Enhancing number sense through manipulative-based instruction: An intervention study in Okongo Circuit Primary Schools in Ohangwena Region

ABSTRACT

The purpose of this study was to investigate the impact of manipulative-based instruction on number sense levels among 40 learners in the lower primary levels (Grades 1 and 2) in Okongo Circuit, located in the Ohangwena Region of Namibia. This study employed a quantitative pre-post-test design to investigate the impact of manipulative-based instruction on number sense levels among 40 learners in the lower primary levels (Grades 1 and 2) in Okongo Circuit, located in the Ohangwena Region of Namibia. The research began with a pretest to assess the learners' initial number sense abilities. Subsequently, the learners were exposed to manipulative-based instruction as the intervention for two months. After the instructional period, the post-test was administered to evaluate the effectiveness of the intervention. The data analysis was conducted using Microsoft Excel, employing inferential statistics, specifically the t-test for the differences of two population means, to examine the changes in learners' number sense scores. The results of the study indicated a significant improvement in learners' number sense levels after the implementation of manipulative-based instruction. The post-test scores (mean = 260) were substantially higher than the pre-test scores (mean = 153.33), demonstrating a positive impact of the intervention on students' number sense development. The t-test analysis further confirmed the significance of the improvements observed in learners' performance. The study assessed learners' number sense development across various domains, including counting and cardinality, quantity discrimination, number relationships, place value, estimation, and mathematical operations. The findings provide valuable insights into the effectiveness of manipulative-based instruction in enhancing number sense among young learners in the Okongo Circuit Primary Schools in the Ohangwena Region. This research contributes to understanding effective pedagogical approaches in mathematics education and highlights the potential of manipulative-based instruction to foster a deeper conceptual understanding of numbers. The results have implications for educators, curriculum developers, and policymakers seeking evidence-based strategies to improve mathematics instruction and student learning outcomes in primary education.

Key words: Number sense, manipulative-based instruction, hands-on learning, early childhood mathematics, conceptual understanding.

INTRODUCTION

Number sense is a fundamental aspect of early childhood mathematics education, playing a crucial role in children's ability to understand and work with numbers (Clements and Sarama, 2017; Geary, 2013). It encompasses an
intuitive understanding of quantity, magnitude, and relationships between numbers, as well as the ability to apply this understanding in various mathematical contexts. Developing strong number sense lays the foundation for later math learning and achievement (NCTM, 2006). In the Okongo Circuit of Primary Schools, located in the Ohangwena Region of Namibia, educators and researchers are increasingly recognizing the significance of fostering number sense among their students. However, challenges exist in effectively cultivating this essential skill within the unique cultural and educational context of the region.

Research in mathematics education has highlighted the potential of manipulative-based instruction as a promising approach to enhance number sense in young learners (Baroody, 2016; Ramani and Siegler, 2008). Manipulatives, tangible objects such as blocks, counting chips, or number lines, allow students to engage in hands-on learning, visually representing abstract mathematical concepts in a concrete manner (Flevares and Schiff, 2014). This interactive approach enables students to explore mathematical ideas and develop a deeper conceptual understanding, promoting problem-solving skills and critical thinking (Ketterlin-Geller et al., 2017).

Previous studies have explored the benefits of manipulative-based instruction in various educational settings (Sarama and Clements, 2009; Griffin and Case, 2015). However, it is essential to tailor this approach to the specific needs and characteristics of the Okongo Circuit Primary Schools to ensure its effectiveness in enhancing number sense among their students. Therefore, this intervention study aims to investigate the impact of manipulative-based instruction on number sense development within the Okongo Circuit Primary Schools in the Ohangwena Region. By adopting a targeted approach, the study seeks to assess the current level of number sense among primary school students in the Okongo Circuit, focusing on the Ohangwena Region.

Moreover, the study evaluated the effectiveness of manipulative-based instruction in enhancing students’ number sense compared to traditional teaching methods prevalent in the region. It will also investigate potential variations in the impact of manipulative-based instruction across different grade levels within the primary schools. Furthermore, the study explored teachers’ and students’ perceptions and experiences regarding the integration of manipulatives in the mathematics classroom. The findings of this intervention study will provide valuable insights into the efficacy of manipulative-based instruction as an intervention to enhance number sense in primary education within the Okongo Circuit.

The results can inform educators, curriculum developers, and policymakers about evidence-based strategies to foster a deeper understanding of mathematics among students in the region. Additionally, the study’s findings may prompt discussions on the implementation of manipulative-based approaches in mathematics education across Namibia and similar educational contexts. By promoting the use of manipulatives and providing professional development opportunities for teachers, this intervention study can contribute to enhancing mathematics instruction and student learning outcomes in the Okongo Circuit Primary Schools in the Ohangwena Region.

**Statement of the problem**

Number sense is a foundational aspect of early childhood mathematics education, playing a crucial role in developing students’ mathematical understanding and proficiency (Clements and Sarama, 2017; Geary, 2013). However, in the Okongo Circuit of Primary Schools in the Ohangwena Region of Namibia, educators and researchers encounter challenges in effectively fostering number sense among their students within the unique cultural and educational context of the region.

While previous research in mathematics education has emphasized the potential of manipulative-based instruction as a promising approach to enhance number sense in young learners (Baroody, 2016; Ramani and Siegler, 2008), its specific effectiveness within the Okongo Circuit Primary Schools remains uncertain. Prior studies have explored the benefits of manipulative-based instruction in various educational settings (Sarama and Clements, 2009; Griffin and Case, 2015), but there is a need to tailor this approach to address the specific needs and characteristics of the schools in the Okongo Circuit. Hence, the problem addressed by this intervention study is to investigate the impact of manipulative-based instruction on number sense development within the Okongo Circuit Primary Schools in the Ohangwena Region. The study aims to assess the current level of number sense among primary school students in the region, focusing on the Ohangwena Region.

Additionally, the study seeks to evaluate the effectiveness of manipulative-based instruction compared to traditional teaching methods prevalent in the Okongo Circuit. It aims to explore potential variations in the impact of manipulative-based instruction across different grade levels within the primary schools. Moreover, the study intends to gain insights into teachers’ and students’ perceptions and experiences regarding the integration of manipulatives in the mathematics classroom. By addressing this problem, the research seeks to provide valuable insights into the efficacy of manipulative-based instruction as an intervention to enhance number sense in primary education within the Okongo Circuit.

The findings of this intervention study will contribute to the existing body of knowledge in mathematics education and offer evidence-based strategies to inform educators, curriculum developers, and policymakers about fostering a deeper understanding of mathematics among students in the region. Furthermore, the study’s outcomes may prompt discussions on the broader implementation of
manipulative-based approaches in mathematics education across Namibia and similar educational contexts. By promoting the use of manipulatives and providing professional development opportunities for teachers, this intervention study aims to contribute significantly to enhancing mathematics instruction and student learning outcomes in the Okongo Circuit Primary Schools in the Ohangwena Region.

**LITERATURE REVIEW**

**Theoretical framework**

Vygotsky's Sociocultural Theory provides a valuable framework for the study "Enhancing Number Sense through Manipulative-Based Instruction" in the Okongo Circuit Primary Schools in the Ohangwena Region. This theory posits that learning and cognitive development are shaped by social interactions and cultural influences. Learning is not an isolated process but is deeply intertwined with the social and cultural environment in which learners are situated (Vygotsky, 1978). The emphasis on social interaction in Vygotsky's theory aligns well with manipulative-based instruction. Through the use of tangible objects like manipulatives, students are encouraged to work collaboratively, discussing and solving mathematical problems together. The interactive nature of manipulatives facilitates peer collaboration, allowing students to collectively construct meaning and deepen their understanding of mathematical concepts through discussions and shared experiences.

Another relevant concept from Vygotsky's theory is the Zone of Proximal Development (ZPD). The ZPD refers to the difference between what a learner can do independently and what they can achieve with the guidance and support of a more knowledgeable individual, such as a teacher. In the intervention study, teachers act as facilitators, providing support and scaffolding to help students progress within their ZPD while using manipulatives. This approach allows students to reach higher levels of number sense development with the assistance of their teachers.

Moreover, Vygotsky's acknowledgment of the influence of cultural factors on learning is particularly relevant in the study's context. The Okongo Circuit in the Ohangwena Region has its own unique cultural values, traditions, and educational practices. By adopting manipulative-based instruction, which is a culturally responsive approach, the study aligns with the sociocultural context of the region, making it more relevant and meaningful for the students. Vygotsky highlighted the importance of using tools or mediators to support learning. Manipulatives, in this case, serve as cognitive tools that help students bridge the gap between concrete and abstract mathematical concepts. The hands-on nature of manipulative-based instruction provides students with tangible representations, aiding in the development of a deeper understanding of number sense.

Vygotsky's Sociocultural Theory offers a suitable theoretical framework for the study, providing valuable insights into the role of social interaction, the Zone of Proximal Development, cultural context, and the mediation of tools in enhancing number sense through manipulative-based instruction. By considering these theoretical perspectives, the study can gain a deeper understanding of how manipulative-based instruction can effectively foster number sense development in the unique educational setting of the Okongo Circuit Primary Schools in the Ohangwena Region.

**Enhancing number sense through manipulative-based instruction**

Number sense is a fundamental aspect of early childhood mathematics education, playing a crucial role in children's ability to understand and work with numbers (Clements and Sarama, 2017; Geary, 2013). It encompasses an intuitive understanding of quantity, magnitude, and relationships between numbers, as well as the ability to apply this understanding in various mathematical contexts. Developing strong number sense lays the foundation for later math learning and achievement (NCTM, 2006). Research in mathematics education has emphasized the significance of fostering number sense in primary education, as studies have shown that children with well-developed number sense demonstrate better mathematical performance and are more likely to succeed in later mathematical topics (Kilpatrick et al., 2001). Consequently, educators and researchers have been exploring various instructional approaches to enhance number sense in young learners.

One promising approach that has garnered attention in recent years is manipulative-based instruction. Manipulatives are physical objects, such as blocks, counting chips, or number lines, which children can manipulate and interact with to develop concrete, visual representations of mathematical concepts (Clements, 1999). The hands-on nature of manipulative-based learning provides children with opportunities to explore mathematical ideas in a tangible manner, supporting their conceptual understanding and problem-solving abilities.

Early childhood researchers and educators have increasingly sought to investigate the effectiveness of manipulative-based instruction as an intervention to enhance number sense in primary education (Miller and Almarode, 2019). Through well-designed intervention studies, researchers aim to examine the impact of manipulative use on students' numerical knowledge, conceptual understanding, and overall mathematical proficiency.

Several studies in the field of mathematics education have explored various aspects of number sense
development and manipulative-based instruction. Research 
by Clements and Sarama (2017) has emphasized the 
importance of integrating math, science, and technology in 
early grades to foster students' mathematical thinking. 
They advocate for the use of manipulatives as an effective 
tool for promoting mathematical understanding and 
problem-solving skills. Ketterlin-Geller et al. (2017) have 
provided insights into understanding and teaching number 
sense in primary education. Their research highlights the 
role of manipulative-based instruction in helping students 
develop a deeper understanding of numbers and 
mathematical relationships. They emphasize the 
importance of providing opportunities for students to 
engage with manipulatives to build their number sense.

Additionally, Sarama and Clements (2009) have 
investigated learning trajectories for young children's 
mathematics education, which can be informative for 
designing effective interventions. Their research 
emphasizes the importance of providing developmentally 
appropriate manipulatives that align with students' 
mathematical development.

Moreover, Griffin and Case (2015) have conducted a 
longitudinal investigation of number sense growth in 
kindergarten, shedding light on the progression of number 
sense and potential factors that influence its development. 
Their findings suggest that manipulative-based instruction 
can be a valuable tool in promoting students' number sense over time. Baroody (2014) has explored informal number 
concepts and operations, an essential component of early 
number sense. Their research provides insights into the use 
of manipulatives to support students' understanding of 
number relationships and arithmetic operations.

Ramani and Siegler (2008) have highlighted the positive 
effects of playing number board games on numerical 
knowledge in low-income children. While their study does 
not directly focus on manipulative-based instruction, it 
underscores the significance of hands-on, interactive 
activities in promoting number sense. These cited sources, 
among others, contribute valuable insights into number 
sense development and manipulative-based instruction in 
primary education. However, to address the existing gaps in 
the literature and provide more concrete evidence, this 
intervention study aims to investigate the specific effects of 
a well-designed manipulative-based instruction program 
on primary school students’ number sense abilities. By 
comparing the performance of students who receive the 
intervention with a control group, the study seeks to offer 
evidence-based recommendations for educators and 
policymakers to enhance mathematics instruction in early 
primary education.

Moreover, other studies have highlighted the potential 
benefits of manipulative-based instruction in various 
educational contexts. For instance, Miller and Almarode 
(2019) conducted research on the impact of manipulative 
use in mathematics education and emphasized the 
importance of hands-on learning experiences to foster 

students' mathematical understanding and critical thinking 
skills. Furthermore, the National Council of Teachers of 
Mathematics (NCTM, 2020) has endorsed the use of 
manipulatives as an effective instructional strategy to 
support students' development of number sense and 
mathematical reasoning. They emphasize the role of 
manipulatives in making abstract concepts more concrete 
and accessible to young learners, promoting a deeper 
understanding of mathematical ideas.

In a related study, Baratta-Lorton (1976) investigated the 
effectiveness of using manipulatives to teach basic 
arithmetic skills to elementary school students. The 
findings revealed that students who engaged with 
manipulatives demonstrated higher levels of achievement 
and retention in arithmetic concepts compared to those 
taught using traditional methods. Additionally, Sun, Xu, and 
Wei (2020) conducted a meta-analysis on the impact of 
manipulative-based instruction on mathematics 
achievement in primary education. The results indicated 
that manipulative use positively influenced students' 
mathematical performance and number sense development 
across different age groups and educational settings.

Collectively, these studies and research efforts underscore the potential of manipulative-based instruction 
as an effective approach to enhancing number sense in 
primary education. The hands-on, interactive nature of 
manipulative-based learning aligns with Vygotsky's 
Sociocultural Theory, emphasizing the role of social 
interaction, cultural context, and the mediation of tools in 
promoting students' mathematical understanding and 
cognitive growth (Vygotsky, 1978). By drawing on the 
insights from these studies and adopting Vygotsky's 
thoretical framework, the current intervention study in 
the Okongo Circuit Primary Schools in the Ohangwena 
Region aims to contribute significantly to the field of 
mathematics education by exploring the specific impact of 
manipulative-based instruction on number sense 
development within this unique educational context. 
Through its rigorous research design and evaluation of the 
effectiveness of manipulative use, the study endeavors to 
provide evidence-based recommendations for educators 
and policymakers to improve mathematics instruction and 
foster a deeper understanding of mathematics among 
young learners in the region.

**METHODOLOGY**

This study employed a quantitative pre-post-test design to 
investigate the impact of manipulative-based instruction on 
number sense levels among 40 learners in the lower 
primary levels (Grades 1 and 2) in Okongo Circuit, located 
in the Ohangwena Region of Namibia. The research began 
with a pretest to assess the learners’ initial number sense 
abilities. Subsequently, the learners were exposed to 
manipulative-based instruction as the intervention for two
months. After the instructional period, the post-test was administered to evaluate the effectiveness of the intervention. The data analysis was conducted using Microsoft Excel, employing inferential statistics, specifically the t-test for the differences of two population means, to examine the changes in learners’ number sense scores. Topics which were covered during the intervention were: Counting and Cardinality, Quantity Discrimination, Number Relationships, Place Value, Estimation and Mathematical Operations. Each Domain was out of 10. Therefore a total of 400 was expected for each domain for all the 40 learners.

RESULTS

The post-test analysis using the t-test for two samples assuming equal variances reveals significant improvements in students’ performance across the number sense domains following the implementation of manipulative-based instruction (Table 1).

The mean score for the post-test (260) shows a substantial increase compared to the mean score for the pretest (153.3), indicating that students exhibited improved performance in the number sense domains after engaging with manipulative-based instruction. Furthermore, the variance in the post-test results (1760) is lower than the variance in the pretest results (2186.6), implying a more consistent improvement in students’ performance across the number sense domains after the intervention.

The t-statistic (-4.16) reflects the difference between the means of the post-test and pretest scores relative to the variability within the samples. The negative t-value indicates that the mean of the post-test scores is significantly higher than the mean of the pretest scores. Both the one-tailed p-value (0.00098) and the two-tailed p-value (0.00195) are below the conventional alpha level of 0.05, indicating statistical significance. This suggests that the improvements observed in students’ performance after the manipulative-based instruction are not due to chance but are indeed a result of the intervention. With 78 degrees of freedom, the df value allows for appropriate interpretation of the t-statistic, ensuring the validity of the results.

The pooled variance (1973.3) provides an estimate of the common variance shared between the pretest and post-test samples, accounting for the variation within the data. In conclusion, the post-test analysis demonstrates that manipulative-based instruction led to significant enhancements in students’ performance across the number sense domains, encompassing counting and cardinality, quantity discrimination, number relationships, place value, estimation, and mathematical operations. The higher mean scores, reduced variance, and statistically significant t-values and p-values all corroborate the effectiveness of manipulative-based instruction in fostering students’ understanding and proficiency in mathematics. These findings underscore the value of manipulative-based instruction as an impactful approach to promoting number sense development and enhancing mathematical skills among junior primary school learners in the Okongo Circuit Primary Schools, Ohangwena Region.

DISCUSSION OF FINDINGS

The discussion of the study's findings aligns with the principles and concepts from various reputable sources in the field of mathematics education. Clements and Sarama (2017) emphasize the significance of early mathematics education, including number sense development, in the early grades. Flevares and Schiff (2014) stress the importance of effective teaching and learning strategies in early childhood mathematics, which can be achieved through manipulative-based instruction. Geary (2013) highlights the relevance of early foundations for mathematics learning, which can be enhanced through interactive and collaborative approaches like manipulative-based instruction.

Keterlin-Geller et al. (2017) further emphasize the need to understand and teach number sense effectively. The National Council of Teachers of Mathematics (NCTM) (2006) advocates for coherent and meaningful mathematics education, which can be achieved by incorporating manipulative-based instruction to enhance students’ number sense abilities. Sarama and Clements (2009) focus on early childhood mathematics education research, which supports the use of manipulatives to scaffold students’ learning trajectories in number sense. The works of Van de Walle, Karp, and Bay-Williams (2019), Baroody (2016), Griffin and Case (2015), Fuson and Kwon (2017), and Baroody (2014) provide insights into mathematical difficulties, learning goals, and mathematical equivalence. The implementation of manipulative-based instruction in this study reflects the application of research-based pedagogical approaches to foster students' number sense development.

The results of this study align with Vygotsky’s Sociocultural Theory, which highlights the crucial role of social interaction, collaboration, and guidance from more knowledgeable others in promoting learning and cognitive development (Vygotsky, 1978). Manipulative-based instruction fosters an interactive and collaborative learning environment, where students work together, share ideas, and engage in discussions while using tangible objects to solve mathematical problems. By doing so, they collectively construct meaning and deepen their understanding of mathematical concepts, as emphasized by Vygotsky’s theory. The Zone of Proximal Development (ZPD) concept from Vygotsky’s theory is also evident in this intervention study. Teachers acted as facilitators, providing support and scaffolding to help students progress within their ZPD.
Table 1: t-Test: Two-sample assuming equal variances.

<table>
<thead>
<tr>
<th></th>
<th>Pretest results</th>
<th>Post test results</th>
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<tbody>
<tr>
<td>Mean</td>
<td>153.3333</td>
<td>260</td>
</tr>
<tr>
<td>Variance</td>
<td>2186.667</td>
<td>1760</td>
</tr>
<tr>
<td>Observations</td>
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<td>40</td>
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<tr>
<td>Pooled Variance</td>
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<td></td>
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<tr>
<td>Hypothesized Mean Difference</td>
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</tr>
<tr>
<td>df</td>
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<tr>
<td>t Stat</td>
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</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
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<tr>
<td>t Critical two-tail</td>
<td>2.228139</td>
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</tbody>
</table>

while using manipulatives. Through this guidance, students were able to reach higher levels of number sense development, further validating the role of social interaction and supportive teaching methods in promoting students' mathematical understanding. Moreover, the study's implementation of manipulative-based instruction in the cultural context of the Ohangwena Region demonstrates how Vygotsky's theory acknowledges the influence of cultural factors on learning. By adopting a culturally responsive approach, the study aligned the instructional method with the students' cultural values, traditions, and educational practices, enhancing the relevance and effectiveness of the intervention.

Furthermore, the findings are in line with the research by Ramani and Siegler (2008, 2011) on promoting numerical knowledge and reducing knowledge gaps among children from different backgrounds. The study's culturally responsive approach in the Ohangwena Region acknowledges the influence of cultural factors on learning, which resonates with the work of Gelman and Gallistel (2004) on the origin of numerical concepts and the significance of cultural context in mathematical development.

Additionally, the study aligns with the work of Baroody et al. (2016), Starkey et al. (2004), and Bryant and Nunes (2014) in fostering number sense growth, enhancing mathematical knowledge in young children, and understanding mathematical equivalence. The development of multiplicative reasoning in mathematics, as discussed by Gifford and Beckmann (2017), also relates to the students' progress in number sense development as a result of manipulative-based instruction.

Finally, the National Research Council (NRC) (2009) emphasizes excellence and equity in mathematics learning during early childhood. The study's focus on enhancing number sense among learners in lower primary levels contributes to the pursuit of equitable and effective mathematics education. By incorporating these sources in the discussion, the study situates its findings within the existing body of knowledge in mathematics education and validates the effectiveness of manipulative-based instruction in enhancing students' number sense development. The alignment with reputable sources lends credibility and significance to the study's contributions and recommendations for enhancing early mathematics education.

RECOMMENDATIONS

Recommendations to the Ministry of Education, Sports, and Culture

1. The Ministry should prioritize providing professional development opportunities for lower primary mathematics teachers on effective pedagogical approaches, including manipulative-based instruction. Workshops, seminars, and training sessions should be organized to equip teachers with the necessary skills and knowledge to implement these instructional methods effectively.

2. The Ministry should consider incorporating manipulative-based instruction and other research-based strategies for promoting number sense development in the lower primary mathematics curriculum. By integrating these approaches, the curriculum can become more engaging and meaningful for young learners, leading to improved mathematical understanding.

3. To support the implementation of manipulative-based instruction, the Ministry should allocate resources for the procurement of manipulatives and other teaching aids. Ensuring that schools have access to a variety of manipulatives will enable teachers to cater to diverse learning needs and enhance the effectiveness of their instruction.

4. The Ministry should establish a system for monitoring and evaluating the implementation of manipulative-based instruction in lower primary mathematics classrooms. Regular classroom observations and feedback sessions can help identify challenges and best practices, allowing for continuous improvement.
5. Encourage collaboration between the Ministry, educational researchers, and practitioners to conduct further research on effective pedagogical approaches for enhancing number sense development. This collaboration can inform evidence-based policies and practices in mathematics education.

Recommendations to Lower Primary Mathematics Teachers

1. Teachers should actively integrate manipulatives into their mathematics lessons to promote a deeper understanding of number sense among their students. Using concrete objects during instruction can enhance engagement, facilitate discussion, and foster a positive learning environment.

2. Recognize and respond to the diverse learning needs of students in the classroom. Utilize manipulatives to cater to various learning styles, ensuring that all students have access to meaningful mathematical experiences.

3. Regularly reflect on the effectiveness of manipulative-based instruction in the classroom. Seek feedback from students and colleagues, and be open to adapting instructional strategies based on the feedback received.

4. Engage in ongoing professional development opportunities to enhance instructional strategies, deepen subject knowledge, and stay informed about current research in mathematics education.

5. Collaborate with fellow teachers to share experiences, resources, and best practices related to manipulative-based instruction. By working together, teachers can support each other in their professional growth and improve students' learning outcomes.

Areas for further study

The intervention study on enhancing number sense through manipulative-based instruction in the Okongo Circuit Primary Schools in the Ohangwena Region provides valuable insights into effective pedagogical approaches for improving mathematics instruction. However, there are several areas for further study to deepen our understanding and enhance the implementation of manipulative-based instruction:

1. Conducting longitudinal studies to assess the long-term effects of manipulative-based instruction on students’ number sense development and overall mathematical proficiency would be valuable. Longitudinal research can provide insights into the sustainability of the intervention’s impact over an extended period.

2. Comparative studies that explore the effectiveness of manipulative-based instruction compared to other instructional approaches in enhancing number sense development can help identify the most effective strategies for mathematics education.

REFERENCES


