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Fostering Inclusivity: A Critical Emancipatory Approach to Dyscalculia in Primary School Mathematics

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ABSTRACT
This research endeavoured to revolutionise primary school mathematics education by implementing an active learning approach tailored to addressing dyscalculia. The study used a critical emancipatory framework as the theoretical foundation, and participatory action research as the chosen methodology. The researcher employed purposive sampling to select two mathematics teachers, one school-based teacher, a district education psychologist, two learners displaying dyscalculia symptoms, and two parents. The research collaboratively engaged participants to identify challenges, crafting interventions, and reflecting on outcomes through the lens of the critical emancipatory framework and participatory action research. The researcher assessed the effectiveness of the active learning strategy to enhance students' mathematical abilities, self-efficacy, and attitudes toward mathematics. Critical discourse analysis shed light on the potential of active learning strategies to improve mathematical learning outcomes and create a supportive learning atmosphere. The results indicated that the implemented active learning strategy offers effective pedagogical practices for learners with dyscalculia by influencing positive changes in their attitude towards mathematics and the learning environment. The participating teachers gained insights into understanding the behaviour of learners with dyscalculia and the role of active learning in intervention strategies. The study's findings can guide educators, policymakers, and researcher in developing inclusive mathematics instruction for diverse learners in primary school classrooms.

KEYWORDS
Active learning; critical emancipatory framework; dyscalculia; inclusive education; participatory action research; primary school mathematics.

BACKGROUND AND INTRODUCTION TO AN ACTIVE LEARNING STRATEGY FOR DYSCALCULIA

This study delved into the development of an active learning strategy tailored to address dyscalculia within the framework of a primary school mathematics classroom. Mathematics education often divides learners into two distinct groups, those who approach the subject with confidence and enthusiasm, and those who do not (Röj-Lindberg, 2001). Regrettably, individuals who grapple with mathematics during their primary school years frequently continue to face challenges in adulthood, and research demonstrated that mathematics proficiency significantly influences students' career choices (Adhikari, 2013). Dyscalculia is a developmental learning disorder characterised by deficits in various mathematical skills and reasoning, and it poses a substantial hurdle to mathematical learning (World Health Organization, 2020).

The prevalence of dyscalculia ranges from 3.38% to 13.8% (Barbaresi et al., 2005; Reigosa-Crespo et al., 2011), making it a matter of considerable educational concern. The principle of 'Education for all' endorsed in South Africa's White Paper 6 (Department of Education, 2001) emphasises equal and equitable education for all learners, regardless of their abilities. Dyscalculia can manifest in various aspects of mathematics learning and performance (Nfon, 2016), necessitating a comprehensive exploration of active learning as an intervention strategy.

Dyscalculia, often as prevalent as dyslexia but less recognised, can lead to distress, low self-esteem, stigmatisation, and disruptive behaviour in the classroom (Bastos et al., 2016; Butterworth, 2003). Research indicated that learners with dyscalculia encounter challenges in three key areas of mathematical cognition, namely semantic memory, procedural memory, and visuospatial memory (Geary & Hoard, 2005; Kunwar, 2022; Szucs et al., 2013; Wadlington & Wadlington, 2008). The Curriculum and Assessment Policy Statement (CAPS) views mathematics as a vital language and cognitive activity that is essential for critical thinking and problem-solving (Department of Basic Education, 2011). According to Bird (2009), learners with dyscalculia have a weak concept of numbers, which results in them either guessing the correct answer or resorting to immature strategies to derive an answer. The most common strategy is counting and using fingers for different calculations, including simple calculations.

This study proposes an active learning intervention strategy for learners with dyscalculia. Active learning actively engages students in their learning process, moving away from passive listening. Primary school mathematics encompasses topics crucial for developing mathematical skills. Learners with dyscalculia particularly grapple with concepts related to operations and mathematical relationships, numbers, patterns, algebra, measurement, space, shape, and data handling. South Africa faces high failure rates in mathematics, which highlights the urgency of addressing dyscalculia awareness and providing effective interventions.

Bolstad et al. (2012) presented an argument that effective learning requires active engagement and that "learners need to be actively engaged in ways that allow them to process, interpret, and adapt an experience". Learning is a process of knowledge construction and absorbing or recording information, and implementing an active learning strategy to address

dyscalculia offers learners the opportunity to own their learning. An active learning strategy rebuilds learners' confidence, enhances their memory of mathematical facts, and improves their ability to conceptualise and solve mathematical problems. This holistic approach addresses the three main areas of difficulty, namely semantic memory, procedural memory, and visuospatial memory. Effective intervention strategies for dyscalculia should encompass elements such as activities to enhance concentration, critical thinking stimulation, and interest generation (Drake & Battaglia, 2014). The selected key elements of active learning in this context include an effective questioning strategy, manipulative and multisensory approaches, peer teaching, writing and reflecting, and cooperative learning. In conclusion, by actively engaging learners with dyscalculia in these strategies, the study aimed to improve their mathematical understanding and to boost their self-esteem and enthusiasm for learning mathematics. Hence, the study investigated whether an active learning strategy can create an inclusive learning environment that accommodates dyscalculic learners in a mathematics classroom and to further unveil the elements of an active learning strategy that enhances the learning of mathematics for learners with dyscalculia.

Mathematics Education

The CAPS curriculum (Department of Basic Education, 2011, p. 8) states that mathematics is a language that uses "symbols and notations to describe numerical, geometric and graphical relationships". Mathematics involves analysis and understanding the patterns and relationships that exist between objects. Mathematics enhances the logic and critical thinking of learners, and empower them with problem-solving skills. Mathematics learning generally involves calculations in various forms. The PBS (2012) held the view that neurological and cognitive functioning are critical in learning mathematics because learners use their memories to recall facts and formulas, recognise patterns, and invoke rules about sequential ordering. The brain has to function at a certain level for learners to apply various aspects of mathematics to solve a problem and to be able to understand and use the correct vocabulary involved in mathematics learning. Mathematics learning also requires students to understand spatial ordering so they can recognise symbols and understand the three-dimensional representation of objects (PBS, 2012). It is evident that mathematics learning is critical in our society. Henning (2010) added that people with "poor numeracy skills are twice as likely to be unemployed". However, mathematics proficiency is a challenge to many people, and more so to individuals with dyscalculia.

THEORETICAL FRAMEWORK

The researcher used the critical emancipatory framework to guide this study. This framework is rooted in the critical emancipatory framework, which is deeply entrenched in critical theory, education, and social justice (Freire, 1970; McLaren, 2003). This framework served as the lens through which the researcher examined the transformative potential of education, with a particular focus on the emancipation of teachers, learners, and parents.

This critical emancipatory framework posits that when emancipated, teachers become empowered to challenge traditional pedagogical norms (Giroux, 1988), question existing power structures within educational systems, and advocate for equitable practices. Emancipated teachers are envisioned as critical thinkers who actively engage in transformative pedagogy to address the needs of diverse learners (hooks, 1994).

The emancipation of learners from oppressive educational practices is central to the framework. Emancipated learners are encouraged to critically analyse the socio-cultural contexts of their education (Freire, 1970), challenge stereotypes, and actively participate in their own learning. The framework promotes inclusive and active learning strategies that cater to diverse needs (Gutierrez, 2008) to foster an environment in which learners feel empowered, valued, and capable.

The emancipation of parents recognises the importance of parental involvement in a child's education, and therefore, the critical emancipatory framework extends to parents. Emancipated parents are viewed as active partners in the educational process (Delgado-Gaitan, 1992) who collaborate with teachers and school administrators. This emancipation involves breaking down communication barriers, fostering a sense of agency among parents to advocate for their children's educational needs (Epstein, 2010), and challenging any systemic inequalities that may exist within the educational system.

Application in Participatory Action Research

Within this theoretical framework, the researcher used participatory action research as a methodological approach (Stringer, 2014). Participatory action research aligns with the principles of emancipation by actively involving teachers, learners, and parents in the research process. Through collaborative efforts, participants collectively identify challenges, co-design interventions, and reflect on outcomes (Reason & Bradbury, 2008). This participatory approach ensures that the voices of all stakeholders are heard and contributes to the emancipatory goals of the study.

The adoption of the critical emancipatory framework provided a theoretical foundation that emphasised the transformative potential of education to emancipate teachers, learners, and parents (McLaren, 2003). By actively engaging with this framework, the study aimed to contribute insights into fostering inclusive and equitable educational environments that empower all stakeholders in the primary school mathematics context.

METHODOLOGY

This paper is part of a larger study that qualitatively explored using the active learning strategy to address dyscalculia. The data for this study were collected using purposive sampling aimed at selecting participants who could provide valuable insights into the implementation of an active learning strategy to address dyscalculia in a primary school mathematics classroom. The participants included two mathematics teachers who were purposively selected on the basis of their experience in teaching mathematics, two Grade 6 learners with dyscalculia symptoms, two

parents of the Grade 6 learners, one school-based teacher with knowledge of the primary school's educational environment, and one district education psychologist. The two teachers were selected because they taught learners with dyscalculia symptoms and also had interest in using the active learning strategy as part of their teaching methodology. They both had over five years' experience teaching mathematics in primary school. One of the participant teachers presented at the Association for Mathematics Education of South Africa (AMESA) on usage of manipulatives in a mathematics classroom. The two learners from Grade 6 were selected based on their performance in mathematics in comparison to other subjects: For their Term 1 results, they obtained Level 5–7 in school subjects and Level 1 in mathematics. The participating learners completed an assessment extracted from The Davis Maths Mastery program that is used to diagnose learners with dyscalculia (Whitehead, 2007). The district education psychologist has experience in the Free State and he showed a keen interest in knowing more about dyscalculia and how learners with dyscalculia can be assisted in understanding mathematics.

The research team was divided into two groups. The first group consisted of learners and parents, allowing learners to express themselves freely without feeling intimidated by their teachers' presence. Some of the meetings with the learners were held in the comfort of their homes. The second group comprised teachers and an education psychologist.

The principle that guided this study was critical emancipatory research (CER) as the theoretical framework. CER was the lens through which individual participants in the study were viewed. This framework emphasises the collaboration between researchers and participants. According to Mahlomaholo (2009), CER addresses issues of inequality, social justice, and lack of hope, which are mitigated through the creation of an interaction space with marginalized individuals. Nkoane (2012) added that CER aims to "critique and challenge, to transform and empower; it is geared towards social justice and enhances the principles of democracy". CER serves people with disabilities by empowering them through a human rights approach that creates awareness and understanding of their rights (Deeper, 2012). This study sought to emancipate those impacted directly or indirectly by dyscalculia. It is crucial to address challenges that limit equity in learning and understanding mathematics. The involvement of participants allowed them to understand the existence of dyscalculia as a hindrance in learning mathematics. They also contributed their views and experiences to provide solutions and conditions that will make the solution effective.

Prior to data collection, the researcher obtained written permissions from the Department of Basic Education in the Free State, South Africa, as well as from the school where data were collected. Ethical considerations included informed consent from all participants, assurance of confidentiality, and adherence to ethical guidelines for research involving human subjects (Bryman, 2016). The researcher used a combination of data collection methods to ensure a comprehensive understanding of the phenomenon. The first data collection method was focus group interviews that were separately conducted with the teachers, the learners, and the parents to elicit their perspectives on the active learning strategy and its impact on

dyscalculia intervention (Krueger & Casey, 2015). The second data collection method was class observation sessions during which the researcher observed the active learning strategy being employed in order to gather real-time insights into its implementation and effectiveness (Punch & Oancea, 2014). The final data collection method that was used was document analysis of the learners' written assignments and assessments to assess their mathematical progress and the influence of the active learning strategy on their learning outcomes (Merriam, 2009).

To ensure validity and reliability, participants received training, and an education psychologist was available to elevate participants' understanding to the level of the researcher. Data were collected during focus group interviews where participants shared their views and perspectives based on the forum meeting agenda. Additionally, data were gathered through class observations and reflections from the participating teachers during lessons.

The generated data in this study were analysed using critical discourse analysis (CDA). Van Dijk (2015) described CDA as a type of analytical research that focuses on how social power, abuse, dominance, and inequality are enacted, reproduced, and resisted through text and talk in the social and political contexts. The study sought to emancipate those impacted by dyscalculia, either directly or indirectly. It is important to deal with challenges that limit equity in learning and understanding mathematics.

RESULTS AND FINDINGS

The researcher used critical discourse analysis to analyse and explore the need for an active learning strategy to address dyscalculia in a mathematics classroom, and the study yielded the findings discussed in the following sections.

Understanding Dyscalculia

All participants acknowledged that they were unfamiliar with dyscalculia. During a facilitated workshop with participants, it was established that dyscalculia often leads to low self-esteem and that learners with dyscalculia may exhibit behaviours such as hiding, poor time management, lack of concentration and boredom during a mathematics lesson, and isolation due to their difficulty with mathematics. Despite the potential of learners with dyscalculia in other areas, their inability to perform everyday mathematical tasks can significantly impact their lives.

Identification of Active Learning Elements

The focus group discussions were aimed at selecting the elements of active learning, such as (a) effective questioning and assessment, (b) peer teaching, and (c) manipulatives, because these elements may help address observed concerns of disengaging and being isolated when in class and losing focus because of their poor number sense.

Effective Questioning and Assessment as an Intervention Strategy

Learners with dyscalculia are observed to have poor self-esteem, hide their weaknesses, and use compensation strategies. According to Attwood (2002) and Chinn (2012), learners with

dyscalculia do not benefit from being told the correct answer or shown the workings of the correct answer, but they benefit from figuring out problems by themselves.

The results from the focus group discussions with teacher participants indicated the need for a different approach to teaching and assessing mathematics and that learners with dyscalculia will benefit from active problem-solving rather than simply being provided with answers. The teachers acknowledged the importance of well-planned questions to assess learners' understanding. The learners indicated that they find it embarrassing when their results are called out aloud in class, and that they require a different approach in teaching, questioning, and assessing.

Peer Teaching as an Intervention Strategy

The results from the critical discourse analysis indicated that teachers often noticed that learners understand each other better when arranged in pairs, and that they often use language that is common to them to simplify concepts. It was also found that as part of peer teaching, the classroom sitting arrangement can be re-arranged; however, teachers should ensure that learners are comfortable with whom they are paired. Furthermore, learners with dyscalculia must be paired with learners who have a strong mathematical aptitude.

It was agreed during focus group discussions that peer teaching is valuable in building confidence among learners with dyscalculia. Activities like think-pair-share and think-aloud pair-problem-solving were introduced to facilitate peer learning. The participants emphasised the importance of comfortable pairing and clear communication.

Usage Manipulatives as an Intervention Strategy

Kennedy et al. (2007) described manipulatives as objects used to assist with thinking, such as building blocks, games, puzzles, stones, sticks, and crayons. Attwood (2009) and Prabavathy and Sivaranjani (2020) postulated that when teaching mathematics to learners with dyscalculia, a teacher must work on the same topic a few times, use manipulatives that include multimedia elements (Ahmad et al., 2012), and encourage learners to verbalise what they are learning. Learners with dyscalculia learn best through hands-on experience, demonstrations, experimentation, observation, and visual aids.

The findings of this inquiry confirmed the benefits of employing manipulatives in the teaching and learning of mathematics for learners with dyscalculia. Teacher participants indicated that learners with dyscalculia respond positively to using manipulatives such as games and blocks. However, it was also mentioned that it is not always possible to create or use appropriate manipulatives of value when teaching mathematics. Parents found using manipulatives such as counting plates or food valuable in teaching the learners mathematical concepts through play. The school-based teacher confirmed that mathematics is a fundamental skill and that a variety of things, such as buttons, rice, dried peas, and colourful items, can be used to create patterns that can stimulate and grab the attention of learners with dyscalculia. Learners agreed that mathematics is more interesting when the teacher use blocks or different colourful objects. The participants made the following comments:

I have noted that every time I ask my learners to work on blocks and other manipulatives that I have in my class, learners get very excited. And that tells me that they are having fun while learning. I therefore believe that even learners with dyscalculia will benefit. (Teacher A)

I like that example about asking my child to get plates. For example, during dinnertime, I can ask my child to get plates for everybody in the family. We are a family of five. So I can say get plates for everyone, or perhaps say, I will not be eating dinner tonight. Please get plates for everyone in the house, except myself. (Parent A)

The focus group agreed that this would be a nice continuation of learning at home, and made the following comments:

I can also ask my child to get four slices of bread to make sandwiches. We could even count the time it takes to make a sandwich. (Parent C)

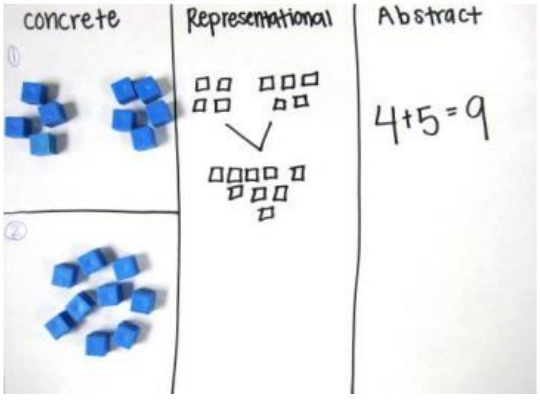
I can see the value of using manipulatives in class, but I don't think it is always possible. Teachers cannot always afford to create manipulatives, which they consider relevant. (Teacher A)

Other than the expense of bringing the appropriate manipulatives, learners perceived to have dyscalculia are really less interested in learning mathematics. That also contributes in creating a less stimulating learning environment. (Teacher C)

During the Focus group workshop, the dyscalculia specialist illustrated how manipulatives may be used to assist learners with dyscalculia in understanding addition and said that "making pattern is a fundamental mathematics skill as illustrated in Figure 1below. All sorts of things can be used to make patterns, buttons, rice, dried peas, lentils, small pieces of shiny, or coloured papers, the child's toys, etc". Learners E and A concurred and said the following:

Figure 1.

Manipulatives used to teach addition.



I enjoy the mathematics lesson when we use different objects, and we use colourings to create learning stuff; for example, when we learn about fractions. (Learner E)

I also enjoyed the game of cards. (Learner A)

It was clear that the participants understood the need to create a stimulating environment; however, that is not easy considering the challenges faced by learners with dyscalculia. These learners have a challenge remembering and conceptualising learned facts. On the other hand,

teachers often have overcrowded classes, and this makes it difficult to create a stimulating learning environment. The use of manipulatives, such as blocks and counting objects, excited learners and facilitated comprehension. Teachers and parents discussed creative ways to incorporate manipulatives at home to make learning a continuous process.

Class Observation

During the class observation, the researcher observed the teachers and the responses and progress of learners with dyscalculia. It was decided to apply selected active learning elements based on the class observations. The focus group decided on the topics that would be taught based on the baseline test results, and these topics were basic number sense and mathematical patterns.

Presented Lesson 1

The first lesson was presented by one of the participant teachers on basic number sense. Other participant teachers and the researcher were also in class as observers. It was a class of 30 Grade 6 learners set in a group of five learners per group. Each group was a combination of boys and girls, with at least one learner who is a high performer, average, and struggling learner. Basic number sense gives learners the ability to use and understand numbers. The researcher asked Teacher B to lead the activity by introducing the research team to the learners. The lesson started with the number game in which learners were asked to do mental addition. The sitting arrangement of the class was also changed from the traditional rows to sitting in a circle.

Scenario 1. The class was presented with the following problem: When adding 32 + 9 = 41. To get the correct answer (41), you add 1 to the first number 3 and subtract 1 from the second number 2, and then the answer is 41. The activity encouraged learners to use their reasoning ability and to realise that they can add large numbers without using the calculator.

Scenario 2. The learners were given the following scenario: Thabo is given R20 by his mum to go buy bread, which costs R17. How much change does he get? Teachers told the learners to ensure Thabo does not forget what he is going to buy at the shop. It is essential that Thabo builds the picture of bread in his head.

Learners were also given colourful counting blocks. They were asked to take out 20 counting blocks; the counting blocks represented the number of Rands Thabo's mum gave him. Then learners were asked to take out 17 counting blocks, representing the R17. Learners were then asked to count the number of remaining blocks.

The research team reflected on the general reaction of the learners on the application of active learning, and made the following comments:

I think the learners came alive when it was time to use the manipulatives. (Teacher C)

Yes, even Learner B was engaged. He had his hand up most of the time when a question was asked. (Teacher B)

I think the lesson went fine. However, we could still improve on the peer learning. I observed that the smart learners were not keen on sharing how they got the correct answer.

Especially, in a group where Learner A was involved in, she seemed confused most of the time. (Teacher A)

The research team also felt that the sitting arrangement led to cooperative involvement. Learners could learn from one another, and it was easy for them to share the manipulatives. This also allowed the teacher to reach more learners at the same time.

The research team also reflected on the presentation of the content by the teacher. The team felt the teacher moved too quickly to the 'abstract' concept. The mental game that was first presented in class was difficult for most learners, and the learners with dyscalculia failed to participate. The team felt that the lesson could start with something 'concrete', then move to 'pictorial', and then to 'abstract'. This would allow learners to build the association of numbers from the beginning. The team made the following comments:

I noticed that when Learner A was asked, "How many hundreds are in 200?", it seemed to me that she first did not understand the question. I suspect that the problem may not be only in mathematics but also the language. (Teacher C)

That may be a possibility because the question had to be repeated a few times, presenting it in different scenarios. (Teacher B)

The team also observed that the other learners perceived to have dyscalculia participated in class. However, when they were asked to build three-digit numbers, they struggled with units. The peers at the table were of good assistance.

During the class observations of active learning activities during Lesson 1 on basic number sense, the teacher started the lesson with the number game and learners were asked to do mental addition. It was found that the activity encouraged learners to use their reasoning ability, and allowed learners to realise that they can add large numbers without using a calculator.

Lesson 2: Presentation of Patterns

Lesson 2 was also presented by one of the participant teachers on mathematics patterns. Similar to Lesson 1, other participant teachers and the researcher were also in class as observers. It was a class of 30 Grade 6 learners set in a group of five learners per group. Each group was a combination of boys and girls, with at least one learner who is a high performer, average, and struggling learner.

Scenario 1. Learners were given an opportunity to choose a number from the placed cards. If a learner chose 5, they had to clap their hands five times; if they chose 3, they had to jump three times; and some were asked to identify two boys wearing a sweater that day. The activity helped learners with core numbers. According to Hornigold (2015), learners with dyscalculia need encouragement with core numbers and these types of activities help learners make a connection between numbers, quantities, and symbols.

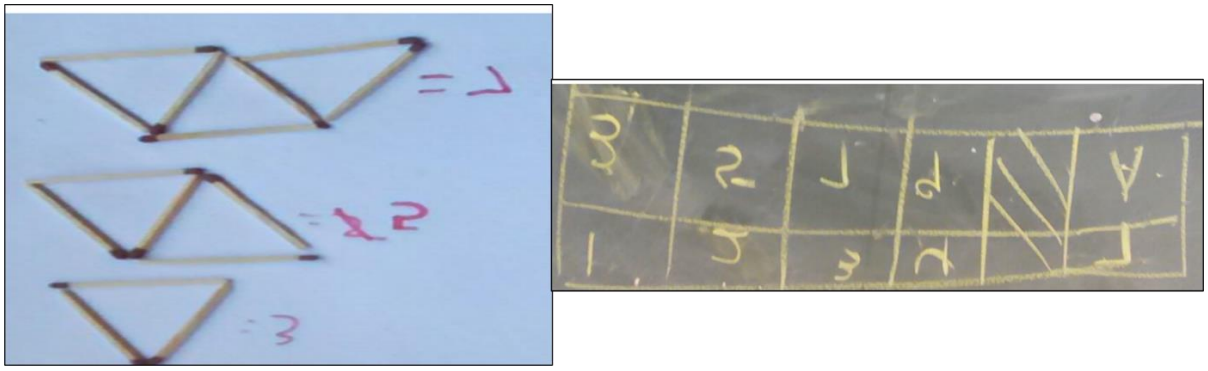
Scenario 2. The teacher shared a tower built with building blocks. The tower was composed of blocks in two colours: Red, blue, blue, red, red, and so forth. Learners were then asked to say what the next colour block would be. They then did the activity in groups in which each group

was asked to build the tower with the correct pattern. The groups presented their patterns in class, and the correct presentations were selected.

Scenario 3. The second task was forming triangles with matchsticks. For example, 3 matchsticks form 1 triangle, 5 matchsticks form 2 triangles, and 7 matchsticks form 3 triangles. Learners had fun working on the pattern. Figure 2 is an example of the completed work.

Figure 2.

Forming triangles with matchsticks to determine a mathematical pattern.



Reflection from the Presented Lesson: Patterns

The research team reflected, and there was consensus that the lesson went well. Learners were excited by the use of manipulatives. However, there was room for improvement in building the lesson from simple to complex. This will ensure learners who are struggling with a certain concept are incorporated. Teacher C explained the "even when learners were asked to come up front to present their created patterns, there was excitement in class". The research team felt that the lesson started with a difficult pattern because it was difficult for most learners to initially see the pattern. However, learners were observed to be engaging and participating throughout the lesson. The selected learners with dyscalculia symptoms were observed to be participating and excited about the lesson. The same learners normally sleep in class or are passive.

Lesson 2 entailed an interactive and fun learner card game relating to mathematical patterns. Hornigold (2015) and Kunwar (2022) asserted that learners with dyscalculia need encouragement with core numbers and activities to make a connection between numbers, quantities, and symbols to form mathematical patterns. The findings from the class observation during Lesson 2 on patterns indicated that learners initially found identifying mathematical patterns challenging. Furthermore, once learners with dyscalculia became engaged and had fun, they participated for the duration of the lesson.

CONCLUSION

Dyscalculia is a condition that makes it difficult to understand mathematics. Learners with dyscalculia often give up on learning mathematics because they believe it is too difficult or impossible to understand. The primary research question of the study was how dyscalculia can

be addressed in a mathematics classroom through an active learning strategy, and based on the findings, it can be concluded that dyscalculia can be addressed in a mathematical classroom by using active learning strategies. There is no evidence of one intervention strategy that fully addresses mathematics learning for learners with dyscalculia; however, the active learning elements used in this study helped teachers and parents to support learners with dyscalculia and helped learners with dyscalculia to engage more positively in mathematics. The study evidenced that amending and adapting the way in which learners with dyscalculia is taught and assessed, introducing peer teaching practices, and using a variety of appropriate manipulatives in class can indeed address dyscalculia through an active learning strategy in a mathematics classroom. This study will inform further research and investigation into educators' and parents' awareness and understanding of dyscalculia. The limitation of the study is that it was done over a short period of time. Future studies can be done as a cohort study in which learners with dyscalculia are followed over a period of time.

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