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Number sense skills in the foundation phase through technology-enhanced mental mathematics activities

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Background: Foundation phase teachers are encouraged to develop learners' number sense skills in their teaching and learning activities. Despite the significance of teaching number skills in mental mathematics activities, there are inadequate guidelines that could assist teachers in developing number sense skills through technology-enhanced mental mathematics activities.

Aim: To examine the development of number sense through technology-enhanced mental mathematics skills in the foundation phase.

Setting: The study was conducted in Limpopo province from three primary schools.

Methods: A case study design was employed in qualitative research. Semi-structured interviews, interpretive document analysis and non-participant observations were used to collect data from six Grade 3 teachers.

Results: This article found that foundation phase teachers possess strong content and pedagogical knowledge for developing number sense skills, often using play-based and game-based strategies to engage learners. However, they face challenges in integrating technology because of limited resources and insufficient guidance in the curriculum framework.

Conclusion: There is a need to integrate technology-enhanced mental mathematics activities to develop number sense skills in the foundation phase. Even though teachers demonstrate strong content and pedagogical knowledge, findings relating to technological integration highlight the need for professional development and curriculum support.

Contribution: This article contributes to theory, practice and policy by demonstrating how technology-enhanced mental mathematics activities support the development of number sense skills in the foundation phase. It extends the Technology pedagogical and content knowledge (TPACK) framework to the foundation phase of mathematics teaching, highlighting the interplay between the use of technology, content knowledge and pedagogical approaches to create inclusive, engaging, play-based pedagogies and effective learning environments.

Keywords: foundation phase; number sense skills; mental mathematics, technology, technology; pedagogical; and content knowledge (TPACK).

Introduction

In recent years, teaching and learning mathematics in the foundation phase through the integration of enhanced technology has been an exciting research subject. Technology integration is also applied in teaching and learning number sense skills. It can be understood that number sense features in all content areas in mathematics in the foundation phase. The authors acknowledge that number sense does not develop solely through mental mathematics activities as affirmed by Bisaillon (2023). It evolves through various phases, including perception of small quantities and additive thinking, which are foundational for early arithmetic learning. It should also be noted that young children develop number sense through sensory and perceptual play, by learning words and interactively connecting meaning to those words (Vygotsky 1986) and by hierarchically building on previously learnt concepts (Fritz, Ehlert & Balzer 2013). Children experience mathematics in their everyday lives and learn to manipulate concepts. Furthermore, Winkel and Zipperle (2023) assert that only when a child fully understands mathematics concepts, those concepts are stored as mathematical facts and procedural knowledge which can be used in mental mathematics by retrieving facts from memory. Noticeably, the South African curriculum

(Curriculum Assessment and Policy Statement [CAPS]) encourages teachers to integrate technology in teaching these mathematical skills (DBE 2011). Even the National Council of Teachers of Mathematics (NCTM) supports the idea that technology is crucial in teaching and learning mathematics because it influences learners' interests and improves their understanding of mathematical concepts (Sun 2023). The authors argue for the development of number sense skills through technology-enhanced mental mathematics activities.

This is also true in different countries worldwide. For example, the Ontario Association curriculum in Australia states that teachers need to use technology-based learning to teach young children mathematics (Johnson et al. 2020). Even Rwanda's competence-based curriculum states that for learners to develop number sense skills, teachers must use technology tools to enhance their mathematical thinking (Nsengimana et al. 2023). In this context, the authors understand the importance of integrating technology-enhanced activities in teaching mathematics. It is further viewed that teachers can develop foundation phase learners' number sense through technology-enhanced mental mathematics skills. According to Clarke and Beck (2021), number sense is the ability to work with numbers and solve different mathematical problems. While Vale and Westaway (2024) explain that mental mathematics is a process of solving mathematics calculations mentally. Finally, the use of technology involves integrating multimedia tools, including technological devices, digital resources, interactive content and learning management systems (Haleem et al. 2022). This is corroborated by Wulandari et al. (2022), who state that when learners engage in mental mathematics activities that integrate media, they develop number sense skills. On the same note, Carvalho and Santos (2022) added that they enhance meta-cognitive and collaborative skills that assist them with arithmetic counting. Attard and Holmes (2019) explain that the significance of coding skills in teaching mathematics is to enhance learners' mental mathematics skills. Building on Attard and Holmes (2019), the strong proportional relationship between mental mathematics and number sense skills directly contributes to a deeper understanding of number sense. The connection emphasises the relevance of technology-enhanced tools in mathematics teaching. Consequently, it becomes imperative for teachers to integrate technology-enhanced mental mathematics activities to develop learners' number sense skills effectively. Kurvinen et al. (2020) affirm that teachers can adopt digital lessons in teaching mathematics. Against this background, the authors understand that teachers can use innovative strategies in teaching number sense skills through mental mathematics skills in the foundation phase. However, there are no clear strategies from the educational policies to assist teachers in enhancing learners' number sense development through technology-enhanced mental mathematics skills.

Recent literature from sources such as Mabena, Mokgosi and Ramapela (2021) and McHugh et al. (2024) caution that there is a need for more innovative teaching strategies in the foundation phase, given that South African learners are performing poorly in mathematics. Mabena et al. (2021) assert that Grade 9 learners continue to fail mathematics in Grade 9 in Mpumalanga province because of a lack of advanced mathematics strategies. Internationally, the recent 2023 Trends in International Mathematics and Science (TIMMS) showed that Grade 5 South African learners performed below the average compared to Morocco, Brazil and Saudi Arabia (McHugh et al. 2024). With these statistics, one can conclude that these learners did not exit the foundation phase with high mathematical skills. Fitri, Syahputra and Syahputra (2019) affirm that there is a challenge in using hybrid teaching in Malaysia, and it contributes to poor mathematics performance in high schools. Mazana, Montero and Casimir (2020) also acknowledge that ineffective mathematics curricula contribute to the poor performance of learners in secondary schools in Tanzania. Even though the literature did not focus on foundation phase learners, it shows that learners still need to exit Grade 3 with solid number sense skills (DBE 2011).

While the above-mentioned research has contributed to teaching and learning mathematics, none of the studies focused on developing number sense in the foundation phase through technology-enhanced activities. Thus, our article is distinctive in that it views number sense as being developed through technology-enhanced mental mathematics skills. With this in mind, the article aims to examine the development of number sense in the foundation phase through technology-enhanced mental mathematics skills. The authors reviewed the literature and discussed the theoretical framework and methodology, and presented the results, findings and conclusion.

Research question

Drawing from the research problem, this article answered the following question: *How can number sense skills in the foundation phase be developed through technology-enhanced mental mathematics?*

Literature review

This article reviewed existing literature to identify knowledge gaps in previous studies relevant to this research. The review was conducted to address the research question outlined in the preceding section. The analysis revealed key gaps, such as a lack of learner-centred approaches like play-based pedagogy and limited integration of technology in foundation phase mathematics teaching. These findings informed the selection of an appropriate research methodology for this article.

Digital games contribute to the teaching and learning of mathematics. This is supported by Behnamnia et al. (2020), who stated that using digital game-based learning (DGBL) can assist in developing foundation phase learners' number sense skills. In a different study, Deng et al. (2020) demonstrate that primary learners can learn mathematical relationships

with the help of digital games. Fadda et al. (2022) also mentioned that digital games motivate learners in mathematics. Ahmad et al. (2021) agree that learners acquire higher-order, critical and scientific inquiry skills necessary for teaching and learning mathematics through digital games. As learners play digital games, they develop holistic development integrated into subjects like Life Skills (beginning knowledge and personal and social well-being) in the foundation phase. Tang, Nine and Wang (2023) suggest that different digital games should be given to children according to their age, maturity and math proficiency. Against this background, learners in Grades 1, 2 and 3 should play different digital games to develop their number sense skills. The authors reviewed the literature from different regions to understand how can number sense skills in the foundation phase be developed through technology-enhanced mental mathematics.

Galeano et al. (2023) conducted their study in Sweden on pedagogical actions that result in mathematics anxiety in preschool children. Their research used exploratory research design within a quantitative approach to examine early childhood teachers' mathematics anxiety with its frequency of pedagogic actions. A total of 189 preschool teachers and 163 caregivers participated by answering online questionnaire questions. The findings of Galeano et al. (2023) demonstrate that preschool teachers avoid mathematics content because of mathematics anxiety. Their study highlighted early childhood teachers' awareness strategies to prevent mathematics anxiety (Galeano et al. 2023). Therefore, the authors note the importance of using appropriate tools to develop learners' mathematical skills from preschool to avoid mathematics anxiety's implications for teachers and learners.

Drawing from Galeano et al. (2023), the authors note that mathematics anxiety can hinder teachers' ability to engage learners in meaningful number sense activities, as anxious teachers may avoid mathematical content or deliver with reduced confidence. This avoidance may also influence learners' attitudes towards mathematics. This study addresses the dual challenge of supporting teachers and learners by incorporating technology-enhanced mental mathematics activities. Technology-enhanced resources, such as interactive games and digital learning platforms, offer structured, engaging and user-friendly activities that reduce cognitive load on teachers, thereby minimising their anxiety.

Wulandari et al. (2022) conducted a study using interviews, observations and questionnaires from six Grade 1 learners in Indonesia. The findings of Wulandari et al. (2022) indicate that dynamic number card games positively affect number sense skills development. Their research recommended a dynamic number card game as a technology integration tool to teach number sense to Grade 1 learners. Even though they focused only on Grade 1 learners, it can be noted that dynamic number card games can be used during mental mathematics activities in the foundation phase to develop their number sense skills. What is interesting about Wulandari et al. (2022) is that they incorporated play-based pedagogy, emphasised in the foundation phase, as it develops learners' holistic skills. The authors were of the view that using technology-enhanced mental mathematics could infuse play-based activities.

Venketsamy (2022) explored the experiences of foundation phase teachers in teaching number sense for curriculum support in teaching number sense. This research uses a single case study in qualitative research. Data were collected through semi-structured interviews and document analysis from three foundation phase teachers, one head of department and one subject adviser in Gauteng province. The findings revealed that teachers need to receive full instructional support. It was recommended that foundation phase teachers still need intensive training on pedagogical content knowledge in teaching number sense.

Perini et al. (2023) developed and evaluated Number Express, a digital game to teach number sense to young learners. They solicited input from researchers, teachers and an education specialist with experience teaching and learning mathematics in primary schools. A small group of preschool learners played this game to assess its usability and fix any technological issues. Number Express was further implemented to check its efficiency in developing children's numeracy skills. Their findings indicated that Number Express helps teach mathematics skills. It promotes parental involvement in teaching and learning mathematics to young learners. Perini et al.'s (2023) study offers relevant examples of how digital game-based interventions, expert collaboration, parental involvement and iterative design processes can contribute to the development of technology-enhanced mental mathematics activities aimed at improving number sense in the foundation phase.

Alkan and Korkmaz (2021) conducted a study to analyse digital games in teaching mathematics. They employed qualitative case studies to analyse different digital games on the Steam digital game sales platform. Alkan and Korkmaz (2021) found that digital games are used for entertainment rather than mathematical teaching. Therefore, they recommended incorporating digital games in the teaching and learning of mathematics. They emphasised that digital games that provide instant, immediate responses can be used to teach learners mathematics. In addition, it shows that level-based digital games increase learners' interest in mathematics.

This literature review section demonstrates that technology-enhanced activities, including digital games (Alkan & Korkmaz 2021; Behnamnia et al. 2020; Fadda et al. 2022), can provide learners with engaging interactive and age-appropriate learning experiences that foster holistic development. These insights align with the theoretical framework underpinning this study, which is unpacked in the next section.

Theoretical framework

This study is underpinned by a theory of technology pedagogical and content knowledge (TPACK) developed by Mishra and Koehler (2006). The rise of this framework was

to encourage teachers to use technological tools in their teaching and learning activities. The central assumption of TPACK is that it highlights interaction, connection and communication between learners and the teacher in the classroom. It can also be understood from 'Those who understand: Knowledge growth in teaching' by Shulman (1986:4), who focused on pedagogical content knowledge. The discussion of Shulman's (1986) teaching knowledge explained that teachers have pedagogical and content knowledge. Teachers know how to prepare, including using various teaching pedagogies or strategies, pedagogical expertise, specific knowledge about the subject they are teaching and content knowledge. Shulman (1986) argues that teachers already possess pedagogical and content expertise from teacher training institutions, combining them into a set that encompasses their subject matter expertise. Mishra and Koehler (2006) added technology elements to the assumptions of Shulman's (1986) pedagogical and content knowledge maintained by teachers.

This theory is relevant to frame the study as it provides teachers with knowledge of integrating technology context in teaching and learning mathematics in the foundation phase. Technology pedagogical and content knowledge emphasises integrating the three key components: technological knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK). While TK refers to teachers' understanding of how to use various digital tools, platforms and software for teaching mathematics, PK relates to teachers' methods and strategies to facilitate learning and CK pertains to a deep understanding of mathematical concepts such as number sense.

Kong and Lai (2021) propose that TPACK should guide curriculum development and teacher education. According to Bhagwonparsadh and Pule (2024), teachers' PK and CK in mathematics has been given enough attention. This is supported by Venketsamy (2022), who states that this influences young learners to develop number sense skills. Given the above-mentioned, teachers need to know how to apply TPACK theory in teaching and learning number sense to young learners. Teachers can use technology-enhanced mental mathematics skills to integrate TPACK in developing number sense in the foundation phase.

The authors chose this theory because it addresses using technology-enhanced mental mathematics skills in the foundation phase to develop number sense. Teachers can use TPACK to teach mathematics to young learners by choosing the most effective mathematics outcomes, which are the content (Young et al. 2019). For this study, teachers' outcomes should align with developing number sense skills. Tanak (2020) further demonstrated how TPACK is used, stating that it is crucial to choose the pedagogical approach that will be used to achieve the outlined outcomes. Vanbecelaere et al. (2020) suggest that teachers can use digital games in teaching number sense to integrate technology in teaching and learning. Understanding Vanbecelaere et al. (2020), game-based learning can be a pedagogical approach to teaching mathematics in the foundation phase. Technology pedagogical and content knowledge addresses the problem of not knowing how to integrate technology in teaching and learning number sense in the foundation phase and contributes to the proposed solutions for developing number sense in the foundation phase through technology-enhanced mental mathematics skills.

Technology pedagogical and content knowledge, as the theoretical framework underpinning this study, provides a comprehensive foundation for this study, emphasising the interconnectedness of TK, PK and CK required to develop number sense in the foundation phase. It also informs this study's research methodology by guiding the selection of data generation methods and sampling and analysis processes. This alignment with research methodology ensures that the study captures teachers' lived experiences and the impact of technology on number sense development.

Research methods and design

The study used the interpretivism paradigm because it aligns with the assumptions of TPACK theory. Technology pedagogical and content knowledge assumes that foundation phase teachers have PK and CK in teaching number sense. Furthermore, they know the significance of integrating technology-enhanced activities in developing number sense skills in the foundation phase. The interpretivism paradigm was used to interpret teachers' views on developing number sense in the foundation phase through technology-enhanced mental mathematics skills.

This is a qualitative study that is supported by the interpretivism paradigm. Mezmir (2020) explains that to understand the aspects of the qualitative research approach within the interpretivism paradigm, the researchers need to collect data from social settings and interpret it to understand the reality of teachers. Thus, this study collected data from public primary schools in South Africa because schools are seen as social settings, and learners are encouraged to interact with one another and their teachers. The schools are in the rural areas of Limpopo province and are classified as quintile 2, serving the poorest 20% of learners (i.e., they are no-fee paying schools because they fall into a socioeconomic category that is classified as 'poor'). The teachers in these schools are offered laptops, and there is a data projector in each school that is shared by the teachers. However, they are limited. The schools are allocated funds for learning, teaching and support materials (LTSMs), and the school management teams (SMTs) and school governing bodies (SGBs) agree on which materials to prioritise according to the schools' context and needs. Directed by qualitative research employed in this study, a multiple case study design was used to examine the development of number sense in the foundation phase through technology-enhanced mental mathematics skills. This design was chosen because it is usually used in qualitative research to explore a community, group, institution, person or phenomenon (Prosek & Gibson 2021).

To strengthen the confirmability and trustworthiness of results, through homogenous purposive sampling, six Grade 3 teachers from three primary schools in Limpopo province were selected based on their mathematics experiences in the foundation phase. At least two teachers were from the same school in Capricorn South District, Limpopo province. The criteria used to select participants were their 3 years of teaching experience in teaching mathematics in the foundation phase and national qualification framework (NQF) level 4. Keeping the theoretical framework in mind, these teachers have PK, CK and TK of teaching mathematics in the foundation phase.

Data were collected through semi-structured interviews, interpretive document analysis and non-participant observations. During the interviews, the authors used interview schedule containing open-ended questions to gather teachers' views on how they develop number sense skills through technology-enhanced mental mathematics skills in the foundation phase. An audio recorder was used to capture the conversation during the interview sessions planned for 45 min each, which increased the reliability of findings (Saarijärvi & Bratt 2021). The authors were able to seek clarity from the teachers to understand their responses. During the interview, teachers demonstrated their CK and PK of mathematics in the foundation phase when responding to the questions. Teachers' copies of lesson plans were requested to corroborate their planning of the content and pedagogical approaches through interpretive document analysis. Document analysis tool was designed with a set of questions to assist the authors to gather data from the lesson plans. The data were used to validate what the teachers said during the interviews. To triangulate the views gathered during the interviews and the evidence found in the lesson plans, non-participant observations were used to see how teachers assist learners to develop number sense and how they implemented what they planned in their lesson plans in their mathematics classrooms. Six classroom observations from six teachers were conducted during the mathematics lessons which took 45 min per each. An observation schedule was used to record the observation data from all the teachers. Through the observations, the authors intended to know the contribution of technology-enhanced mental mathematics skills in developing number sense skills to foundation phase learners.

Data analysis

Content data analysis in qualitative research was utilised to analyse, categorise and interpret the content of communication in a systematic and replicable manner to examine the development of number sense through technology-enhanced mental mathematics skills in the foundation phase (Lim 2024). It involved breaking down data into manageable data codes and categories, often to identify trends, patterns or underlying themes. Before the data analysis process, the professional transcriber transcribed interview data into text as recorded. Thus, three data sets from semi-structured interviews, document analysis and non-participant observation were analysed through content analysis. Two phases of data analysis were used. In the first phase, data were analysed manually on a computer. Codes were created from the keywords of the study's research questions.

In the second phase, all three data sets were imported on ATLAS.ti 23, and three projects were created and named according to the pseudonyms of each school, S1 to S3. ATLAS.ti 23 is a computer-assisted qualitative data analysis software that facilitates qualitative data analysis.

The same codes from the first phase of analysis were used to ensure transparency and authenticity of content analysis (Tracy 2019). According to Tracy (2019), this process is known as recoding in qualitative research. A total number of 289 codes were created from the three data sets using ATLAS.ti 23. Guided by Lim (2024)'s steps in content analysis, the codes were grouped to formulate the categories, and the categories were grouped to formulate the themes. Categories and themes were also created on the ATLAS.ti 23 guided by literature review and theoretical framework (Lindgren, Lundman & Graneheim 2020). Outputs such as networks, word clouds and word lists were exported to present and interpret the data. Themes used to discuss the findings were created from the research questions.

Ethical considerations

An ethical clearance letter was obtained from the University of South Africa's college of education ethics committee. It was approved with (reference no: 2020/10/14/64019209/07/AM). Permission to conduct a study from primary school was approved by the Department of Basic Education through the Limpopo Department of Education. To participate in the study, participants were asked to sign consent letters provided by the researchers. To ensure credible findings, method triangulation was used to gather data from participants because data from one instrument cannot be trusted. To ensure internal validity in qualitative research, audio recordings were used in semi-structured interviews. Pseudonyms were used in the presentation of results and discussion of findings to protect the anonymity and confidentiality of participants.

Results

The results of this article are presented in two categories: CK and PK of developing number sense skills. These categories align with the lens of the reviewed literature and theoretical framework.

Teachers' content knowledge on developing number sense skills

Teachers' views on securing number sense to Grade 3 learners demonstrated the significance of exiting the foundation phase with a sense of numbers. It was further shown that number sense integrates with all mathematics content areas. This is evident from interview transcripts, whereby teacher 1 said:

> 'Number sense is the core foundation of mathematics. It is vital to assist learners in developing this mathematical concept because it is incorporated in measurement and patterns.' (Teacher 1, School 1, Female)

Building on this perspective, teacher 2 emphasised the broader applicability of number sense across various mathematical concepts and real-life contexts. This view highlights the interdisciplinary nature of number sense and its role in fostering problem-solving abilities. Teacher 2 illustrated this by stating:

> 'Learners can apply number sense skills in data handling and to solve real-life situations.' (Teacher 2, School 1, Female)

This shows that teachers understand mathematics content in the foundation phase because they can integrate number sense skills with other mathematical concepts. The participants' responses further showed that developing number sense in the foundation phase is essential because it could assist in higher grades. Teachers' responses were as follows:

> 'Number sense is more evident in numbers, operation, and relationship, which has maximum percentage across all grades in the foundation phase. Developing these skills could assist learners to pass mathematics well.' (Teacher 3, School 2, Female)

> 'The number sense that learners develop in the foundation assists them in solving mathematical problems in higher grades.' (Teacher 4, School 2, Female)

> 'It prepares them to deal with mathematics in Grade 4.' (Teacher 5, School 3, Female)

> 'Developing number sense skills could assist learners to perform mathematics well in the foundation phase and higher grades.' (Teacher 6, School 3, Female)

The lesson plans revealed that teachers planned their lesson activities. However, only teacher 5's lesson plan included clear outcomes that relate to the development of number sense, which the teacher aimed to achieve by the end of the lesson. The data from non-participant observations indicated that some of the teachers utilised technology tools to teach number sense during mental mathematics activities, highlighting how these skills are developed in practice. This demonstrates that teachers recognise the importance of fostering number sense skills in Grade 3 learners.

Teachers' pedagogical knowledge on developing number sense skills

Teachers' interview responses showed that they use play pedagogy to develop learners' number sense skills, among other pedagogical approaches. When the teachers were asked about their view on using play pedagogies, technology-enhanced mental mathematics activities and its role in teaching number sense, they mentioned limited technology use and the importance of play pedagogies in mental mathematics activities developing number sense. This was apparent because they explained:

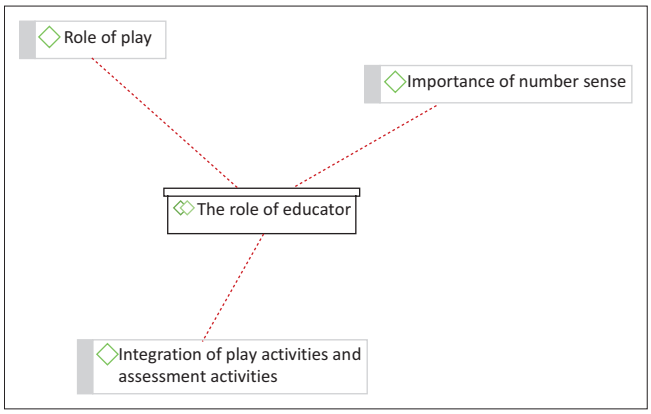

FIGURE 1: Network on the teacher's role in teaching number sense.

> 'It is learner-centred, it increases learners' listening skills and promotes learners' understanding of numbers … it promotes less teacher-centred activities.' (Teacher 1, School 1, Female)

> 'Play activities incorporating number sense skills connect to teaching and learning measurement, data handling, and space and shape.' (Teacher 2, School 1, Female)

> '… I use it to grab learners' attention; they become more interested in the lesson.' (Teacher 3, School 2, Female)

> 'It is inclusive, it helps with motivation, and different play activities can be used to teach number sense. Especially, when including Kahoot quizzes.' (Teacher 4, School 2, Female)

> 'It helps to boost learners' confidence; it encourages participation and motivation.' (Teacher 5, School 3, Female)

> '… It builds a relationship between learners and teachers. The use of digital resources increases participation in the lesson and motivates weak or underperforming learners.' (Teacher 6, School 3, Female)

A network output created from ATLAS.ti 23 in Figure 1 shows that teachers understand the content and pedagogical context in teaching and learning number sense. The figure includes examples of number sense skills, teaching pedagogy such as play activities, and the presence of assessment activities. It demonstrates that teachers understand how to assess learners' understanding of number sense and adapt their teaching methodologies. Figure 1 does not provide evidence of technology-enhanced mental mathematics, reflecting the absence of data on these concepts in the semi-structured interviews and lesson plans.

Figure 1 presents the teacher's responsibility to align the CK and PK in developing number sense skills. The teacher should further link play and assessment activities to achieve the lesson outcomes.

Data from lesson plans demonstrated that teachers use play activities to develop number sense through mental mathematics activities. The outcomes linked to teaching and learning number sense were evident in teacher 4's lesson plan. The observations revealed that teachers experienced minimal technological devices, but they utilised mental mathematics activities to develop learners' number sense skills. In teacher 4's classroom, learners played an indigenous

game, *Tsheretshere*, during mental mathematics sessions to enhance their counting skills and number naming. However, a lack of technological tools was evident during the classroom observations. For example, in teacher 1's classroom, a shortage of printed resources was observed. As a result, the teacher improvised by creating physical cards. Learners were paired during mental mathematics activities to foster number sense development.

Participant 1 incorporated a word game to teach place value, helping learners enhance their understanding of numbers. In addition, learners used flashcards with numbers to practice rounding to the nearest 10. In teacher 6's classroom, the observations confirmed statements made during the interviews. Teacher 6 remarked, 'We do not have enough technological devices to mathematics'. This was supported by the observed lack of laptops and learner tablets, which hindered the integration of technology in mental mathematics activities. The results demonstrated that teachers combine play-based pedagogy with game-based learning to teach number sense during mental mathematics activities.

Discussion

Two themes responding to the research question, such as the development of number sense skills in the foundation phase and the contribution of mental mathematics skills in developing number sense skills in the foundation phase, were used to discuss the findings.

Theme 1: The development of number sense skills through play pedagogies during mental mathematics activities in the foundation phase

This study asked: *How can number sense skills in the foundation phase be developed through technology-enhanced mental mathematics skills?* Study conducted by Wulandari et al. (2022) showed that playing the dynamic number card game helps improve number sense. The theoretical framework suggests that digital games motivate learners to learn mathematical concepts (Fadda et al. 2022). Tanak (2020) also described that teachers can use digital games to teach number sense.

The findings of this article disclosed that teachers have CK and PK of developing number sense to foundation phase learners. Teachers have explicit CK because they can integrate numbers sense throughout five content areas in mathematics in the foundation phase. They use play-based and game-based learning to motivate learners to develop number sense skills. This was clear from teacher 4 that '… it helps with motivation and different play activities can be used to teach number sense'. The findings reveal that foundation phase teachers still lack technology knowledge in teaching number sense because they complain about the minimal resources used in different play activities. However, they utilise the provided laptops to create quizzes and other activities aimed at improving number sense skills through mental mathematics activities. This is whereby they played different play activities in mental mathematics.

Theme 2: Lack of technology knowledge to develop learners' number sense skills in mental mathematics activities

The findings reveal that teachers lack the knowledge of developing learners' number sense skills through technology-enhanced mental mathematics in the foundation phase. It was shown during the observations that there is a lack of technological devices in the mathematics classrooms. Only teacher 4 and teacher 6 used technology-related activities during mental mathematics to develop learners number sense skills. Majority of teachers possess sound CK related to number sense development. Teachers' understanding of mathematical content allows them to recognise the role of number sense as the fundamental concept that extends to various mathematical areas, such as measurement, patterns and data handling. This is consistent with the argument made by Shulman (1986) that teachers must possess in-depth CK to teach effectively. Teacher 1 emphasised the need to assist learners in developing number sense because of its core foundation of mathematics and the fact that it is incorporated in measurement and patterns. Teacher 1's statement aligns with Venketsamy's (2022) assertion that number sense plays a critical role in shaping learners' mathematical development and is essential for fostering problem-solving skills. The author further argues that number sense promotes mathematical thinking that extends beyond computational proficiency.

This study further found that teachers recognise the longitudinal significance of number sense in supporting mathematics achievement in later grates. Teacher 4 and teacher 6 noted that number sense prepares learners for higher-grade mathematics. This perspective is supported by Bhagwanparsadh and Pule (2024), who state that the early development of number sense provides the conceptual foundation for mathematical reasoning. Lesson plans and classroom observations revealed that mental mathematics activities, such as rounding numbers using flashcards and solving place value problems through word games, are designed to enhance number sense. According to Tanak (2020), developing number sense requires well-structured learning activities where learners engage in conceptual exploration and problem-solving. The integration of interactive activities observed in the classrooms illustrates how teachers are implementing CK by connecting mathematical concepts to real-life situations.

The results also show that teachers employ various pedagogical strategies to develop number sense, particularly play-based and game-based learning. This approach aligns with the theoretical lens of TPACK, which highlights the importance of effective pedagogy in supporting learners' understanding of content through meaningful activities. The reviewed literature supports play-based learning, particularly by Vanbecelaere et al. (2020), who affirm that it encourages active learning, facilitates problem-solving and provides learners with multiple opportunities to explore mathematical concepts.

The contribution of the study

This study offers theoretical, practical and policy-related contributions to the growing discourse on integrating technology into foundation phase mathematics teaching. By demonstrating how technology can complement play-based pedagogies, the study offers practical insights for teachers, teacher trainers and curriculum developers to create inclusive, engaging and effective learning environments.

The findings reveal that teachers possess sound CK related to number sense development. Their understanding of mathematical content enables them to recognise number sense as a fundamental concept extending across various mathematical areas, including measurement, patterns and data handling. This aligns with Shulman's (1986) argument that in-depth CK is essential for effective teaching. Teacher 1 emphasised the importance of developing number sense as a core foundation for mathematics, incorporated in areas like measurement and patterns. This perspective supports Venketsamy's (2022) assertion that number sense is vital for promoting problem-solving skills and shaping learners' mathematical development.

The study also highlights the limited use of technology-enhanced activities to support number sense development. For instance, only teachers 4 and 6 integrated digital quizzes to reinforce learners' mental mathematics skills. These quizzes enabled learners to visualise mathematical concepts such as rounding numbers, place values and operations, promoting a deeper conceptual understanding. These activities also engaged learners and provided opportunities for differentiated learning, making mathematical concepts accessible to all.

Lesson plans and classroom observations revealed how teachers 4 and 6 used technology to design mental mathematics activities that blended gamified elements with conceptual exploration. For instance, learners participated in online quizzes requiring them to solve mental mathematics problems within time constraints. Such activities supported the development of mathematical fluency and reasoning. This finding aligns with Tanak's (2020) argument that developing number sense requires well-structured learning opportunities that promote problem-solving and exploration.

The theoretical contribution shows TPACK theory, emphasising the interplay between CK, PK and TK in supporting effective teaching. Although only few teachers used technology to contextualise mathematical concepts, it is evident that learners benefited comprehension and engagement. This approach aligns with Vanbecelaere et al. (2020), who advocate for play-based learning as a means of fostering active participation and problem-solving.

Conclusion

This article highlights the critical role of integrating technology-enhanced mental mathematics activities to develop number sense skills in the foundation phase. Teachers who participated in this study exhibit strong CK and pedagogical strategies for teaching number sense. However, the findings reveal significant gaps in TK, emphasising the need for professional development focused on the TPACK framework. This study reaffirms the importance of mental mathematics activities as a foundational concept that enhance the development of number sense. By incorporating play-based and game-based pedagogies, including digital and indigenous games, teachers can foster deeper learner engagement, motivation and confidence in mathematics. Tools like Kahoot and dynamic number games exemplify how technology can support interactive and adaptive learning, making mathematical concepts accessible and enjoyable for foundation phase learners.

This article highlights the critical role of integrating technology-enhanced mental mathematics activities to develop number sense skills in the foundation phase. Teachers in rural South African schools exhibit strong CK and pedagogical strategies for teaching number sense. However, the findings reveal significant gaps in TK, showing a need for professional development focused on the TPACK framework. This study reaffirms the longitudinal importance of number sense as a foundational mathematical concept influencing learner success in higher grades and diverse mathematical domains. By incorporating play-based and game-based pedagogies, including digital games and culturally relevant indigenous activities, teachers can foster deeper learner engagement, motivation and confidence in mathematics. Tools like Kahoot and dynamic number games exemplify how technology can support interactive and adaptive learning, making mathematical concepts accessible and enjoyable for young learners.

The theoretical framework of this article extends to the foundation phase by integrating TK, PK and CK in mathematics teaching. The article suggests actionable strategies for teachers to integrate technology and mental mathematics into their lesson plans. Policymakers are urged to allocate resources and develop curricula that support technology-enhanced learning, while teacher training programmes should prioritise equipping teachers with the digital skills necessary for modern classrooms. For future research, the authors recommend exploring the potential of indigenous games in developing number sense and their integration into technology-enhanced mathematics teaching. Such research could provide further insights into creating culturally responsive and engaging learning environments that promote mathematical proficiency from an early age.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

M.A.S. and R.S.M. equally contributed towards the conceptualisation of this project. M.A.S. conceptualised the ideas of the original draft, data analysis and methodology. R.S.M. served as a supervisor, and reviewed, edited and validated the data analysis process.

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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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