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Supporting neurodiverse learners via cultural play and technology in early childhood mathematics

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Background: Neurodiversity in mathematics classrooms embraces learners with mathematical barriers. This article contends that cultural play and technology can be used to support neurodiverse learners in teaching mathematics in early childhood as they incorporate inclusivity, equity and diversity.

Aim: The article explores the educators' lived experiences in supporting neurodiverse learners through cultural play and technology in teaching mathematics in early childhood.

Setting: Twelve mathematics foundation phase teachers in Limpopo province, South Africa, participated in the study.

Methods: In this qualitative study, hermeneutic phenomenology was employed. The data were collected through semi-structured interviews, document analysis and non-participant observations to gather educators' lived experiences of this phenomenon.

Results: It was showed that educators have lived experiences in using digital games that integrate African culture to teach mathematical skills to neurodiverse learners. Their lived experiences were expressed during the interviews, while lesson plans and observations showed a gap in teaching practices.

Conclusion: It is suggested that educators need more training on how to use the knowledge from the curriculum framework to integrate cultural play and technology to support neurodiverse learners in teaching mathematics.

Contribution: The novelty of this research lies in using digital play that integrates cultural practices to teach young learners with mathematical difficulties. Differentiated teaching can also be incorporated in these approaches.

Keywords: cultural play; mathematics; multi-sensory learning theory; neurodiverse; technology.

Introduction

The South African curriculum policy in education mandates that educators support neurodiverse learners in their holistic development (Department of Basic Education [DBE] 2014). In addition, the Education White Paper 6: Special Needs Education: Building an Inclusive Education and Training System encourages inclusivity, equity and support to all children (DoE 2001). This is aligned with the international policies and Sustainable Development Goal (SDG) 4 that advocates for inclusive, equitable and quality education to transform education systems worldwide (United Nations Educational, Scientific and Cultural Organisation [UNESCO] 2017). To do this, early childhood educators are required to use multi-sensory approaches to develop learners' holistic skills. Given that, Bianculli (2024) argues that multi-sensory approaches are not intended to align with the individual learning styles of children but rather involve the use of pedagogical approaches that make teaching early mathematics more inclusive, accessible and developmentally appropriate. In the context of this article, Gardner (2024) argues that individual learning style does not refer to multiple intelligences, including auditory, logical-mathematical or interpersonal learners, which are seen as neuromyths. Considerably, individual learning styles are broad, diverse approaches that engage different learners given their divergences in learning mathematics, as noted by Purwasih and Dahlan (2024), in early childhood. The author maintains that educators can use cultural play and technology to support neurodiverse learners in teaching mathematics in early childhood.

Note: The manuscript is a contribution to the topical collection titled 'Advancing neurodiversity in education for equity, inclusion and employability', under the expert guidance of guest editors Prof. Maximus Monaheng Sefotho and Prof. Veronica Dwarika. This article was republished with an updated title. This correction does not alter the study's findings of significance or overall interpretation of the study's results. The publisher apologises for any inconvenience caused.

This article argues towards neurodiversity within Africanised pedagogical approaches (play) integrated with technology in teaching and learning mathematics in early childhood. Strengthened by the philosophy of Ubuntu and curriculum implications of Indigenous knowledge systems (IKSs) and play-based pedagogies, this approach is not only inclusive but also responsive to learners' cognitive profiles (Moloi et al. 2021). Similarly, Tovar-Gálvez (2021) notes that inclusive education within cultural epistemologies recognises individual differences of each child and their learning potential. To robustly link cultural epistemologies and indigenous pedagogies to the neurological learning differences observed in neurodiverse children, teachers can integrate technologies in teaching mathematics in early childhood teaching. Thus, this article is unique as it integrates cultural play and technology in supporting neurodiverse learners in teaching mathematics in early childhood.

Cultural play pedagogies involve a rich appreciation of culture, diversity and inclusivity. For example, the philosophical views of ethnomathematics agree that cultural activities such as beadwork, weaving and indigenous games embed mathematical concepts (Clements, Lizcano & Sarama 2023). According to Rosa and Orey (2024), educators need to implement ethnomathematics as it leads to a culturally embedded pedagogy in their mathematics classrooms. Technology is also an essential approach for teaching mathematics to neurodiverse learners in early childhood, offering individualised, multi-sensory and engaging learning experiences (Hutson, Hutson & Harper-Nichols 2024). In contrast, the research from Mpofu and Sefotho (2024) asserts that technology itself is not useful for neurodiverse learners, but rather the pedagogy underpinning technology is. This article argues that digital games that integrate cultural play can be used to support neurodiverse in teaching and learning mathematics in early childhood. Shilling (2020) asserts that technological apps or digital games inspired by African cultural practices can enhance relevance and promote inclusivity in mathematics classrooms. Neurodiverse learners especially with Attention-Deficit Hyperactivity Disorder (ADHD), dyslexia, dyscalculia and dysgraphia often struggle with sustaining attention in learning activities (Hudson 2024). That being the case, gamified learning classrooms that are fun, engaging and structured can support learners with attention challenges, and Subramaniam and Saleh (2024) agree that this approach can reduce mathematics anxiety in learners. Echoing this viewpoint, African researchers such as Owusu and Obuo Addo (2023) agree that cultural games such as Ludo or Morabaraba, when digitised, can be used to engage different learners as they provide thinking and problem-solving skills while integrating mathematics play. It is against this backdrop that the author argues that using cultural and technological play in teaching early mathematics aligns well with the views of Vygotsky's Zone of Proximal Development (ZPD) when teaching neurodiverse learners. Educators can use digitised cultural play to support neurodiverse learners in early childhood by working with young children in their comfort zones and gradually scaffolding the mathematics activities to higher levels.

A digital game that is based on cultural practices, such as Morabaraba, can be used to teach counting, patterns, mathematics thinking and problem-solving skills. Meeran et al. (2024) note that it combines kinaesthetic, tactile and visual components, which makes it ideal for learners who are neurodiverse (Selepe 2024). In a different study, Rizqiyani et al (2025) affirm that playing a Ludo game online can teach young learners' spatial orientation and counting skills in mathematics. In the same perspective, Ogundare, Alabi and Jebson (2024) provide that a Sudoku game integrate both cultural play and digital literacy skills. Thus, the author understands that by integrating culturally relevant play activities with technology, educators can create inclusive and effective mathematics teaching that meets the diverse needs of all learners.

What does neurodiversity mean in the context of early childhood mathematics?

Generally, neurodiversity refers to the natural variation in human brain function and the resulting differences in how individuals learn, process information and interact with the world (Nwachukwu et al. 2024). This spectrum encompasses a wide range of conditions, each with its own unique set of strengths and needs (Nwachukwu et al. 2024). Moreover, Dunne (2024) and Dwyer (2022) agree that neurodiversity in teaching and learning is the notion of recognising and accepting various neurological differences among young learners, including conditions like ADHD, autism, dyslexia and others. In the context of early childhood mathematics, researchers such as Genc and Erbas (2020) explain that these differences in mathematics classrooms are known as learners with mathematical barriers as these differences can influence how children learn and engage with mathematical concepts. Psychologists such as Thomas Armstrong and Judy Singer, among others, suggest that neurodiversity is a function of all children, as they are all diverse, yet some are divergent (differ from the norm) (Strijbos & De Bruin 2025). The author aligns with the views of Filmer (2024) that while all children are neurologically unique, this article focused on the latter learners who have learning differences that present mathematical barriers.

The South African curriculum encourages educators to adopt diverse teaching strategies that accommodate neurodivergent learners, promoting an inclusive environment where all children can develop their mathematical skills effectively (DoE 2001).

Background

The alarming poor mathematics results of South Africa are a cause of concern. Recent Trends in International Mathematics and Science Study (TIMMS) (2023) statistics indicate that South African learners continue to perform poorly in mathematics compared to the other countries. In the same vein, Bayaga, Ndamase-Nzuzo and Bossé (2022) show that foundation phase learners are facing difficulty in counting skills. This could mean that neurodiverse learners with mathematics barriers need support in learning mathematics from the early grades. This is despite the multi-sensory approaches put in place by different policymakers with the

aim of improving early mathematics education worldwide. For example, play-based learning is given priority in South Africa's Curriculum and Assessment Policy Statement (CAPS), which integrates African games and technology (DBE 2011). Furthermore, the Early Years Foundation Stage (EYFS) in the United Kingdom emphasises the importance of outdoor play by offering chances to incorporate math exercises based on nature and cultural games (Garden 2023). Differentiated teaching, which uses technology to provide customised learning experiences for neurodiverse learners, is highly valued in the United States (Asbell-Clarke et al. 2024). Furthermore, Australian curricula emphasise indigenous storytelling and cultural practices, which complement multisensory and imaginative approaches to early mathematics teaching (Sarra & Ewing 2021). However, teachers lack experience in balancing technological innovation with play-based pedagogies and cultural contexts, ensuring that mathematics education is accessible and meaningful in rural areas.

Little is known about the best ways to teach mathematics to neurodiverse young learners in rural regions using multisensory methods that use African play-based pedagogy and technology. Specifically, the interplay between traditional cultural knowledge, modern technological tools and their accessibility in teaching mathematics to young learners in resource-constrained rural settings remains underexplored (Saal, Mdlulwa & Hannan 2024). Furthermore, more knowledge is needed on how these approaches can address the unique needs of neurodiverse learners in such contexts while fostering inclusivity and engagement (Ker & Van Gorp 2023). Therefore, there was a need to explore teachers' lived experiences in African cultures and technology to teach mathematics to neurodiverse learners in early childhood. Despite the potential of integrating African cultural practices with technology to enhance mathematics education, there is a critical gap in understanding how these approaches can be adapted and implemented effectively in rural settings to ensure equitable and inclusive learning opportunities for neurodiverse learners in early childhood. As such, this article asked: *How do educators support neurodiverse learners through cultural play and technology in teaching mathematics in early childhood?*

Theoretical framework

Multisensory learning theory underpins this article as it emphasises inclusivity, equity and diversity in teaching and learning in the early childhood. Thus, it supports the integration of cultural play and technology for teaching mathematics to neurodiverse learners in early childhood. In addition, this theory posits that engaging multiple senses, such as visual, auditory and kinaesthetic, enhances learning and memory retention (Craft 2023). By drawing on the strengths of African cultural resources and integrating them with technology, educators can create a mathematics teaching framework that includes neurodiverse learners (ed. Efthymiou 2024). This theory addresses sensory processing needs and fosters cultural pride and global awareness, preparing learners to thrive in diverse educational and social contexts. Using multisensory approaches in teaching mathematics helps neurodiverse learners' process information more effectively by catering to their unique sensory strengths (Azuka et al. 2024).

Incorporating elements of cultural play

Incorporating culturally relevant play-based pedagogy helps situate mathematical concepts within familiar settings, facilitating better understanding. Play-based activities such as indigenous games, art, traditional dance and storytelling in multisensory mathematics teaching make learning more relatable and meaningful for learners from African backgrounds (Green 2020). For example, Babu, Nagaraju and Johnson (2023) affirm that teaching geometry in early childhood through African architectural patterns or using rhythms in music can be used to explain fractions and ratios. Against this background, the author understands that cultural play is one of the multi-sensory approaches to accommodate neurodiverse learners in teaching mathematics to early childhood learners. Other than that, technological tools can also support different learners with mathematical barriers in early childhood.

Technological tools

Technology provides innovative tools that enhance multisensory learning experiences. Interactive software, educational apps and digital games can simultaneously engage visual, auditory and kinaesthetic senses, making mathematics learning more dynamic and interactive (Emma 2024). Even though Boyd (2024) does not point to the idea of teaching mathematics through technological tools, he shows that these tools can be adapted to individual learning needs, offering personalised multisensory experiences that cater to the specific requirements of neurodiverse learners. Emma (2024) and Boyd (2024) show that implementing educational software that offers multisensory math games with African cultural contexts provides visual, auditory and interactive experiences.

Literature review

The author reviewed the recent literature from different regions to gain insights on supporting neurodiverse learners through cultural play and technology in teaching mathematics in early childhood. The literature shows a critical gap in this field. This article integrates pedagogical approaches and teaching tools in a rapidly changing curriculum focusing on early mathematics in South Africa. The author focuses on equity, inclusion and diversity.

An international study conducted in Vienna by Werner et al. (2024) focused on technologies and social play in supporting a neurodiverse group of children aged 8–10. Their study used a participatory design process through comparative and participatory evaluation between MusicPads, LightSpaces and social play to support neurodiverse children. The impact

of these technological devices and children's playing experiences and reflections was also assessed. Their findings indicated that technology supports learners with diverse needs when integrated with ideas of play (Werner et al. 2024).

The study of Scott et al. (2023) compared the impact of playful opportunities digital technologies between South Africa and the United Kingdom. In a mixed-method study, interviews and observations were conducted in both countries, which resulted in 60 interview sessions with parents and observation of children between 3 and 11 years old. Some of the children had special needs such as autism and ADHD. Scott et al.'s (2023) findings indicate that even though South African children had limited access to technological tools, they were able to engage in digital play compared to the United Kingdom.

A sub-Saharan study by Hamukwaya and Haser (2021) focused on learners' difficulties in learning mathematics in secondary schools of Namibia. They used interviews to explore the beliefs of six pre-service and in-service mathematics educators within a qualitative approach. Their findings indicated that to improve their future practices, teacher education programmes should focus on increasing pre-service teachers' awareness of how their knowledge, practices and beliefs about mathematics learning difficulties might affect learners (Hamukwaya & Haser 2021). A key aim in Namibia is to address learners with mathematics difficulties in early childhood by emphasising inclusive education and differentiated teaching strategies (Ministry of Education, Arts and Culture 2017). The findings of these empirical studies in different contexts show that incorporating culture and technology in teaching and learning mathematics may promote opportunities for neurodiverse children, but that there may also be some challenges that need to be addressed.

Despite that the international policies such as Australian and EYFS curricula compromise the use of cultural approaches, digital technologies and pedagogical approaches in early childhood, South Africa is still experiencing contextual barriers such as infrastructure, teacher training gaps and cultural mismatches in technological learning. The research from Rwodzi and De Jager (2021) confirms that South African schools in rural areas experience limited infrastructure such as lack of digital devices and unreliable internet connection. Moreover, technology-enhanced activities are often designed without consideration of cultural context, which creates a curriculum disconnect (Verawati & Nisrina 2025). In addition, teacher training support is grounded in Eurocentric frameworks, which affect educators' preparedness in integrating meaningful pedagogical approaches in context-sensitive practices (Ogodo 2024). Therefore, this article situates itself within Africanisation, decolonisation and digitalisation by advocating for neurodiverse learners using cultural play and technology in teaching mathematics within rural South African realities.

The opportunities and challenges of cultural play and technology in mathematics learning to neurodiverse learners

On one hand, incorporating cultural play and technology benefits children by developing mathematics skills in ways that resonate with their backgrounds and new trends. This can include using familiar stories, games and practices that reflect diverse cultural experiences. Ng, Kewalramani and Kidman (2022) agree that cultural play helps establish connections between mathematical concepts and children's lived experiences, making learning more meaningful and engaging. In a similar view, Adams, Asemnor and Nkansah (2024) affirm that play-based approaches that include cultural elements promote engagement and intrinsic motivation. This is crucial for neurodiverse learners who may struggle with mathematical concepts. The author understands that playing cultural games during mathematics teaching can foster social skills and peer interactions, providing opportunities for neurodiverse children to learn from and with their peers in a supportive environment. Sobel et al. (2024) maintain that educational apps and digital games can provide multisensory experiences that are particularly beneficial for neurodiverse learners. These tools allow for individualised, differentiated learning and adaptive learning pedagogies in learning literacy and mathematics in early childhood education. This argument is backed up by ed. Efthymiou (2024), who states that many technological tools offer visual aids, sounds and animations that cater to various learning styles, helping neurodiverse children grasp abstract mathematical concepts. Educators can use culture and technology to explore the brain, and its functions of neurodiverse children see and engage in play-based activities to teach mathematics concepts.

On the other hand, not all learners have equal access to technology, especially in rural schools, which can create disparities in learning opportunities and achievement of mathematics. In addition, Weber and Greiff (2023) explain that neurodiverse learners with visual impairment may be limited in using technology, potentially hindering the development of critical problem-solving, thinking and reasoning skills. A significant issue remains the insufficient teacher training in understanding neurodiversity and adapting pedagogical approaches. Venketsamy, Sing and Smart (2020) argue that there is a need for teacher training to understand and accept inclusivity, equity and diversity in early childhood classrooms. Educators' understanding of how neurodiverse children's brains work will create safe, secure and trusting relationships in mathematics classrooms. Thus, it is significant to balance these opportunities and challenges of using cultural play and technology to support neurodiverse learners in teaching mathematics in early childhood. The research methodology adopted is discussed in the next section.

Research methods and design

The interpretivist paradigm was used in this article. This selection was guided by Panya and Nyarwath (2022), who

argue that a subjective epistemology and a relativism ontology influence one's behaviour and experiences. This view aligns with the multisensory learning theory (theoretical framework), as it encourages inclusivity, equity and diversity in a classroom. In addition, Moisander, Närvänen and Valtonen (2020) agree that different learning abilities are influenced by their history, cultural and social perspectives. A qualitative research approach was adopted because it suits the chosen paradigm. Al-Ababneh (2020) asserts that the qualitative research approach values social truth that is embedded in social surroundings. Hermeneutic phenomenology was employed to explore the educators' lived experiences in supporting neurodiverse learners through cultural play and technology in teaching mathematics in early childhood (Dangal & Joshi 2022). This was helpful to obtain an in-depth and rich understanding on the phenomena under the study. Homogenous purposive sampling was used to select 12 foundation phase educators (Grades 1 to 3) from four public primary schools situated in the Capricorn south district, Limpopo, South Africa. The rationale for focusing on a single district was for a deep context-specific understanding of how educators support neurodiverse learners through cultural play and technology in teaching mathematics in early childhood. This limited geographical and demographical sampling approach allowed an in-depth and rich exploration of participants' shared lived experiences within a similar infrastructural context and teacher support. These participants had similar lived experiences of teaching mathematics in the foundation phase, and they used the CAPS to teach neurodiverse learners in the foundation phase (Dangal & Joshi 2022). The selection criteria were that they had to be educators with at least 3 years' experience in teaching mathematics in early childhood.

Data triangulation instruments such as semi-structured interviews, document analysis and non-participant observations were used. Semi-structured interviews were used to solicit educators' lived experiences in supporting neurodiverse learners through cultural play and technology in teaching mathematics in early childhood. Furthermore, document analysis was used to corroborate educators' responses from the interviews. The educators' lesson plans were requested to understand how they planned their lessons and used cultural play and technology. In addition, classroom observations were conducted to see how educators supported neurodiverse learners in the implementation of lessons (their practices).

The participants and parents signed consent forms to give their permission for classroom observations. The ethical considerations were carefully navigated and transparent, particularly given the rural and culturally distinct context. This research process was conducted with cultural sensitivity, recognising community norms and respecting local values during data collection. Pseudonyms for schools (School 1, Foundation Phase Educator 1 [S1FPE1] to School 4 Foundation Phase Educator 3 [S4FPE3]) were used to safeguard the anonymity and confidentiality of the schools and educators. The study's credibility was established through data triangulation methods, which increased the validity and credibility of the research findings (Striepe 2021). To ensure that the findings are transferable and reduce internal bias, an audio recorder was used to capture the conversation during the interviews (Stenfors, Kajamaa & Bennett 2020). Coding, co-coding and recoding strengthened authenticity, reliability and consistency of the data through multiple coding (Kawamoto, Koizumi & Yoshikane 2023). This process of multiple coding is discussed in data analysis section.

Data analysis

Supported by Rajasinghe and Garvey (2023), an interpretative phenomenological analysis was used to analyse three data sets from the interviews, lesson plans and observations to interpret educators' lived experiences in supporting neurodiverse learners through cultural play and technology in teaching mathematics in early childhood. Keeping in mind the subjective epistemology and relativism ontology in interpretivism research (Panya & Nyarwath 2022), the data analysis for this article followed Smith, Flowers and Larkin's (2022) Interpretive Phenomenological Analysis (IPA) model by creating codes, categories and themes. Before data analysis, interview data were transcribed into text as required by the qualitative research. The requested lesson plans were interpreted by answering predefined questions from the document analysis tool, and observation schedule was used to understand the educators' practices in their classrooms.

During the first stage of data coding, the author created codes from key terms of the research question. This was done manually on the computer using Microsoft Word. In the second stage, three data sets – interview transcripts, document analysis tools and observation schedules from 12 participants – were uploaded on the NVivo 14 software for the recoding process. The same codes from the initial coding were used. In the final stage, a co-coding process was performed by an independent coder to ensure authenticity and consistency of data analysis (Gupta 2024). The reviewed literature and theoretical framework were later uploaded on the software to create categories and themes. This was done to ensure that multisensory learning theory still served as a lens throughout the research. Thus, data saturation was reached as the identified themes were sufficient to discuss the findings and draw the conclusion (Naeem et al. 2024).

Ethical considerations

Ethical clearance to conduct this study was obtained from the University of South Africa (UNISA) College of Education Ethics Review Committee (ref: 2023/10/11/64019209/38/AM). The Limpopo Provincial Research Ethics Committee (LPREC), through the premier's office, also approved the conduct of this research, with research project number LPREC/144/2023: PG. The participants and parents signed consent forms to give their permission for classroom observations. Pseudonyms for schools (S1FPE1 to S4FPE3) were used to safeguard the anonymity and confidentiality of the schools and educators.

Results

This article asked: *How do educators support neurodiverse learners through cultural play and technology in teaching mathematics in early childhood?* The results indicated that some educators used digital play that integrated culture to support neurodiverse learners through cultural play and technology in teaching mathematics in early childhood. However, there is a gap between teachers' lived experiences of cultural play and technology and its practical implementation in teaching mathematics to neurodiverse learners. Teachers expressed their experiences of the significance of using cultural play and technology during the semi-structured interviews. However, this was not reflected in their lesson plans, and traditional approaches were frequently used during non-participant observations to teach mathematics to neurodiverse learners.

Participants' conceptual understanding of cultural play and digital tools in early mathematics

Teachers explained how they included visual aids in their mathematics lessons using videos through projectors, smartboards, Google and YouTube. S3FPE2 and S1FPE3 explained how they used images and videos to supplement the lessons in teaching mathematics concepts:

> 'Videos are also available for download. For instance, you can google a picture or a video of kids having fun with a skipping rope. I would go over it again with the projector.' (S3FPE2)

> '… Sometimes, I must use technology in my classes, like taking learners to a smart room. I will start by playing a video related to the ideas I discussed in my lesson. This helps learners understand mathematics …' (S3FPE2)

> 'Learners can use the tablets to view a video and then go outside the classroom to play the games. Learners can learn number patterns with this game…' (S1FPE3)

In the same view, S3FPE1 and S4FPE2 shared that through online sources like Google and YouTube, educators could find digital content that aligns with mathematics teaching in early childhood to neurodiverse learners. They said:

> 'I would look up videos on Google that link to the mathematics topic of the week. I wish to teach children addition techniques, for instance. Since we are discussing Grade 1 learners, I suggest zero to twenty. Songs that relate to the subject would be sent to me.' (S3FPE1)

> 'I can use a variety of YouTube mathematical play games for mental mathematics…' (S4FPE2)

The observations indicated that some of the educators (S1FPE3 and S3FPE3) used play-based pedagogy and digital resources to teach mathematics to neurodiverse learners. However, digital games that integrate African culture, such as Morabaraba, were not used during their lessons. The technological tools were used to engage learners with cognitive processing difficulties through step-by-step guided instruction and visualising mathematics animations to assist neurodiverse learners. The learners responded positively, particularly during activities that involved movement or tapping on the smartboard. However, these activities were not planned in the educators' lesson plans.

The challenges and gaps between lived experiences and classroom practices

During the interviews, S1FPE3 and S4FPE4 highlighted that they experienced both challenges and opportunities in integrating cultural play and technology in teaching mathematics:

> 'Online resources that employ African play-based education are scarce. On the other hand, I can produce web content that might benefit other teachers. For instance, the Diketo game teaches counting and multiplication to learners. This shows that old techniques of teaching young learners are mixing with new ways. Learners can use the tablets to view a video and then go outside the classroom to play the games. Learners can learn number patterns with this game. Multiples of two or four, for instance. Sometimes, I must use technology in my classes, like taking learners to a smart room. I will start by playing a video related to the ideas I discussed in my lesson. This helps learners understand mathematics.' (S1FPE3)

> 'It was hard to use play that integrates African culture in teaching mental mathematics. However, I used a game that incorporates numbers to teach learners patterns. Learners played the Dibeke game physically while counting numbers from zero to ten. If I knew how to use an indigenous game online, I would have used it.' (S4FPE4)

To contextualise the readers, Diketo (pebbles) is an African game that uses stones for playing. A child can use one stone to toss and throw up, with the aim of catching the stone and grabbing more stones from a circle on the ground (Mathodi & Dlamini 2024). This game teaches learners counting and eye-hand coordination. Tachie and Galawe (2021) explain that Dibeke is a physical game with indigenous approaches; it can be played in teams while running and kicking a ball. It is used to develop learners' physical, spatial orientation, counting and number pattern skills. S1FPE3 and S4FPE4, respectively, used Diketo and Dibeke to teach young learners mathematics skills. Other than that, S1FPE2 and S4FPE1 mentioned cultural play-based activities (such as the Morabaraba game) that could be played through the use of technology to teach neurodiverse learners' mathematics. They stated:

> 'I think using different games that I have mentioned, such as Chess, Diketo and Morabaraba, to develop a sense of mathematical skills for foundation phase learners. It is just that I do not know how to play them both physically and through smartphones or tablets.' (S4FPE1)

> 'I integrated an indigenous game called Morabaraba. Through the projector, I demonstrated how this game is played. I showed learners how to play Morabaraba and its rules. I incorporated mathematical concepts like patterns, geometry, and algebra in mental mathematics.' (S3FPE3)

In addition, it was observed that educators were faced with the challenges of limited technological tools in their school, and they also were under pressure to adhere to the guidelines

in the curriculum policies. However, the observations also indicated a significant absence of culturally relevant digital content. Specifically, although educators expressed a belief in the value of integrating local cultural games, no instances of digitalised African games such as Morabaraba were observed in the actual teaching practices. Instead, most educators relied on generic educational apps, which, while interactive, lacked cultural resonance for the learners.

Furthermore, many educators faced structural and systemic barriers. It was noted that several classrooms had only one functional digital device, which had to be shared among large groups of learners, limiting consistent engagement. In one case (S4FPE2), a teacher resorted to describing the app activity verbally because of technical difficulties, thus reducing the multisensory potential of the task. These observations reinforce the gap between participants' expressed lived experiences beliefs (as narrated during the semi-interviews) and their enacted classroom practices. While there was verbal support for the use of cultural play and technology, the practical integration of these methods was inconsistent and heavily constrained by contextual challenges.

Discussions of findings

Theme 1: Integration of cultural play with technology to enhance mathematical learning

One of the key themes emerging from the teachers' interviews is the integration of cultural play and technology in teaching mathematics to learners in early childhood. These teachers acknowledge the importance of integrating multi-sensory approaches to teach learners mathematics with different learning needs. These findings are consistent with those of Werner et al. (2024) and Sobel et al. (2024), who explained the support that neurodiverse learners receive from educational apps, digital games and technology, as they provide multisensory experiences. This literature shows that using technology in teaching mathematics in early childhood allows for learners with different mathematical barriers to grasp mathematical concepts. Furthermore, Adams et al. (2024) highlight that playing cultural games such as Morabaraba fosters engagement and motivation, showing that using games in teaching mental mathematics is beneficial for neurodiverse learners. These findings further support the idea of Babu et al. (2023) from the theoretical lens that using African patterns and music can teach neurodiverse learners' fractions and patterns. This article has been unable to demonstrate how neurodiverse learners develop visual, auditory, kinaesthetic and memory retention through an integration of cultural play with technology to enhance mathematical learning, as explained in the theoretical framework (Craft 2023). One of the issues that emerge from these findings is the lack of curriculum support and teacher training in teaching mathematics to neurodiverse learners. The findings corroborate Venketsamy et al.'s (2020) findings that there is a need for educator training to support neurodiverse learners in teaching mathematics in early childhood.

The findings were correlated with the reviewed literature and the lens of the theoretical framework. The findings of this article indicated that the participants had challenges of integrating the curriculum content of African culture and technology in teaching mathematics to neurodiverse learners in early childhood. However, they use the digital tools such as smartboards, projectors and videos to demonstrate cultural games (Dibeke and Diketo) to teach mathematical skills. More interestingly, they also used digital games that incorporated culture (Morabaraba) to teach neurodiverse learners patterns, geometry and algebra in mental mathematics. The mathematics curriculum encourages educators to use Morabaraba games in their lessons, but there are limited guidelines on how they can use it to support neurodiverse learners (DBE 2011).

Theme 2: The use of digital, visual and interactive resources to support neurodiverse learners

Another prominent theme is the use of digital and interactive visual resources, which are especially helpful for neurodiverse learners who could gain from multisensory engagement in learning mathematics. The findings revealed that the participants also used digital, visual and interactive resources to teach mathematics in early childhood. These resources are used to support neurodiverse learners to develop counting skills. For example, S3FPE1 explained that a video found on Google can teach Grade 1 learners counting skills. This finding supports ed. Efthymiou's (2024) findings, which showed that digital visual aids and animation assist neurodiverse learners in learning abstract mathematical concepts. However, this is contrary to the literature from Weber and Greiff (2023), which argued that learners with visual impairment may not benefit from the use of digital, visual and interactive resources, as they may be affected by the technological tools and may hinder them to develop mathematical skills. The theoretical framework demonstrated a need to use multi-sensory approaches to engage visual, auditory and kinesthetic senses with a support of interactive software in teaching mathematics (Emma 2024). Thus, this article suggests that educators could use digital games that integrate cultural context, such as Morabaraba, to teach learners mathematics skills in early childhood classrooms.

Theme 3: Gap between ideal and practices

The triangulation of data from the interviews, lesson plans and observations brought to light a gap between the ideal and the practices of supporting neurodiverse learners through cultural play and technology in teaching mathematics in early childhood. The findings showed an inconsistency between educators' responses from the interviews, how they planned their lesson and what they practised in their classrooms. Themes 1 and 2 explained that the educators, during the interviews, said that they integrated cultural play with technology to enhance mathematical learning and used digital, visual and interactive resources to support neurodiverse learners. The interviews highlighted the

educators' awareness and willingness to incorporate cultural play and technology in teaching mathematics, but the lesson plans did not reflect this shift.

The dissonance between teachers' adopted beliefs and actual classroom implementation may arise from several factors. Firstly, infrastructural challenges, such as limited access to technological devices in rural schools, which aligns with the literature from Rwodzi and De Jager (2021). Secondly, while the semi-structured interviews indicate that the participants show the significance of integrating cultural play and technology into teaching mathematics to neurodiverse learners, they lack sufficient teacher training support in implementing these approaches in their classroom practices (Ogodo 2024). Thirdly, the CAPS curriculum linked to educators' challenges in implementing cultural play and technology in their mathematics classrooms reflects broader contextual, pedagogical and systemic barriers that obstruct inclusivity and culturally technological play-based pedagogical approaches for neurodiverse learners (Verawati & Nisrina 2025).

These findings corroborate Scott et al.'s (2023) study, which indicated that South African children have more limited access to technological tools compared to those in developed countries. The multisensory learning theory showed the importance of developing visual, auditory and interactive experiences to neurodiverse learners in teaching mathematics (Boyd 2024; Emma 2024). The article suggests that educators can work with children in groups because of limited technological tools in their mathematics classrooms. As a result, this article contributes to the existing literature on supporting neurodiverse learners by using digital play that integrates cultural practices to teach mathematics in early childhood. For example, to implement this innovation in practice, educators can download and play the Morabaraba game available at https://play.google.com/store/apps/details?id=com.donkeycat.mill&hl=en_ZA. Furthermore, it is recommended that educators use virtual resources and culturally themed mathematics games that provide visual, auditory and kinaesthetic senses to provide inclusive, equitable and diverse environments where neurodiverse learners can explore mathematical concepts at their own pace.

Conclusion

This article set out to explore educators' lived experiences in supporting neurodiverse learners through cultural play and technology in teaching mathematics in early childhood. The findings emerged that educators had an awareness and willingness to use these multisensory approaches in their classrooms. The educators expressed their lived experiences during the interviews, which differed from what was included in their lesson planning and classroom practices. To bridge the gap between policy ideals and classroom practices, this article recommends a targeted curriculum support and practice-based teacher training tailored to rural educational contexts on the integration of cultural play and technological strategies suited for neurodiverse learners in teaching and learning mathematics in early childhood. The generalisability of these findings is subject to certain limitations; for instance, the small sample of participants was selected from one district in Limpopo province and the nature of qualitative research. It would be interesting to compare the lived experiences of educators from mainstream and inclusive schools within the same district in supporting neurodiverse learners in teaching mathematics in early childhood.

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Data availability

The data that support the findings of this study are available from the corresponding author, M.A.S.. upon reasonable request.

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