But what research points out and what the South African population prefers, stand in stark contrast to one another. Gordon and Harvey (2019) found that most South Africans favour English as the language of instruction at all levels of education. Reasons for this are economic concerns as English proficiency is linked to socio-economic advancement and the lack of school resources and training required for educators in the indigenous languages (Gordon & Harvey, 2019).

Notwithstanding the emphasis for L1 education in the early years of schooling and popular preference Koyuncu, Kumpulainen and Kuusisto (2023) and Alisoy (2024) also put forward a compelling argument for introducing English as a second language in early childhood. In the modern interconnected world, proficiency in multiple languages becomes increasingly essential for communication and learning. These authors claim that introducing a second language during early childhood not only enhances linguistic skills but also contributes to cognitive, social, and cultural development.

The authors of this article do not take a stance for, or against, second language as language of instruction. What is important for the discussion in this article is that many early childhood children in South Africa attend pre-school centres where the language of instruction is different from the language spoken at home. With any number of the 11 official languages that might be spoken in one classroom, it is understandable that teachers may resort to English as the language of instruction. The focus of this article is, therefore, to support early childhood children and teachers who find themselves within this conundrum, to create an understanding of the impact of learning mathematics in a second language during the early childhood years, and to put forward methods to address the challenge.

4.1.2 Morning-Ring or Circle Time in Early Childhood Classrooms

Naude (2022) observed with a study of two second language early childhood facilities in South Africa, the poor quality of learning that often occurs during morning ring in the classrooms. As the learners at these facilities came from various language backgrounds, the learning and teaching at these facilities were English. Teachers at these facilities used ineffective practices that did not meet the learners' needs for learning in L2, for example, in one class the teacher conversed with the learners in English during the mathematics morning ring presentation, however, the learners were disengaged from the mathematics lesson as they played with their peers or spoke over the teacher in their own vernacular to their peers. In the second classroom, there was better control by the teacher over the learners, however, the learners did not participate at all but were mere 'onlookers' while the teacher did all the talking. Bustamante et al. (2018) found that the quality of learning and instruction during morning ring in early childhood facilities is poor and child engagement was 40% in classrooms in their study. Bustamante et al. (2018) suggest that even modest improvements in these areas, along with a greater emphasis on child participation, could ensure that educators maximize valuable learning opportunities during morning ring.

By using verbal and visual communication techniques, especially during morning ring in second language, teachers can make new mathematical ideas and concepts accessible and engaging to their learners (National Association for the Education of Young Children [NAEYC], 2015). Teachers must employ effective strategies such as visual aids, hands-on activities, and bilingual support to mitigate problems related to understanding the specific mathematical concepts the teacher tries to convey (Steffanson, 2013), as well as to keep learners engaged during the morning-ring presentation.

4.2 Direct Instruction

Direct instruction is a teacher-directed teaching method (SAGE, 2017). Direct instruction can be divided into two streams: Direct Instruction (capital letters) and direct instruction (lower case letters) (National Institute for Direct Instruction, 2024). Direct Instruction refers to programmes designed for optimal learner performance, while direct instruction refers to a set of variables found to be significantly related to learner performance, such as engaged time, small group instruction, and specific and immediate feedback (National Institute for Direct Instruction, 2024). For the remainder of this discussion, the authors will focus on direct instruction as an approach to learning and teaching, especially during morning ring presentations in early childhood classrooms.

4.2.1 Direct Instruction as an Approach to Learning and Teaching

Direct instruction starts with a clear and structured presentation of knowledge. Its aim is to build learners' foundational understanding, enabling them to apply and connect it with new information (National Institute for Direct Instruction, 2024). Contrary to misconceptions, direct instruction is not passive learning or mere drill-and-practice (Fisher, Frey & Hattie, 2016). It is a systematic teaching method where teachers explicitly outline learning objectives, use precise instructional language, actively monitor learner progress, and provide immediate constructive feedback (Queensland Department of Education, 2024). It differs meaningfully from rote learning, which emphasizes memorization and mechanical repetition of information (Education Hub, 2024).

Direct instruction furthermore differs from child-centred, play-based learning, as can be seen from Fig 1. below, demonstrating the relationship between different kinds of play, which put the child at the centre of learning (on the left-hand side) to more teacher-directed instruction where the teacher leads the process of learning (opposite end).

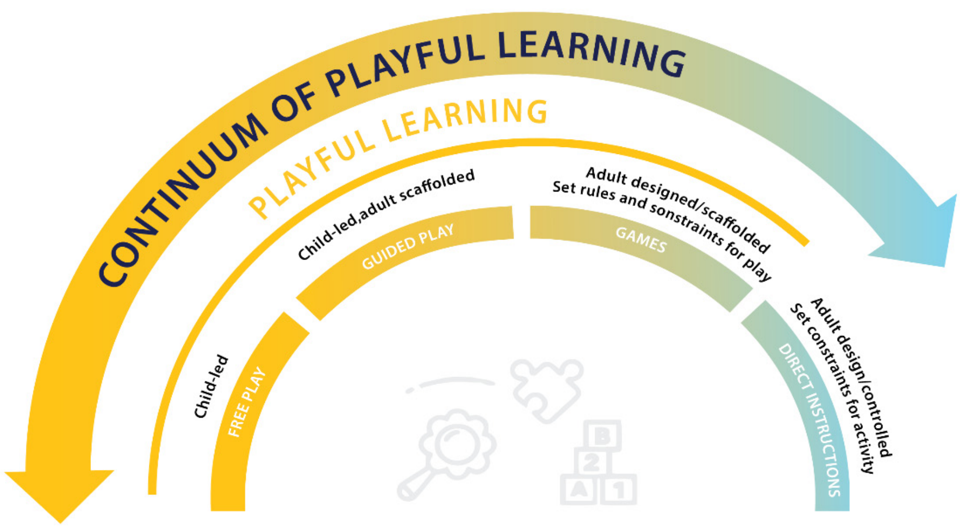

Figure 1. Continuum of Playful Learning Source: UNICEF Lego Foundation (2018)

Figure 1 shows the different levels of child-adult involvement in playful experiences – at one end, free play gives children the freedom to play, explore, and discover. This progresses towards more guided or structured play with adult participation (UNICEF Lego Foundation, 2018). Direct instruction may furthermore be seen by some proponents in early childhood teaching as an inflexible approach to education because of its structured framework (Fisher et al., 2016).

In the context of early childhood classrooms, Queensland Government (2024), in Australia, however reports that direct instruction proves to be a good strategy for learning when utilized for brief intervals to impart particular knowledge. For instance, teaching letter/sound knowledge, an essential element in the journey of learning to read, exemplifies its efficacy. Direct instruction is also intended to introduce new skill sets and knowledge that young learners acquire, replicate and with practise, transfer to new learning situations. When applying teacher directed instruction to early childhood learning, teachers typically make decisions in relation to the presentation of content (i.e., whole class learning, small groups instruction or individual instruction), the resources to be used (i.e flashcards, rhymes and concrete materials) and the choice of instructional language to be used to ensure the goal of the learning activity is reached (Queensland Government, 2024).

Using direct instruction as pedagogical approach with early childhood learners implies that the learning experience has a clearly stated purpose, the learning task is short with a concentrated focus on the skill to be developed, and that feedback is immediate and specific to ensure mastery of skill (Queensland Government, 2024). A typical example of such an activity will be when the teacher demonstrates to learners the counting out of objects in a one-to-one correspondence style. By breaking down mathematical learning into manageable tasks or skills, teachers reduce the cognitive load in the minds of the learners, thereby supporting WM, and facilitate the absorption of mathematical concepts (Shvartsman & Shaul, 2023). Effective direct instruction, tailored to the capacities of WM, proves instrumental in nurturing mathematical proficiency in early childhood (Cockroft, 2015).

4.2.2 Working Memory

To establish mathematical proficiency in early childhood second language, the child will rely heavily on the executive functions (EF) in the brain. EF is an over-arching term that includes the higher-order processes (Cristofori, Cohen-Zimerman & Grafman, 2019; Kumar & Singh, 2020). Most neurocognitive scientists define these higher-order processes as WM, planning, goal-directed action, resistance to distraction, problem-solving, strategy development and the adaptation of actions to meet task demands (Cristofori et al., 2019; Kumar & Singh, 2020). The EF of children matures over time due to the growth of the neuro-substrates of the frontal lobes and the associated increase of interconnected regions in the brain (Cristofori et al., 2019). A mature executive function implies that the learner is able to hold information in the mind (memory) while manipulating that information and acting upon it out of choice rather than impulse (Cristofori et al., 2019).

Kumar and Singh (2020) cogently express the view that memory is at the heart of executive function. The 'workstation' in the mind where all the relevant information is kept while working on a task is called the working memory (WM) (Cockroft, 2015). WM can, therefore, perhaps best be defined as the ability that humans possess that enables them to temporarily hold information in the conscious mind while simultaneously working on a relevant task (Baddeley, 2000; Cockroft, 2015).

Two well-known models, namely those by Baddeley and Hitch (1974) and Cowan (1995), explain the composition and role of WM in human thought processes (Baddeley, Hitch & Allen, 2020). The term 'WM' is, however, most commonly attributed to Baddeley and Hitch, who developed the concept extensively in their 1974 multicomponent WM model. This model was subsequently revised in 2000 (Baddeley, 2000). This article draws mainly on the multicomponent model of Baddeley and Hitch since their model has proved most successful for investigations regarding WM (Visu-Petra, Cheie, & Benga, 2007). Thus, WM plays an important role in all learning tasks that take place in a classroom. How WM works and relates to the teaching and learning of mathematics is discussed in the next paragraph, which analyses the composition of the memory systems of the brain with a focus on WM and its function in the learning process.

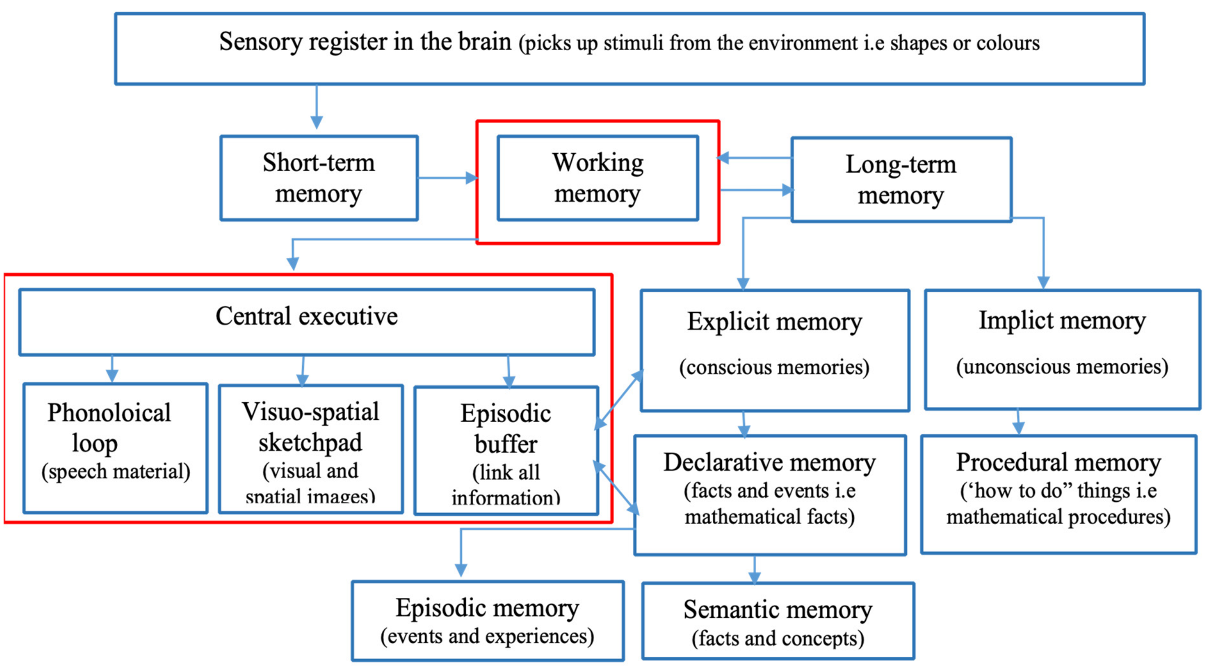

Figure 2. Memory Systems in the Brain

Source: Constructed by author based on Squire (2009)

Many memory systems in the brain work in tandem to support a learner's adaptation to their environment (Squire, 2009). Each of these memory systems is located or activated in a different part of the brain. Although it goes beyond the scope of this article to go into full detail about each memory system, cognisance is taken of the most rudimentary memory systems of the young learner in order to understand the important role that WM memory plays in all the thought processes that take place when learners remember, plan and organize. Figure 2 provides an overview of the different kinds of memory systems in the brain.

Based on the explanations provided by numerous cognitive scientists (Baddeley, 2003; Chai, Abd Hamid & Abdullah, 2018; Cowan, 2022), the multicomponent model of WM, as proposed by Baddeley and Hitch (1974), describes WM as comprising a central executive that functions as an attention control system. This central executive is supported by several 'slave systems': the phonological loop, which assists in verbal language acquisition, such as learning new words, especially during the preschool years; the visio-spatial sketchpad, which helps process visual and spatial stimuli; and the episodic buffer, which acts as a passive store where information from various sources, like visual and auditory data, is integrated. All these components are equally important for early childhood learners to learn mathematics as each of these systems are influenced by the way teachers present information to young learners, especially in the case where early childhood children access new mathematical information through their second language. Successful teaching and learning of mathematics in the second language require teachers who understand the importance of WM and support their learners in building strong memory representation (De Vita, Costa, Tomasetto & Passolunghi et al., 2022).

The aim of information entering the brain is to be stored in long-term memory – a storage system with unlimited capacity (Namaziandost & Ziafar, 2020; Forsberg, Guitard & Cowan, 2021). When WM has made sense of newly received information from the sensory register, it is passed on to the long-term memory to be stored until it is called upon again by the WM to be used. Long-term memory stores this information in schemas (Guo & Wang, 2022). A schema can be seen as a framework for the mind to remember information (Wirzberger, Herms, Esmaeili, Maximilian, & Günter, 2018; Webb & Dennis, 2020). Humans form schemas through perceptions we gain from our experiences and these perceptions can be altered depending on the kinds of experiences we have. When new schemas are formed or existing schemas in long-term memory are altered, learning occurs (Guo & Wang, 2022).

According to schema theory (Guo & Wang, 2022), children progressively construct more intricate schemas as they deepen existing knowledge over time by integrating newly acquired information with existing knowledge. This process of schema construction involves automation, where information is processed automatically with minimal conscious effort after extensive practice (Wirzberger et al., 2018). Automation of concepts in return reduces the burden on WM because when information can be accessed automatically, the WM is freed up to process new information (Martin, 2016). Although there is a limit on the amount of schema WM can take at any specific time, the complexity level of each single schema does not matter (Guo & Wang, 2022). The complexity of these schemata differs from person to person depending on exposure and experience (Wirzberger et al., 2018; Guo & Wang, 2022).

The ultimate purpose of schemata is to help humans to reduce an infinite number of unattached strays of information into categorized 'pockets' that are stored as whole entities in long-term memory thereby reducing the risk of overload of information (Wirzberger et al., 2018; Guo & Wang, 2022). It is postulated that knowledge of WM sheds light on the way humans acquire knowledge and remember while enabling teachers to link the possible causes of barriers to learning to an overload of the WM (Wirzberger et al., 2018; Guo & Wang, 2022), especially where the learning of mathematics is concerned (Goldstein & Naglieri, 2014).

The methods teachers use when teaching learners in their second language have a definite impact on learner's cognitive processes in mathematics and language acquisition. WM plays a pivotal role in mathematical learning, impacting both the initial phases of acquiring number knowledge and the subsequent development of problem-solving abilities (De Vita, Costa, Tamasetto, Passohunghi, 2022). Learners of all ages depend on their memory systems in the brain in order to learn mathematics and without the ability to store and retrieve information, mathematical activities will be an arduous task (Dehn, 2008).

Numerous researchers (Baddeley, 2020; Weil, 2011) explain that WM is a fundamental cognitive function that holds immense significance in the development of early childhood children. The WM system enables young learners to temporarily store and manipulate information, making it crucial for tasks like following instructions, problem-solving, and understanding complex concepts. As children explore their environment and engage in learning experiences, their WM is continually challenged and refined. Activities that require memory retrieval, such as counting, recognizing patterns, and recalling information, exercise this cognitive skill and facilitate intellectual growth.

Although evidence shows that high-quality preschool experiences can build language and mathematics competencies during morning circle presentations, Bustamante et al. (2018) and Naude (2022) point out that the quality of a teachers' instruction during morning circle time, is often extremely poor. Keeping in mind the importance of WM when new mathematical concepts and vocabulary are presented to early childhood learners, coupled with the complexities of second language and its impact on WM during education in early childhood, the question arises how early childhood teachers effectively present mathematical concepts such as colours, numbers, and shapes to second language early childhood learners during morning circle time. To provide an answer to this question, it is important to first understand what systems exist in the mind that play a role when learning mathematics in a second language.

In the next paragraph, the phonological loop and the visio-spatial sketch pad will be discussed as these components of WM are of central importance for the learning of new vocabulary, specifically the learning of mathematical vocabulary during the pre-school years in the second language.

4.2.3 Phonological Loop and Visio-Spatial Sketch Pad

In terms of language acquisition, research has established strong connections between the phonological loop and the learning of vocabulary in both L1 and second language (Stevenson et al., 2014; White 2020). The phonological loop is a component of the WM model responsible for the temporary storage and manipulation of verbal and auditory information. The phonological loop, which connects phonological memory and vocabulary acquisition, appears to be operational from the early stages of language development (Cockroft, 2015; White, 2020).

The phonological loop consists of two parts: the phonological store, which holds spoken words for a short duration, and the articulatory rehearsal process, which allows for the subvocal repetition of words to keep them in memory (Baddeley & Hitch, 1974; Baddeley, 2000; White, 2020). This system is crucial for tasks such as language comprehension, learning new vocabulary, and performing mental mathematics. A child's ability to learn new words is significantly influenced by the capacity of their phonological loop, along with their existing language knowledge stored in long-term memory (Cockroft, 2015; White, 2020). When faced with unfamiliar phonological forms that lack supporting stored knowledge, the child must rely entirely on the phonological loop system to temporarily store the phonological material while more stable long-term phonological representations are established.

Baddeley and Hitch (1974) explain that the phonological loop in the WM is responsible for processing and storing new verbal material and plays a central role in the acquisition of unfamiliar sound sequences such as new words. Weil (2011) confirms this premise of Baddeley and Hitch by concluding that the larger the phonological loop of toddlers 24 to 30 months old, the larger the toddler's vocabulary size. It is also applicable to a toddler's ability to remember new words. When a preschool learner hears a new word for the first time, he or she needs to link the word (label) to the word's meaning and referent in the long-term memory. This process is called fast mapping (Jackson, Leitão, Claessen, & Boyes, 2021). According to fast-mapping learning theory the learner will initially have an incomplete interpretation of the new word and its associated meaning but with repeated exposure to the word, the information regarding the word in the long-term memory system is deepened to the extent that the learner has a more complete concept of the word (semantic knowledge) that can easily be used for future reference (Jackson, Bailey, Barnes & Partee, 2021). Vlach and Sandhofer (2012) confirm that pre-school learners undergo a process of fast-mapping when they hear an unfamiliar word for the first time. However, they emphasize that pre-schoolers will forget the fast-mapped word if it is not repeated over time. The research conducted by Vlach and Sandhofer (2012) explains that important information that is repeated over time necessitates the retrieval of previous knowledge from long-term memory. If learners retrieve existing knowledge repeatedly, forgetting this important information will appear at a slower rate which ultimately promotes learning (Vlach & Sandhofer, 2012).

Long-term memory supports the phonological loop by supplying it with existing knowledge of specific words that the phonological loop encounters (Baddeley 2000; Baddeley & Hitch, 1974; Dil, Fonolojik, Kelime, Uzun, Bellek, 2016). If long-term memory can supply the phonological loop quickly and easily with existing knowledge about a word, the phonological loop integrates the existing knowledge with the new information and will pass this newly formed knowledge about the word, back to the long-term memory to be stored again, thus enabling the phonological loop to hold less words at a time. The less congested the phonological loop, the faster and easier the reference process will become (Dil, Fonolojik, Uzun, Bellek, 2016) and the easier and more effective the learning process will become.

At the practical level in the classroom, this implies that the faster and easier the reference process, the more effective the learning process becomes for the learner, as the phonological loop has more space left to attend to new words and their meanings (Dil et al, 2016). Successful fast-mapping paradigms often require word-learning activities that promote memory retention through the prominence of the labelled object with regard to other objects, repetition of the labelled object (the object is labelled up to nine times) and the engagement of the learners in the mapping process (Vlach & Sandhofer, 2012).

As discussed above, the phonological loop is only one component of WM, albeit an extremely important component. The second component that plays a critical role in the pre-schooler's memory is the visio-spatial sketchpad. According to the multi-component model of Baddeley, Hitch & Allen (2020), the visio-spatial sketchpad is responsible for a learner's memory tasks that usually involve the retention of either spatial or visual information (McGonnell, Orr, Backman, Johnson, Davidson & Corkum, 2024). The visio-spatial sketchpad is responsible for the rehearsing of items from long-term memory in the form of visual images of how and where they would occur in the learner's visual field (McGonnell et al., 2024). The function of the visio-spatial sketchpad is better described as remembering the 'what' (features) of an object (i.e., the colour or the shape/form of the image or object) as well as the 'where' of the object i.e., where has it been seen (SAGE, 2011). A strong visio-spatial sketchpad WM in young learners constitutes well-established counting skills and rapid recognition of small numbers (numbers 1-9) (McGonnell, Orr, Backman, Johnson, Davidson, Corkum, 2024).

The above paragraphs explain the systems in the mind that play a role in early childhood learners' acquisition of mathematical skills and the influence of second language learning. Although intricately related, each system plays an important role in how young learners try to make sense of their world. While they learn mathematical vocabulary and link it to images in the mind, they simultaneously must plan mathematical strategies, stay focused on the task at hand, exhibit control and monitor their way of thinking to find solutions to mathematical problems.

Knowledge of the role of these systems in early childhood mathematics learning is important information for early childhood teachers as it contributes to the teacher's understanding of the appropriate methods and activities suitable for young learners to learn and discover the mathematical world (McGonnell et al., 2024). Not only is it important for teachers to understand the relation of the different systems, but teachers also need to be aware of the limitations placed on each of these systems if it is overloaded by environmental stimuli.

In the next part of the article, the cognitive load of the WM will be discussed with reference to the cognitive load theory. This theory is primarily interested in ways how instruction in the classroom can be planned to reduce the cognitive load of the WM.

4.3 Cognitive Load Theory

Cognitive load theory posits that cognitive capacity in WM is limited and if a learning task requires too much cognitive capacity, learning will be hampered (Pack, Choi & Kim, 2023). To give meaning to, understand and adapt to the environment, humans place a high premise on the ability to store (and retrieve) seemingly unlimited amounts of information in long-term memory (Kirshner, Kirchner & Paas, 2009). This is possible with the support of WM, which holds new information while the brain works on retrieving previous information and linking it to the new information in WM. Cognitive load theory holds the principle that due to the limited space available for WM to retain information, complex instruction can easily place a high demand on WM memory, which will contribute to an overload when WM cannot hold all the information required from long-term memory to solve problems or to make sense of new information (Kirshner et al., 2009). When an overload of information occurs in WM (extraneous cognitive load), some information passed on by the long-term memory will eventually get lost, resulting in less learning (Pack et al., 2023).

Learners who learn mathematics in their second language while simultaneously learning new vocabulary and language forms experience a higher cognitive load of the WM, which results in these learners taking more time to learn mathematics than their peers who learn mathematics in their L1 (Harris & Petersen, 2017; Robertson & Graven, 2019). If WM is overloaded, there is a greater risk that the learner will not understand the concept being introduced, will be misinterpreted or confused, will not be effectively encoded in long-term memory, and learning will be slowed down (Martin, 2016). It is therefore important for teachers to note that classroom instruction should be designed in such a way that the least possible chance for an overload of information exist.

It is imperative for mathematics teachers of second language learners, especially in the early years of learning when new vocabulary is established for effective communication, to seriously consider the direct teaching of mathematical vocabulary to reduce extraneous cognitive load (Shammas, 2023). At preschool level this may implicate for example, the direct teaching of number names, colours and the names of basic shapes in the second language.

To overcome the overload of burden to WM, direct instruction is suggested as one approach that supports the formation of schemas in the minds of young children. According to Martin (2016) decades of research show that when teaching novice concepts and skills, it will be more effective when offering clear guidance along with ample opportunities for practice and feedback to progress the automation of newly learnt information (in the case of this article, new vocabulary and mathematical skills), rather than expecting learners to discover much of the content and skills on their own.

One particularly useful strategy to implement direct instruction during morning ring in early childhood classrooms is put forward by Naude (2022). Understanding the underlying cognitive structures that play a role in learning, Naude (2022) posits that when direct instruction is used selectively and effectively during morning ring presentations in support of WM, and in view of reducing extraneous cognitive load, fruitful activities can be designed for optimal learning in second language education. Following the above description of direct instruction presentations put forward by NAEYC (2015), Naude (2022) explains that using a technique called 'the isolation of concepts' can add value to reducing extraneous cognitive load when presenting novice concepts such as names of shapes, colours and numbers in the second language to early childhood learners. This technique suggests that when introducing new concepts, for example, new shapes to learners, all the shapes should be in a single colour. That way, WM only has to take note of the shapes to be learnt and not be confused with a range of colours. The opposite also rings true. If new colours are to be learnt, teachers can use a single shape, for example, coloured circles, to introduce the names of colours to the learners. In that sense, WM only takes note of the new colour names and cannot be distracted by a range of shapes attached to the colours. These should be brief sessions of learning to be repeated often to ensure reinforcement and, subsequently, integration of this newly acquired knowledge with the schemas already existing in the child's first language will take place.

The authors of this article concur with this statement. However, they also wish to highlight that it is crucial to acknowledge that not all facets of explicit instruction can be consistently employed in classroom instruction, particularly in early childhood (Naude, 2022; Shammas, 2023). According to Naude (2022), it is recommended that learners have the chance to collaborate in groups and engage in independent exploration. However, this should primarily serve as a way to practise newly acquired content and skills, particularly vocabulary related to mathematical concepts in the second language, such as colours, numbers, and shapes. It is advised not to rely solely on young children to discover information in the second language independently.

Utilising targeted direct instruction specifically designed to align with the limitations of WM is crucial in fostering mathematical proficiency in a second language during early childhood.

The next page summarises the topics and sub-topics of the study's findings and explains the relationship between the topics and the sub-topics.

Table 1. Summary of the Findings and the Relationship between the Topics and Sub-Topics

Findings of the review according to the three topics		
Topic 1: **Early childhood teaching and learning practices**	**Topic 2:** **Direct instruction**	**Topic 3:** **Cognitive load theory**
Many early childhood children in South Africa attend pre-school centres where the language of instruction differs from the language spoken at home. Early Childhood teachers in South Africa evert to English as the Language of Learning and Teaching at these facilities. Poor quality of learning often occurs during morning ring in these classrooms as Teachers at these facilities use ineffective practices that do not meet the learners' needs for learning mathematics in their second language.	With this study, direct instruction refers to a set of variables found to be significantly related to learner performance, such as engaged time, small group instruction, and specific learning and instructional strategies. To demonstrate the impact of direct instruction on early childhood learning, Working Memory (WM), the Phonological Loop and the Visio-Sketchpad in the mind of learners are used as the framework for the study. This creates an understanding of the position early childhood ESL learners find themselves in during morning ring mathematics presentations and the subsequent role improved teaching approaches, such as direct instruction, may render.	Cognitive load theory is directly linked to direct instruction as an approach to learning and teaching. It holds the principle that due to the limited space available for WM to hold information, complex instruction can easily place a high demand on WM memory which will contribute to an overload when WM cannot hold all the information required from long-term memory to solve problems or to make sense of new information. When an overload of information occurs in WM (extraneous cognitive load), some information passed on by the long-term memory will eventually get lost resulting in less learning taking place.

Findings of the review of the sub-topics					
Topic 1 Early childhood teaching and learning practices	**Topic 1** Early childhood teaching and learning practices	**Topic 2** Direct instruction	**Topic 2** Direct instruction	**Topic 2** Direct instruction	**Topic 3** Cognitive load theory
Sub-topic Second language mathematics education	**Sub-topic** Morning Ring	**Sub-topic** Working memory (WM)	**Sub-topic** Phonological loop	**Sub-topic** Visio-spatial sketchpad	
Enhance students' understanding of new mathematical concepts in their second language through bi-lingual communication strategies during the morning ring.	Effective bi-lingual communication strategies for morning ring presentations include visual aids and hands-on activities.	WM enables students to hold and manipulate numerical information. Learning mathematics in the second language may hamper working memory by the need to switch between languages.	Assists in verbal language acquisition, such as learning new words, especially during the preschool years.	Helps students to process visual and spatial stimuli.	Second language learning of mathematics potentially leads to increased cognitive load on WM which my result in slower processing of mathematical information. Using effective Direct Instruction strategies during morning ring math presentations may potentially reduce or prevent cognitive load (overload). ESL communication strategies such as visual aids and hands-on activities can be used to support WM, and reduce cognitive overload.

5. Discussion of the Findings

Early childhood teachers are being cautioned by researchers that the transfer of mathematical concepts can be difficult for young children when they have to use their second language to access these concepts. Language barriers can cause various problems, such as difficulties in understanding, misinterpretation of mathematical terms, and a limited vocabulary for accurately expressing mathematical ideas (Konishi et al., 2014; Robertson & Graven, 2019).

Whenever children learn mathematics in their second language, they face the challenge of learning new mathematics vocabulary and language structures all at once. This increases the cognitive load on their WM, causing them to take longer to learn mathematics compared to their peers who learn mathematics in their L1 (Robertson & Graven, 2019). When the capacity of WM is exceeded, there is an increased likelihood that children will not comprehend the introduced concept, may misinterpret or confuse it, fail to successfully store it in long-term memory, and experience a slowdown in the learning process (Martin, 2016).

These obstacles can impede the establishment of a robust mathematical base and result in enduring misconceptions across subsequent years of education (Harris & Petersen, 2017). Graig and Morgan (2015) remind us that effective communication is paramount in transferring mathematical knowledge to young children as it serves as the bridge that connects abstract mathematical concepts to the developing minds of young children. Teachers should be aware that classroom communication and instruction must be carefully designed to minimise the likelihood of information overload (Kirshner et al., 2009).

By utilising teacher-directed instruction where a specific goal is clearly defined, the learning task is brief, centred on developing a specific skill and feedback is provided promptly (Queensland Government, 2024). Thus, as an approach for teaching mathematics in a second language to young children, teachers can decrease the cognitive load on learners' minds and enhance their WM by breaking down mathematical learning into smaller tasks or skills. This approach will also help young learners to absorb mathematical concepts more easily (Shvartsman & Shaul, 2023). Targeted direct instruction, specifically designed to align with the limitations of WM, is crucial in fostering mathematical proficiency throughout early childhood.

Morning circle time in early childhood classrooms can be one specific moment in the day when teachers can effectively introduce and reinforce new mathematical concepts and related vocabulary to young learners receiving instruction in their second language. Chien, Howes, Burchinal, Pianta, Ritchie, Bryant, Clifford, Early & Barbarin (2010) as well as Zaghlawan and Ostrosky (2011) are of the opinion that in early childhood classrooms, circle time presents a valuable opportunity for direct teaching, especially in the case of second language learning. NAEYC (2015) explains that young children need both direct instruction and hands-on exploration as both approaches work best in different situations. As an example of how direct instruction can be used as an appropriate approach to learning and teaching in early childhood settings, NAEYC (2015) explains that the teacher will typically introduce the new concept during circle time by reading a story, followed by a discussion with learners on the concept to be learned. This concept is then extended by showing/demonstrating to the learners how they will explore the concept further in the manipulative centre/corner, the art centre/corner, the literacy centre/corner, the movement centre/corner et cetera.

Adding to the above suggestion, Naude (2022) argues that selective and effective use of direct instruction during circle time presentations can optimize mathematics learning in second language education by supporting WM and reducing extraneous cognitive load. Naude (2022) supports NAEYC’s (2015) recommendation by advocating one specific direct-instruction technique known as the isolation of concepts. The isolation of concepts involves introducing new mathematical concepts using flash cards in a simplified manner thereby reducing extraneous cognitive load, for example, when teaching new shapes, all shapes on the flash cards should be presented in a single colour to avoid confusion (and by implication extraneous cognitive load). As well, when teaching new colours, a single shape should be used in conjunction with the different colours to be explored (for example green circle, red, circle, blue circle). Naude (2022) further suggests that these flash card exercises should be kept very short to support the short attention span of early childhood learners. By keeping these circle time sessions short, the repeated sessions help reinforce and integrate new knowledge with existing schemas in the child's long-term memory. Naude (2022) further concurs with NAEYC (2015) by suggesting that these short flash card sessions during circle time should be followed by games and activities that give learners the opportunity to explore their newly gained knowledge during art, construction building with blocks, or even movement games where the newly acquired knowledge is further reinforced and integrated with existing schemas in the mind of the child through concrete hands-on activities.

To summarise, direct instruction in mathematics can benefit early childhood second language learners by reducing cognitive burden on their WM. This, in turn, facilitates the development of a solid long-term mathematical vocabulary in their second language.

6. Conclusion

The teaching of mathematics to young children who are second language learners presents a complex cognitive challenge, primarily due to the dual demand of acquiring both mathematical and linguistic competencies simultaneously. As evidenced in the literature, this duality places significant strain on early childhood English Second Language children's working memory, often leading to misunderstandings and long-term misconceptions if not appropriately addressed. To mitigate these challenges, targeted direct instruction—especially during structured morning circle time—emerges as an effective pedagogical approach in the learning and teaching of mathematics. This approach not only simplifies the learning process by isolating mathematical concepts thereby reducing extraneous cognitive load, but also strengthens the retention and transfer of mathematical knowledge through repetition and hands-on reinforcement activities. By integrating techniques such as the use of flash cards and controlled visual stimuli, early childhood teachers can enhance second language early childhood children’s' capacity to process and internalise foundational mathematical concepts. Consequently, thoughtful and research-informed direct instruction holds the potential to significantly improve mathematical outcomes and equity in early childhood education settings, particularly in linguistically diverse contexts such as South Africa.

7. Significance of the Study

This study is crucial in addressing the complex relationship between language acquisition and mathematical learning for young second language learners. By highlighting the cognitive strain on working memory and the risk of long-term misconceptions, the research underscores the need for targeted instructional strategies. The findings demonstrate the effectiveness of structured direct instruction—particularly during morning circle time—in minimizing cognitive overload and enhancing knowledge retention through repetition and visual reinforcement. Moreover, the study offers practical, research-backed solutions, such as the use of flashcards and controlled visual stimuli, enabling early childhood educators to foster foundational mathematical understanding more effectively. By advocating for thoughtful and inclusive teaching practices, this research contributes to improving mathematical outcomes and advancing equity in early childhood education, particularly in linguistically diverse settings like South Africa.

8. Recommendations

This study highlights the importance of direct instruction during morning ring or circle time for enhancing second language mathematics education in early childhood classrooms. To implement these findings, the following are recommended:

Training for educators: Conduct professional development workshops to train early childhood teachers on the effective use of direct instruction during morning circle time, focusing on techniques to reduce extraneous cognitive load and enhance WM.

Curriculum development: Integrate the isolation of concepts technique into existing early childhood curriculums. For example, when introducing new shapes, ensure all shapes are of a single colour to avoid confusion among young learners.

Resource allocation: Provide classrooms with uniform-coloured shapes and other necessary materials to support the isolation of concepts technique and to ensure reinforcement of concepts in aid of strengthening learning. Ensure that these resources are readily available and easy to use.

Adopt structured circle time: Schools should adopt a structured approach to morning circle time, incorporating techniques like the isolation of concepts to enhance second language learning.

Further research: Future research should explore the long-term impact of structured circle time on second language acquisition and cognitive development in early childhood.

By following these guidelines, educators and policymakers can better support second language learning in early childhood mathematics education, ultimately leading to improved educational outcomes in South Africa.

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Authors contributions

Dr. Naudè and Prof. Meier were jointly responsible for the design of the study and its critical revision throughout the research process. Dr. Naude conducted the data collection and was the primary author of the initial manuscript draft. Prof. Meier provided substantial revisions to enhance the academic quality and coherence of the manuscript. Both authors read and approved the final version of the manuscript. There were no special agreements concerning authorship; contributions were distributed according to the roles described, and both authors acknowledge and agree upon the order of authorship as reflective of their respective contributions.

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