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Teaching “bridging-through-10” as a mental calculation strategy to improve grade 4 learners’ number sense: Insights of cognitive neuroscience

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Abstract

Mathematics teachers' cognitive closure increases as they struggle to understand how learners process mathematics in their minds when teaching mental calculation strategies (bridging through ten) to improve number sense. This paper seeks to use the insights of cognitive neuroscience to teach "bridging-through-10" as a mental calculation strategy to improve grade 4 learners' number sense. This qualitative study followed a participatory action research design to provide an intervention to two mathematics teachers about teaching bridging-through-10 as a mental calculation strategy to grade 4 learners in two weeks (10 days). Data were collected using the Ballard pretest, the Discussion forum, and the Ballard posttest. Data from the pretest and posttest were analysed descriptively. At the same time, narrative analysis was used to analyse data from the discussion forum. The findings revealed that the decrease in one mathematics teacher's cognitive closure due to cognitive neuroscience insights, with bridging through ten as a mental calculation strategy, improved learners' number sense. At the same time, there was no improvement in learners' number sense with the mathematics teacher, with increased cognitive closure and fewer cognitive neuroscience insights. This study concludes that bridging through 10 strategies with the insights of cognitive neuroscience can be used in grade 4 mathematics to improve learners' number sense. We argued that cognitive load in mathematics content and presentation must be decreased by breaking down mathematics content into manageable chunks to help learners develop number sense.

Keywords:
Bridging through 10, Cognitive neuroscience insights, Mental calculation strategies

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1. INTRODUCTION

Mathematics teachers frequently understand the steps for computations, such as number addition, number multiplication, or applying algorithms. However, comprehending how learners process these problems mentally is significantly more challenging. It is becoming clear that teachers need to understand how the brain works to help in learning (Looi et al., 2016). There is limited information regarding what the official Initial Teacher Training (ITT) provides in terms of brain research and whether it aligns with scientific standards (Rato et al., 2022). Undoubtedly, mental calculation strategies, including bridging through 10, are taught to primary school learners, especially grade 4 learners. However, Mental calculation strategies are essential for fostering number sense and adaptable thinking, yet they are frequently overlooked in favor of written algorithms (Pjanić et al., 2025). This paper sought to use the insights of cognitive neuroscience to teach "bridging-through-10" as a mental calculation strategy to improve grade 4 learners' number sense. A study by Van Opstal et al. (2012) investigated cognitive neuroscience and mathematical processing, looking at the foundations of number processing. These aspects serve as the basis for cognitive neuroscience insights for this study. The mental calculation strategy used in this study is bridging through 10, which has been a challenge not only in South Africa but worldwide. Learners may have been born with a basic sense of numbers, but when they get to school, many of them find learning and memorising multiple facts on how to add, subtract, multiply, and divide numbers quickly and accurately difficult (Sousa, 2015). However, modern technology and research have provided teachers, researchers, and scientists with the ability to better understand cognitive neuroscience, meaning "how the brain learns" and how learners learn mathematics (Ansari et al., 2011; De Smedt et al., 2010).

This study, grounded in cognitive neuroscience, aims to introduce motivation as a central factor in the creation and flow of knowledge in children's minds. To achieve this, we briefly review the cognitive neuroscience concept of mindfulness and its crucial role in helping fourth-grade students who struggle with number sense. Then, we demonstrate how this concept can help the research community to better understand how focusing on emotion can improve the teaching and learning of Mathematics, especially in a developing country like South Africa, where 80% of learners perform well below what is generally expected for the grade they are in (Schollar, 2015).

1.1. Cognitive neuroscience and "bridging-through-10" as a mental calculation strategy

Gersten and Chard (1999), identified five levels of development to help teachers determine their learners' level of number sense. This study used the five levels of number sense by Gersten and Chard to identify the level of number sense presented by Grade 4 learners after the intervention.

In **Level 1**, learners have not yet developed number sense beyond their innate abilities (INS). In addition, the innate capacity to recognise and distinguish between magnitudes is known as approximation number sense (ANS) (Whitacre et al., 2020), which is linked to all five levels of number sense. is a set of neurological abilities that is common to humans and some animals (Whitacre et al., 2020). **Level 2**: Learners are starting to acquire number sense. They understand the difference between "less than" and "more than" and terminology such as "lots of" and specific numbers. For example, "five", etc (Sousa, 2015). **Level 3**: Learners fully understand "more than" and "less than" and can-do basic computation using their fingers also referred to as early number sense (ENS). According to Whitacre et al. (2017), ENS includes the learned skill that involves explicit number knowledge such as number knowledge such as counting numbers of words and comparing numbers represented symbolically and as numerals. **Level 4**: Learners at this stage make use of "counting up" or "counting down" instead of "counting all" to do calculations. They do not have to count to five, because they know it exists. If they can count accurately at this stage, they can solve any digit problem (Sousa, 2015). **Level 5**: At this stage, learners make use of retrieval strategies to solve problems also referred to as mature number sense (MNS). The MNS involves a multidigit and rational number sense, including studies that focus on primary and secondary school learners, and preservice teachers (Whitacre et al., 2017).

1.2. How the mind works when mental calculation strategy

Several studies have linked learning mathematics and cognitive neuroscience (Menon, 2010; Sousa, 2015; Zambo & Zambo, 2007). Linking this knowledge to theories in school mathematics is something that has grabbed the attention of researchers worldwide (Ansari et al., 2011; Ayvaz et al., 2017). From education, we know that successful learners make use of counting, decomposition, and retrieval to do their calculations (Askew, 2013; Cowan et al., 2011). Neuroscientists have shown us that although they do not have all the answers (Krüger, 2018; Martinez, 2008), the need for interest (Willis, 2007) and fun (Sousa, 2015) to optimise the learning process by connecting the theories in school mathematics and cognitive neuroscience may assist mathematics teachers to be able to help learners improve their number sense.

1.3. Cognitive neuroscience can support the teaching of mental calculation strategies for improved number sense

The teaching of mental calculation strategies with insights into cognitive neuroscience can enable mathematics teachers to improve primary learners' number sense. It is, however, necessary that these teachers base their actions on insights into the cognition process in the brain (Ayvaz et al., 2017). Moreover, Ansari et al. (2011) agree that teachers with a better understanding of the structure and function of the brain, brain mechanisms involved in core cognitive functions, as well as the effects of culture and environment on brain function, will be better able to teach mental calculation skills for epistemological access. Furthermore, having a better understanding of child development and the biological limitations they will encounter in their classrooms when teaching these skills will enable teachers to facilitate the learning process more effectively (Ansari et al., 2011). In fact, Zambo and Zambo (2007) argue that information about the brain and its structure, procedures, and processes should not be accessible only to psychologists, speech therapists, and other professionals involved with children, but to teachers as well. The holistic-functional explanation of how new information enters, flows, and is integrated into the brain is important for teachers teaching mental calculation strategies to improve number sense. Focusing on how to better understand the natural learning cycle in the brain can be used by teachers to improve the learning experience of learners (Zambo & Zambo, 2007). Using insights from cognitive neuroscience can support pedagogical content knowledge (PCK) of mathematics teachers for better understanding and development of basic mathematical structures and connections in the brain to improve learners' number sense.

The main function of the sensory cortex is to make sense of sensory input through sight, sound, touch, taste, and smell (Zambo & Zambo, 2007). By making use of pictures, manipulatives, role play, and the sharing of ideas, the sensory cortex is provided with what it needs to start the construction of specific mathematical concepts. Being able to recognise a small number of objects without counting is part of the inborn number sense (INS), also referred to as subitizing. The use of pictures and manipulatives when teaching number sense includes perceptual subitizing, which involves number recognition (basic counting), and conceptual subitizing, which involves pattern recognition, such as the arrangement of dots on the dice. Mathematics teachers need to comprehend learners' number sense using the perceptual and recognition subitizing to visualise numbers in a variety of ways for them to make sense of numbers. Research has shown that this concept is critical for the development and understanding of abstract numbers and mental calculation skills (Sousa, 2015).

In the integrative cortex, mathematics teachers use the "funds of knowledge" learners bring to the classroom (Gerger, 2014) to connect what needs to be taught in the classroom to the world the learners live in. Mathematics teachers need to keep in mind during this process of teaching number sense, the neuroimaging which has shown that brain cells fire less frequently when learners are not interested or actively involved; for example, learning by rote or when teachers make use of the same method of teaching all the time (Zambo & Zambo, 2007).

In the motor cortex, the learning process includes the input of information through sensory experiences and then reflection and making sense of these experiences in the integrative cortex. Moreover, to determine whether learning has taken place, learners need to move to the next stage in the learning cycle, which is putting it all into action. At this stage, mathematics teachers need to provide support to learners by bringing their ideas and new knowledge to life through talking, drawing, and/or writing them, and can also role-play new insights for understanding. Some studies show that mathematics teachers struggle to show learners that what they learn in the writing of tests or practicing new classroom skills is related not only to school but also to the real world they live in (Holmlund et al., 2018; Mazana et al., 2019). Knowledge ("doing homework") also falls into this concept. Movement in the motor cortex includes physical movement, the creation of new ideas, testing ideas, and the formulation of new plans to execute ideas. This will ensure the consolidation of new information and thus create long-term memory (Jensen, 2015; Sousa, 2008, 2015).

1.4. Theoretical framework

This study used a hybrid theory of Piaget's (1983) developmental stages of thinking and Gersten and Chard's (1999) levels of development that teachers need to go through when teaching grade 4 learners' number sense. According to Piaget (1983), "concrete" is more important than "abstract" for young learners, and to move from the "concrete" to the "abstract", learners' thinking needs to have developed to a certain "stage". More recently, research has pointed out that "abstract" is just as important as "concrete" for learners it is just their lack of experience that hampers their ability to reason abstractly and not the need to wait for them to "develop a certain stage of thinking" (Askew, 2013). At a conceptual level, the characterisation of concrete concepts refers to material and physical objects such a car

(Kurmakaeva et al., 2021). Whereas abstract concepts refer to more complex states such as (dreams and sadness), conditions (uncertainty), relationships (friendship), and situations (encounter) (Kurmakaeva et al., 2021). Abstract calculations are scientific concepts that need to be taught because they are based on "empirical realities" that are "systematically organized" and can be generalised (Askew, 2013). For example, knowing that 7 + 7 = 14 can help a learner calculate more effectively 7 + 6 = 13 (because it is one less than 14) or 7 + 8 = 15 (it is one more than 14). When teachers understand that grade 4 learners can reason both concretely and abstractly and that their limited knowledge due to experience could be enhanced by providing the scaffolding that is relevant for the growth and development related to number sense. Unless teachers keep this in mind when teaching number bonds through mental calculation, many learners will stick to unit counting to do all their calculations; for example, 7 + 6 is 7 and then count to 8, 9, 10, 11, 12, 13 to calculate the answer (Schollar, 2008).

The five levels of development by Gersten and Chard (1999) complement Piaget's (1983) developmental stages of thinking to help mathematics teachers develop learners' number sense in practice.

1.5. Research questions

How do mathematics teachers teach mental calculation strategies using "bridging-through-10" to improve learners' number sense within the insights of cognitive neuroscience?

2. METHOD

The study followed an interpretivist paradigm through a qualitative research approach. Participatory action research (PAR) with three phases of teacher intervention, planning, implementation, and reflection (see Figure 1) redirects the insights of cognitive neuroscience from the researcher to the research assistants (Katsiaficas, 2022), to help grade 4 learners improve their number sense. The authors gained entry by planning the intervention with the two teachers and closed the cycle by reflecting on the outcome (Kortecamp & Steeves, 2002). The PAR identified by Kortecamp and Steeves (2002) was relevant for this study since the research assistants were two mathematics teachers who taught grade 4 mathematics for 30 years in the Motheo District of the Free State province of South Africa. Grade 4 teachers are expected to teach calculation strategies to learners to develop early number sense in the CAPS document. Hence, this study selected two mathematics teachers from the same education district, who wanted solutions for their struggles when teaching bridging through 10 as a mental calculation strategy. The two mathematics teachers from different school backgrounds and different contexts who sought practical solutions for their concerns (poor mental calculation of their learners) within their environment (Jacobs, 2016), were purposively selected.

Data were collected from the Ballard pretest before the intervention, and then the Ballard post-test data were collected after the teacher intervention. In addition, data were also collected using a discussion forum after the two teachers taught briding-through-10 as a mental calculation strategy for 10 days. Ethical considerations were observed in this study, UFS-HSD2018/1627/09.

2.1. Intervention

The mathematics teachers who participated in this research were prepared to better understand the cognitive neuroscience approach by using cognitive motivation to promote learners' interest in learning mathematics to improve the learners' number sense. The first phase of the intervention was the preparation of the two mathematics teachers with the three aspects of cognitive motivation, such as the need for autonomy, the need for competence, and relatedness, to connect mathematics teachers' knowledge of teaching using bridging through 10 as a mental calculation numbers strategy. The second phase allowed these teachers to teach bridging through 10 as part of their 50-minute mathematics lesson each day of the week for 10 days. The researchers did not actively take part other than providing the teachers with a framework to keep in mind when teaching their lessons, based on insights from cognitive neuroscience. The lead author, with the teachers (research assistants), closed the cycle by later reflecting on planning and the implementation stages to see whether it was necessary to start a second cycle. After the reflection from the two teachers, the lead author with the participants agreed that there were improvements in learners' number sense and there was no need to continue with the second cycle.

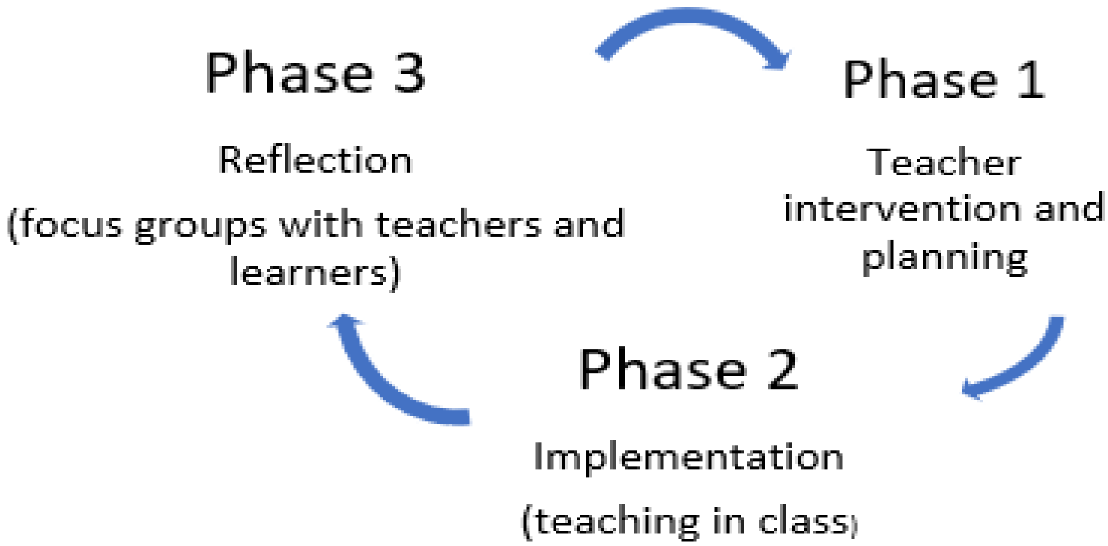

Figure 1. The structure of this PAR study

The framework the teachers needed to use when teaching bridging through 10 as a mental calculation strategy as part when teaching their Mathematics lessons was constructed to ensure that the cognitive process of the learners was kept in mind. During the planning stage, the teachers assisted the researchers in linking the cognitive neuroscientific concepts to the learning outcomes of their lessons.

Table 1. Link cognitive neuroscience insights to the specific learning outcomes

Time limit (50 minutes)	Issue addressed	The practical implication of the lesson	Adjustments (Notes on what to change)
10 minutes (Lesson broken up in chunks of no longer than 10 minutes improves memory compatibility)	Introduction Make sure to get the learners' attention; for example, make use of humor, visuals, or links to what learners are interested in (Willis, 2007).	*For example, use unifix blocks to demonstrate bridging through 10 concepts.* *Keep the cognitive load of learners as low as possible – limit new information (Kalyuga, 2012).*	
	Primacy-recency effect Learners remember best what they hear in the beginning and at the end (Sousa, 2015).	*For example, start with new knowledge and repeat at the end.*	
	Cognitive closure The working memory needs to sum up what has been learned (Sousa, 2015).	*For example: "Please explain in your own words..."*	
10 minutes	Practice/socialising Allow learners to practice in writing or sharing with a friend(s) new knowledge, while the teacher watches to correct any misconceptions (Sousa, 2015).	*For example, ask learners to explain to their friends what they have learned.*	
	Cognitive closure	*Cognitive closure can be addressed during this part of the lesson as well.*	
10 minutes	Writing/individual Work in workbook/homework.	*For example, give a few calculations to complete in the workbook.*	
	Cognitive closure	*Cognitive closure can be addressed during this part of the lesson as well.*	
10 minutes	Differentiation Teachers need to acknowledge the different intelligences in their classrooms (Sousa, 2015).	*Pick one of the identified intelligences to address; for example, write a rap song to address the music-clever learners.*	
	Cognitive closure	*Cognitive closure can be addressed during this part of the lesson as well.*	
10 minutes	Primacy-recency effect Learners remember best what they hear in the beginning and at the end (Sousa, 2015).	*Repeat what you as a teacher want learners to remember.*	
	End of lesson		

Table 1 shows the lesson plan that the teachers of the two grade 4 mathematics classes presented for 10 days. Increasing cognitive closure, mathematics teachers included it in the lesson plan for 25 minutes Thereafter, they were ready to discuss the outcome of their lessons in a focus group. The discussion forum with teachers was conducted before the discussion forum with their learners. This allowed the authors to triangulate the data obtained from the grade 4 mathematics teachers' discussion forum with the data obtained from the learners' discussion forum.

2.2. Data analysis

The data from the pretest and posttest were analysed descriptively using the Statistical Package for Social Sciences (SPSS) version 30. The priori theme developed from the research question is used to present data from the pretest and posttest. Moreover, data from the discussion forum were analysed using codes to identify seven categories, and one theme emerged.

3. RESULTS AND DISCUSSION

3.1. Results

Teacher AR and teacher NZ were purposively sampled in this study. However, teacher NZ was moved from teaching Grade 4 mathematics after the intervention stage was completed. Thereafter, teacher BJ taught grade 4 mathematics when we were preparing for the post-test. This affected the planned intervention. However, teacher BJ's responses from the discussion forum of teachers are presented as data in this study, though she was not part of the intervention session. We present the pre-test and post-test scores to assess the difference between them.

3.1.1. Mental calculation strategies using "bridging-through-10" to improve learners' number sense within the insights of cognitive neuroscience

Data from Tables 2 and 3 show the grade 4 learners' improvement and decline in bridging through 10 performances after the intervention was conducted.

Table 2. Teacher AR classes bridging through ten pretest and post-test scores

	Teacher AR classes					
Classes	**Class A**		**Class B**		**Class C**	
Number of learners	**40**		**41**		**40**	
Tests	**Pretest**	**Post-test**	**Pretest**	**Post-test**	**Pretest**	**Post-test**
Class average out of 30	16	18	15	18	16	18
Percentage	53%	60%	50%	60%	53%	60%
Improvement/deterioration	7%		10%		7%	

After teaching and learning, bridging through 10 as a mental calculation strategy for 10 days, based on insights from cognitive neuroscience. The table above shows an increase of 7 to 10 percentage points in scores on the mean scores. This suggests an improvement in Ballard post-test scores compared with pretest scores in teacher AR classes. The improvement may be attributed to bridging through 10 as a mental calucaltion strategy, though an inferential stitistics is required to measure whether the improvement has a significant relationship to the intervention or not. Further studies are needed to investigate whether there is a significant relationship between grade 4 mathematics teachers' intervention using insights of cognitive neuroscience and bridging through 10 as a mental calculation strategy and the improved learners' number sense.

Table 3. Teacher BJ classes bridging through 10 pretest and post-test scores

	Teacher BJ classes			
Classes	**Class A**		**Class B**	
Number of learners	**28**		**23**	
Tests	**Pretest**	**Post-test**	**Pretest**	**Post-test**
Class averages out of 30	17	15	19	16
Percentage	57%	50%	63%	53%
Improvement/deterioration	-7%		-10%	

In teacher BJ's classes, the table shows a decrease in post-test scores between 7 to 10 percentage points compared to pretest mean scores for both classes A and B. This suggests that there is a decrease in post-test scores in class A compared to class B on the pretest mean scores. The decrease on class B mean scores may be affected by the change of teacher BJ after the intervention before learners wrote the posttest. This is linked up well with the understanding from cognitive neuroscience that emotion shapes and is shaped by cognition (Hinton et al., 2008), which can affect performance in numbers.

The performance in teacher AR and BJ classes shows a huge difference in an increase and decrease in performance when they used of bridging through 10 as a mental calculation strategy. The next is the presentation of data from the discussion forum below to answer the study's research question.

3.1.2. Bridging-through-10 strategy to improve learners' number sense within the insights of cognitive neuroscience

The following categories are presented to find answers to the theme from a discussion forum with teachers. Both teachers, AR and BJ were part of the discussion forum, which was conducted after 10 days of intervention using bridging through 10 strategies. The presentation was categorised into five, Teachers need to be lifelong learners, "I started doubting myself", Continuity is important, "Not as easy as it looks", Continuous evaluation improves understanding, Collaboration improves understanding.

Teachers need to be lifelong learners – "I started doubting myself"

Both teachers responded after teaching bridging through 10 strategies to grade 4 learners in classes, that lifelong learning improves the teaching of mental calculation strategies involving numbers. Both teachers had more than 30 years of teaching experience, and they relied on the support provided by the Department of Basic Education to teach bridging through 10 as a mental calculation strategy. They had a wealth of mathematics teaching experience in grade 4 and had been teaching bridging through 10 as a mental calculation strategy over the years, as expected in the Curriculum Assessment Policy Statements (CAPS) document for mathematics Grades 4-6. Nonetheless, mathematics was not a major subject for teacher AR, but she was allocated mathematics to teach.

After the intervention session, during the teacher discussion forum, both teachers agreed that continuous learning about the subject you teach is important. Nonetheless, Teacher AR stated that she doubted her teaching in the past few years. Furthermore, she noticed that learners were just not coping anymore, and their marks kept getting lower every year. According to teacher AR, it was not always the "*difficulty of the sums*" but that a teacher should be up to date with how learners learn. Murray (2021) agrees with the findings of this study and identified that teachers learn in varied and many ways, but strong evidence shows that good teachers learn always. This suggests that when teachers update on a variety of ways on how learners learn, this leads to lifelong learning.

Continuity is important

Both teachers had more than 30 years of teaching experience, and they agreed that teaching grade 4 mathematics continuously helps the mathematics teacher to understand the content and how learners learn. Teacher AR found that the past three years were very interesting since she taught grades 4 and 5, and that allowed her to see continuity in the number content. Teacher BJ also agreed with this as she moved to the school where she was currently teaching. At the beginning of the year, she felt totally out of her depth as there was no reference to what the learners knew or were capable of. Teacher AR was able to better understand what she needed to focus on in the content to ensure that they were ready to move on to the work they would be doing in Grade 5. Moreover, Teacher BJ also found it very satisfying was see the development over the two years: "It was so nice to know from where we started in Grade 4 and see what they were able to do at the end of Grade 5." In contrast, Teacher BJ thought the move to the new school where she is currently teaching put her out of depth as she had no reference to what the learners knew or were capable of. In her words, "*It felt like I was drowning*." This suggests that without teaching experience in teaching numbers in primary school, teachers may struggle to teach the concept to learners' understanding. Moreover, Olanoff et al. (2014) assert that pedagogical content knowledge (PCK) develops over several years of teaching when teaching a specific concept.

3.1.3. Pathways in the brain for motivation

It was teacher AR who explained how learners were motivated during the teaching of bridging through 10 strategies, since teacher BJ was not part of the intervention. Teacher AR found that explaining to learners how they can develop their brains to improve their ability to do mathematics is very effective. During the intervention in the planning phase, the teachers decided to use the concept of neuroplasticity – to "*rewire*" your brain for improved understanding as part of developing their feeling of autonomy. Teacher AR stated that "*learners enjoyed the idea of how their learning in class was changing the "farm roads" for information to move in their heads – not at all built for speed, but there if you want to use them – into "gravel roads" – knowledge moves faster, but still risky (easily overgrown by bushes if not used regularly), into tarred, city roads where information can move fast and easily.*"

This suggests that the development of learners' knowledge in acquiring number sense should be slower and allow the number concept to stick in their minds. Only teacher AR was able to get the information on a "highway" where information could move fast, also known as the concept of "pruning" (the brain's ability to improve its capability by removing unused and unwanted information). Teacher AR explained what she told the learners. In her words, "*Just like we need to keep the roads in our country clean from bushes to keep the traffic flowing freely, they needed to revise work regularly to ensure that the roads in their head were used regularly to ensure the brain did not see it as unnecessary or unwanted knowledge and allow* *it to be overgrown by bushes*." Teacher BJ admitted that she explained pruning in an unclear manner. This suggests that helping learners know how their minds operate may assist them in using the strategy to make sense of numbers with the bridging through 10 strategies.

Cognitive closure makes the "difficult easier"

During the teacher discussion forum, both teachers found cognitive closure (recap) very effective, and they could make use of it several times during a lesson. According to Teacher AR, allowing learners to repeat what they had learned in their own words helped them to improve their ability to answer more quickly and accurately, for example, bonds. One activity Teacher AR used was allowing learners to draw their mind maps to show their understanding of bonds. Whereas they struggled to provide answers immediately before. Making use of different ways to practice bridging through 10 allowed the learners to answer immediately and with confidence. On the other hand, Teacher BJ stated that the whole concept of having learners repeat in their own words what they had learned and understood was something she could use in all the subjects she taught. This implies that, though the teachers have years of experience in teaching, cognitive closure was not part of their lessons. This could be another factor in the learner's performance decrease in the teachers' classes before the introduction of bridging through 10 as a mental calculation strategy.

Practical application to explain the concept is important: Blocks and "money work"

During the teacher discussion forum, teacher AR responded by using real money to explain number calculation, and teacher BJ built blocks as representations to make sense of numbers to learners during the lesson presentations. During the discussion forum, both teachers agreed that the building blocks help make a mental image for learners as they bridge through 10 in their calculations. In addition, teacher AR showed a picture of the learner's response involving building blocks using the bridging through 10 strategies, though it was time-consuming according to the teacher. Figure 2 shows what was taken when learners drew blocks to represent bridging through ten.

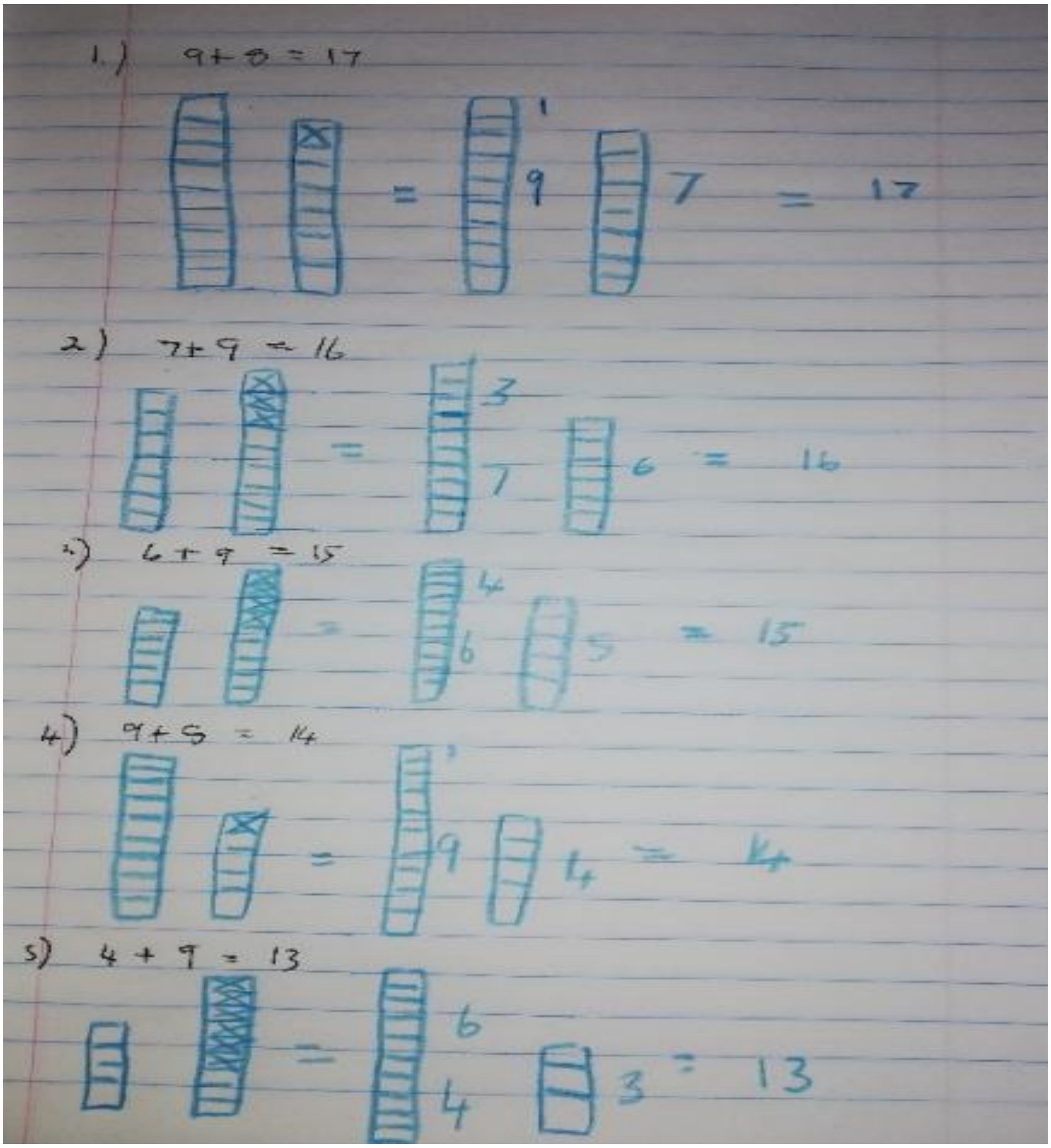

Figure 2. Learner's drawing explaining his interpretation of bridging through 10

Figure 2 shows that the learner was able to display an understanding of bridging through 10 strategies. The graphical representation and the number computation clearly show the sense of numbers in level 4 of Gersten and Chard's (1999) five developmental stages of thinking. This suggests that mental cognitive neuroscience insights with bridging through 10 strategies, improved learners' sense of numbers.

Teaching according to cognitive neuroscience was a personal challenge, but enjoyable

Teacher BJ could not respond to teaching using insights from neuroscience since she took over from Teacher NZ. Therefore, Teacher AR admitted that she found the whole concept of teaching according to cognitive neuroscience insights very challenging. Teacher AR had to work on her personality and ability to complete the project. For example, she used to sing in mathematics class, but when she saw the joy on the learners' faces, she started to enjoy it herself. At the end of the two-week cycle, she used a game to test the learners' new knowledge instead of writing a test, which was a first for her. This also allowed her to easily identify learners who still struggled and use collaborative learning to allow them to catch up while taking part in the game and enjoying it. This shows that the teacher created an environment where learners engaged with the content.

Learners supporting each other to learn

From the discussion forum, it was identified from the response of teacher AR that her class was organised chaos, and on the other side, Teacher BJ missed the teaching session. In Teacher AR's words, "*having rules in class and sticking to them allowed learners to feel safe*". However, she admitted to being very strict but trying to ensure that her behaviour in class was always the same, allowing learners to know what to expect. For example, not letting homework go one day without being marked and then fighting about it the next day. She allowed learners to help their friends when they did not understand the task, and this allowed the learners to feel good about themselves. In her classroom, she calls "*organised chaos*" learners who cannot see clearly on the board, can stand up and walk to the front to write down the work, or help a friend who struggles to understand the task. She went on to reward learners who found a way to help another learner understand the task they found difficult. In the lesson planning stage, the authors and teachers identified a need for learners to feel safe and cared for in class. Then, Teacher AR moved around the class and told learners that "*she was there to help and that this was what she got paid for.*", and all they needed to do was ask for assistance. This suggests that Teacher AR was dedicated to assisting learners.

3.2. Discussion

This study investigated whether teaching "bridging-through-10" as a mental calculation strategy with the insights of cognitive neuroscience can improve grade 4 learners' number sense or not. This study found that teaching bridging through 10 as a mental calculation strategy with cognitive neuroscience insights had contrasting findings. However, there was no improvement in teacher BJ's class. Whereas there was an improvement in the teacher's AR class. This study contrasts with Elwick's (2022) study, which shows that cognitive ability significantly and positively affects learners' achievement. Nonetheless, this study identified seven cognitive neuroscience insights to help grade 4 learners improve their number sense from teacher AR's class, namely, Teachers need to be lifelong learners (I started doubting myself), continuity is important, Pathways in the brain for motivation, A cognitive closure makes the difficult easier, Practical application to explain the concept is important (blocks and money work), Teaching according to cognitive neuroscience was a personal challenge but enjoyable, and Learners supporting each other to learn. This study identified cognitive neuroscience insights that implicitly align with the insights by Chang et al. (2021), who identified two types of insights, basic and general. The three insights include teacher thinking, teacher actions, and the context of educational neuroscience concepts (ENC). Chang et al. (2021) further state that teachers demonstrated insight into the nature of student problems and how to increase student agency. Elwick (2022) agrees with some of the findings that a controlled trial with seven-year-old learners demonstrated that neuroscience training alters their perceptions of their intelligence, motivating them to perceive their intelligence as adaptable. Moreover, Elwick's (2022) study shows that cognitive ability significantly and positively affects academic achievement. The limitation of this study is the short period of cognitive neuroscience intervention, teacher change after the intervention, and a small sample limited the generalization of the findings. It is advisable to develop a lesson plan with cognitive neuroscience insights to increase cognitive closure to help grade 4 learners improve their number sense. Learners need to carry less task load when learning grade 4 number sense. The teachers' responses during the discussion forum pointed out that keeping basic insights from cognitive neuroscience, like the primacy-recency effect, cognitive closure, and breaking up lessons into segments that are memory-compatible in mind, improve learners' understanding and appreciation of numbers. A concept that was not part of the objectives of the study, but emerged, was how big a part the environment and life in general played in the learning process. This means that teachers will need to address these issues, such as, bullying and poor discipline, before they can teach for optimal results. Hence, there was a decline in learner performance in teacher BJ's classes after the teacher was brought into classes that were taught by teacher NZ. Other authors could study this gap and take it further.

4. CONCLUSION

The cognitive neuroscience insights provided contrasting findings on how tachers use cognitive closure to help the grade 4 mathematics teachers understand how their brains and the learners' brain function. They develop the bridging through 10 activities to help increase the cognitive closure on bridging through 10 as a mental calculation strategy from teacher AR's class. This study included cognitive closure in each section of the lesson plan to help learners conclude each activity as they develop numbers using bridging through 10 strategies for the sense of numbers.

When learners work in support of one another, they develop their sense of numbers. Though the posttest results show contrasting decrease and increase in learners scores after the intervention, in Teacher AR's class the performance improved on bridging through 10 tasks. It can be concluded that cognitive closure helped to lessen grade 4 learners task load for number sense. Teachers had to do more than they do every day in classes to engage learners through singing and the addition of games. Our approach can be applied to teachers' teaching for the development of other mathematical concepts for number sense. This has implications for mathematics teachers as they are engaging in cognitive closure in the planning and exwcution of the planned lesson.

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