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Building Strong Numeracy Brains: Pedagogical Approaches In Early Childhood Education

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Abstract — Early childhood numeracy involves understanding numbers and essential mathematical principles, such as counting, comparisons, shapes, positions, and problem-solving. These foundational skills are critical as they form the basis for all future mathematical learning. Teaching mathematics during early childhood is vital due to children's receptiveness to learning at this stage. Early mathematical skills develop through children's innate curiosity and direct experiences, enhancing their verbal, spatial, and memory skills (Vilorio, 2014; Chesloff, 2013). This study investigates the challenges teachers face in improving early numeracy skills among struggling kindergarten learners. Key challenges identified include inadequate motivation and low self-confidence, limited instructional time, diverse classroom settings, and limited resources and technology access. These issues hinder students' engagement, comprehension, and academic progress in mathematics. Effective coping strategies were identified, such as setting achievable goals, providing extended learning opportunities, and linking math to real-life situations. The study also highlights the importance of educational management insights drawn from teachers' experiences, including modeling positive behavior, fostering success, and approaching teaching practically. These strategies collectively aim to create a supportive and effective learning environment for improving early numeracy skills. Future directions for enhancing teacher competency in improving numeracy skills include comprehensive training initiatives for teachers, specialized coaching or mentorship programs, collaborative action research projects among teachers, and exploring the interrelationships between numeracy development and other areas of early childhood education. These efforts aim to inform policymakers, curriculum developers, and educational stakeholders at various levels of educational administration.

Keywords — Early childhood numeracy, foundational math skills, problem-solving, mathematical achievement, educational management, teacher intervention, early education, student engagement, instructional strategies, learning environment, teacher training, collaborative research.

I. Introduction

Early childhood numeracy encompasses a fundamental grasp of numbers and essential mathematical principles. These include abilities such as counting, making comparisons, drawing distinctions, describing shapes and positions, and engaging in problem-solving. These foundational skills are critical as they form the basis upon which all subsequent mathematics courses are constructed. Without these basics, students may struggle with more advanced mathematical concepts. Problem-solving, a fundamental early math skill, is indispensable for success across various academic domains and real-life situations beyond the classroom.

Additionally, the development of early math and numeracy aptitudes parallels the advancement of language proficiency and critical thinking abilities (Vilorio, 2014).

Teaching mathematics during the early years is crucial because this is when children are most receptive to learning. Early mathematical and numeracy skills develop by harnessing children's innate curiosity, their propensity for inquiry, and their exploration of the world around them. Math, irrespective of age, is rooted in curiosity. Young learners possess an inherent curiosity and thrive on gaining knowledge through direct experiences with their environment. They exhibit an eagerness to comprehend the inner workings of things and pose inquiries about various aspects of their surroundings. This intrinsic inquisitiveness makes the early childhood stage the optimal period to begin acquiring early mathematical and numeracy skills. Besides cultivating mathematical abilities, teaching early mathematics also enhances verbal, spatial, and memory skills in young children. These skills are crucial across all facets of life and academics. Establishing a solid foundation for future mathematical learning is of utmost importance during these formative years, as it allows for the optimization of the innate skills that young students already possess (Chesloff, 2013).

Poor achievement in math is a major concern nationwide in the USA. Students in the United States consistently perform below their peers in other countries in math achievement (Fisher, Dobbs-Oates, Doctoroff & Arnold, 2012). This underperformance may impact the country's future in the global workforce. Math is a subject that builds on itself from early childhood. For instance, a student who fails a sixth-grade math course has a 60% chance of dropping out before graduation (Ribner, 2017). A study in Delaware, reflective of the nation, found that 25% of second graders failed to meet state math standards. Early intervention with math and numeracy skills is crucial, as students are not catching up in upper elementary and middle school, leading to an increasing number of students falling behind. A better math foundation is needed for students to succeed in higher-level math classes and pass state tests.

Tanzania faces persistent challenges in mathematics performance, spanning from primary education to higher learning institutions. Despite the government's efforts to allocate resources for enhancing the capacity of mathematics teachers and acquiring teaching materials, there is a growing concern about the increasing number of primary school learners with inadequate mathematical skills. Reisman (2005) contends that students with deficient mathematical abilities often struggle in mathematics while excelling in other academic areas. Various Tanzanian scholars agree that mathematics is a nationwide issue, contributing significantly to academic underachievement among students (Kitta, 2004).

Before the pandemic, the Philippines faced significant challenges in mathematics education, ranking lowest in international assessments (San Juan, 2019). In the PISA 2018 International Report, Filipino students' average score in mathematical literacy was 353 points, significantly lower than the OECD average of 489 points, indicating a below Level 1 proficiency (OECD, 2019). The Philippines also scored 297 in math in the 2019 Trends in International

Mathematics and Science Study (TIMSS) by the International Association for the Evaluation of Educational Achievement (Mullis et al., 2019). Addressing students' confidence in mathematics and developing effective strategies to enhance mathematics education in the Philippines is necessary. Developing strong mathematical skills requires early numeracy development during early childhood.

This study investigates teachers' intervention programs for developing early numeracy skills in struggling kindergarten learners. The insights from this study could inform policymakers, curriculum developers, and other educational stakeholders at various levels of educational administration. These findings could help address the existing problems of poor mathematical skills in early childhood education.

Teaching and Learning Mathematics. Acquiring mathematical skills and retaining factual knowledge is undeniably valuable, but their significance lies primarily in their application. In isolation, facts and skills lack intrinsic importance; their true value becomes evident when employed to resolve real-world problems. When students utilize mathematical facts and skills to tackle authentic challenges, retention and comprehension tend to occur more naturally. In addition to utilizing mathematics as a tool for addressing practical issues, it is equally essential to impart a comprehensive understanding of the various components of mathematics and their interconnectedness. While mathematics can be introduced methodically, segment by segment, it is vital to emphasize the interrelated nature of different mathematical topics. Furthermore, students should be made aware that mathematics is a universal language practiced worldwide.

The overarching objective of mathematics education is to foster students' autonomy and critical thinking, enabling them to grasp the purpose of mathematics and its meaningful application in their daily lives. As noted by Allsopp et al. (2007), several key concepts for effective mathematics education include problem-solving, reasoning, establishing connections between mathematical concepts, effective communication of mathematical ideas, and proficient representation of mathematical concepts. In essence, mathematics education should not be confined to rote memorization and isolated skills but should empower students to engage with mathematics as a tool for problem-solving, logical reasoning, making connections, effective communication, and meaningful representation, thereby equipping them for a more comprehensive and purposeful engagement with mathematics in their daily lives.

Early Math and Numeracy Skills. Early mathematical and numeracy aptitudes represent competencies that most young children naturally employ in their daily activities, such as play and everyday interactions. These proficiencies form the bedrock of primary education and serve as the cornerstone for subsequent elementary math courses, extending into more advanced math classes. The introduction of these skills at an early age is imperative, as they provide the basis for progression through the comprehensive mathematical curriculum. This is particularly crucial because higher-level math courses, including algebra and geometry, rely heavily on a solid foundation of number sense and numerical skills, as emphasized by Jordan et al. (2009). Devoid

of a robust numeracy groundwork, students may encounter difficulties without a scaffold upon which to build when grappling with more advanced concepts, perpetuating their challenges.

The key early math and numeracy themes encompass counting, comparisons, classification, and geometry. Furthermore, early mathematical and numeracy proficiencies encompass logical reasoning, problem-solving, and the ability to engage in systematic thinking, as elucidated by Aunio et al. (2015). Despite their apparent simplicity, these competencies are arguably among the most pivotal for students, as they play a vital role in shaping their future academic success.

Counting. Counting is one of the most basic skills in math. It starts with the basic ability to count verbally forward and progresses into more advanced skills such as being able to add and subtract. Some of the necessary early math skills related to counting are one-to-one correspondence, including seriation and cardinality, and number identification. One-to-one correspondence is the ability to accurately point to objects one-by-one, count in order (seriation), and say how many (cardinality). Students have to understand that each object can only be counted once and that each number can only be said for one object.

Students who struggle with one-to-one correspondence tend to either count or move their finger too quickly over the objects. Number identification is the ability to see a numeral and say what it is called. Students who struggle with number identification cannot accurately and consistently say the correct number name for a numeral. Mastering these skills leads to the ability to say number word sequences, counting in order forward or backward from any number, which are the basis for all future number awareness and a Nebraska State Standard for Kindergarten math (Aunio et al., 2015).

Comparing and Classifying. Comparing and classifying numbers and groups are fundamental skills to mathematical reasoning. Students need to be able to look at two groups and identify how they are different or the same and eventually be able to compare numerals and say which is greater or less. They also need to be able to sort objects by attributes into groups including color, size, and shape. A more advanced version of this skill is sorting by more than one attribute at the same time such as color and shape. By understanding how numbers and items are related, through comparing and classifying, children are creating numerical relationships. These relational skills are not only essential for early numeracy development but also critical for future math learning. Students may always need to be able to know how numbers are related to one another throughout their math career (Aunio et al., 2015).

Geometry. In primary school, geometry mostly refers to spatial relationships, shapes, and measurement in a way to describe the real world. Students are learning vocabulary such as left, right, over, and under as well as colors and shape names. Geometry concepts begin basic with identifying and creating shapes, using positional words, and using measurement words to describe and compare objects in Preschool and Kindergarten and expand on those same skills all the way

through elementary school (Nebraska State Board of Education, 2015). By the end of elementary school, students use their geometry skills to do higher-level geometry such as identifying vertices, graphing on a coordinate plane, and making conversions between metric and standard units of measurement.

Thinking Skills. Being able to count, compare, classify, and understand geometry are necessary skills for elementary school math and beyond but are meaningless unless students can apply their learning outside of a rote math problem. Children also need to learn logical thinking, problem-solving, and reasoning skills alongside early math instruction. Researchers have suggested that logical thinking is the most important skill for early math and numeracy learning. Students need to be able to understand mathematical concepts at a deeper level and understand the logic behind what they are doing. Logical thinking is also present in everyday situations such as what to do if something gets spilled or what to do if there are missing supplies.

Significance of Early Numeracy Development. Early mathematics and numeracy encompass the fundamental grasp of numbers and essential mathematical concepts, encompassing skills such as counting, making comparisons, describing shapes and positions, and problem-solving. According to Harris & Petersen (2019), students who are introduced to and master these early mathematical abilities at a young age are more likely to excel academically. Conversely, students who enter kindergarten with limited math skills often struggle to catch up with their peers in subsequent grades. Consequently, it is imperative that math learning and intervention commence before kindergarten. This is especially critical for at-risk students, who require the opportunity to establish a strong foundational understanding at an early stage.

Clerkin and Gilligan (2018) conducted a study revealing that proficiency in arithmetic in fourth grade is strongly linked to numeracy-related activities at home with young children and their overall attitudes toward mathematics. They observed a significant and positive association between early childhood numeracy play and a positive attitude toward math that persisted at least until fourth grade. Additionally, their research indicated that students harboring a negative attitude toward math in fourth grade also tended to achieve at lower levels. This underscores the direct correlation between early numeracy play and the development of positive attitudes toward mathematics, which, in turn, leads to enhanced performance in upper elementary math courses. It is evident that parents, serving as a child's initial educators, play a pivotal role by introducing numeracy activities at an early age, thus charting a path toward their child's future success in mathematics.

Mathematical Difficulties. Many children and adults experience difficulties with mathematics. A mathematical difficulty refers to children or adults who struggle or fail to cope with some aspects of arithmetic necessary for education or practical purposes. Studies have demonstrated that children with mathematical difficulties have impairments in understanding and processing numerical magnitude (Defective Number Module, 2011). However, little is known about the cognitive deficits that underlie their poor achievement in mathematics. Several cognitive

studies have shown that children with difficulties in mathematics have structural and functional abnormalities in the brain areas involved in numerical magnitude processing.

Learners who are assumed to have mathematical difficulties are learners with the lowest scores in math. Their main features are the inability to translate the problem into appropriate mathematical terms. Grauberg (1998) mentions features such as problems in understanding symbols, lack of organizational skills, weakness in memory, problems with relative concepts, weakness in auditory discrimination, and difficulties in social interaction.

Learners with low mathematical skills are underachieving in mathematics. There are three domains of math skills (also called cognitive dimension components, process competencies, or common competencies) – knowing, applying, and problem-solving. The mathematical skills include two main aspects: knowledge of the number system and arithmetic fluency. Chin (2004) identifies some basic mathematical skills these learners may lack, including problem-solving, communicating mathematical ideas, mathematical reasoning, applying mathematics to everyday situations, estimation, measurement, patterns, probability, geometry, appropriate computational skills, and algebraic thinking.

In line with this, Donlan (1998) argues that learners with low mathematical skills have low arithmetical ability, which includes basic number knowledge, memory of arithmetical facts, understanding of concepts, and the ability to follow procedures. Number knowledge involves recognizing numbers in different forms (numerals, number words, and concrete quantities) and placing them in order. Factual knowledge involves memory for different categories of facts (addition, multiplication, subtraction, and division). Conceptual understanding involves understanding the properties of and relationships between arithmetical operations. Procedural knowledge involves memory for learned procedures. Low mathematical skills may correlate with impairments in mathematical difficulties.

Challenges in Improving Numeracy Skills. Numeracy skills play a vital role in equipping learners with the essential mathematical abilities required to navigate everyday life and pursue further academic and career opportunities. Teachers play a crucial role in fostering numeracy skills among their students. However, they encounter various challenges in their efforts to improve and enhance numeracy skills.

Diverse Classroom Setting. One of the primary challenges teachers face is the diverse range of learning needs within a classroom. Students possess different levels of mathematical aptitude, learning styles, and prior knowledge, making it challenging for teachers to address each student's unique needs effectively. Differentiating instruction becomes essential to cater to learners who require additional support or extension activities, thereby challenging teachers to find suitable strategies for individualized instruction (Lee, 2009).

The need to meet every student’s needs in the mathematics classroom according to their preconditions and needs has been recognized (Roos, 2015). Some teachers believe it is impossible

to meet every student's needs in an inclusive classroom because of the diversity. However, Frederickson and Cline (2009) claim that teaching is interesting because of the diversity among students, and it is possible because of the similarities. By being aware of the diversity, teachers can develop sensitivity toward equality in teaching, putting students' needs at the forefront in explanations and tasks given.

Limited Instructional Time. Teachers often find themselves constrained by limited instructional time. Curriculum demands and time constraints leave teachers with limited opportunities to delve deeply into numeracy concepts or provide extensive practice. This limitation hampers their ability to reinforce foundational skills and engage students in meaningful mathematical explorations. Teachers must balance covering the required curriculum and allowing for sufficient practice and concept mastery (Malofeeva, 2005).

Limited Resources and Technology Access. Teachers often face resource constraints that hinder their ability to provide hands-on experiences and manipulatives for effective numeracy instruction. Insufficient access to appropriate textbooks, supplementary materials, or technology tools can limit teachers' capacity to engage students in meaningful mathematical experiences. Overcoming these challenges may require innovative approaches, such as seeking external resources or adapting teaching strategies to leverage the available resources effectively (Jordan, 2011).

Inadequate Motivation and Low Self-Confidence. Inadequate motivation and low self-confidence in mathematics represent significant challenges. These factors are widely recognized as major impediments to students' proficiency and mastery of mathematical concepts. Anxiety related to mathematics often manifests within mathematical problems and tends to escalate as students' progress through the academic years. Research by Sheffield and Hunt (2006) revealed that students with high levels of mathematical anxiety typically exhibit lower performance in mathematics assessments. Addressing mathematical attitudes proactively in kindergarten is crucial to break the cycle of negative self-perception.

Low Student Involvement. Challenges in sustaining students' involvement in the learning process are noteworthy. Environmental and emotional factors, such as class size, lecture duration, and negative emotional states, contribute to students' limited engagement in classrooms. Research indicates that experienced teachers can introduce innovative teaching strategies to foster student engagement, influencing student achievement through a combination of internal and external factors (Subramanian et al., 2017). Student engagement is pivotal for enhancing the performance of underperforming students, correlating significantly with academic accomplishments (Gasevic et al., 2017).

Linking Math to Real Life. Researchers and educators advocate for teaching math through real-world contexts, pushing students to use numerical reasoning to solve problems they will encounter as adults. Connecting school mathematics to experiences and contexts outside of school

is critical for student learning. Studies suggest that knowledge and experiences from everyday lives can serve as resources for learning mathematics, enhancing student learning when concepts and skills are connected to realistic contexts (Stillman, 2010; Ladson-Billings, 2009; Boaler, 2008).

Applying Differentiated Instruction. Applying differentiated instruction in mathematics is a dynamic, student-centered approach promoting inclusive learning environments and nurturing individual growth. Differentiation involves using various teaching techniques and strategies to teach learners concepts, catering to their diverse educational needs (Jonsen, 2023; UNESCO, 2004; Hannell, 2013).

Incorporating Technology. Incorporating technology into education can enhance both student mathematics achievement and the overall school learning environment. Teachers trained in instructional technology are more likely to employ meaningful uses of computers, such as simulations, applications, and learning games, positively impacting the teaching and learning process (Wenglinsky, 2000). However, there remains a gap between the promise of technology and its practical utilization in classrooms. Teacher educators collaborating with teachers can enhance their proficiency in using technology effectively (Wenglinsky, 2000).

Setting Achievable Goals for Students. Setting achievable goals is crucial for improving motivation and self-confidence in math. Research has shown a strong connection between achieving smaller goals and positive psychological effects, aiding in mastering mathematical concepts and reducing cognitive load (Sylva et al., 2004; Takala, 2009; Murphy et al., 2007).

Providing Extended Learning Opportunities. Providing extra learning opportunities supports students in taking control of their education, enhancing engagement and motivation. Extended learning aligns with differentiated instruction, allowing teachers to adapt to individual learning levels and offer personalized assessment and feedback (Natele et al., 2009; Ohala et al., 2007).

II. Methodology

The philosophical assumptions of this study framed the collection, analysis, and interpretation of data on improving early numeracy skills in kindergarten learners. Ontologically, the study acknowledged multiple realities, particularly from teachers' perspectives, explored through participants' voices and themes. The researcher ensured reliability by meticulously coding and analyzing responses, maintaining authenticity and avoiding personal bias.

Epistemologically, close interaction with participants provided firsthand information. The researcher collaborated with teachers, spending time in the field to gain direct insights. Axiologically, the researcher upheld values by interpreting participants' answers carefully,

preserving their merit. The study's findings were presented in a literary, informal style, using personal voice and qualitative terms.

The qualitative, phenomenological approach aimed to understand teachers' lived experiences at Polocon Elementary School, focusing on their perspectives, challenges, and coping mechanisms. According to Creswell (2012), phenomenology describes specific phenomena through various qualitative methods. Data were read, re-read, and thematized to construct a universal understanding of the phenomenon. In-depth interviews and audio recordings ensured consistent transcription.

Data gathering followed a structured procedure, with permission obtained from school authorities and consent from participants. A researcher-developed, expert-validated questionnaire facilitated in-depth interviews. Responses were transcribed, coded, and thematized, with follow-up focus group discussions for clarification. Thematic analysis, following Creswell's model, involved familiarization, coding, theme identification, and writing up findings.

The flexible analytical framework allowed data analysis during or after collection. It involved identifying key ideas, indexing data to themes, charting, and interpreting to provide a schematic diagram of the phenomenon, reflecting participants' true attitudes and values.

Ethical considerations were paramount. The researcher adhered to principles of informed consent, privacy, confidentiality, justice, and transparency, protecting participants' identities and data. The study was conducted ethically, respecting participants' rights and dignity. The researcher was prepared physically, mentally, emotionally, and financially. Community involvement and respect for local traditions were emphasized, maintaining the study's integrity.

III. Results and Discussion

The result of this is on challenges and strategies for improving numeracy skills among learners. Participants identified several key challenges, including inadequate motivation and low self-confidence, which hinder students' engagement and academic performance in math. Limited instructional time was another significant issue, preventing thorough coverage and practice of numeracy concepts, thus impeding mastery and progress. The diverse classroom settings posed difficulties in personalizing instruction, with struggling learners often hesitating to seek help, further widening the skill gap. Additionally, limited access to resources and technology restricted the ability to conduct practical math activities, affecting students' comprehension of complex concepts. To address these challenges, participants recommended setting achievable goals to boost learners' confidence and motivation. Providing extended learning opportunities, such as additional assignments and resources, catered to diverse learning styles and needs, promoting deeper exploration of math concepts. Linking math to real-life situations was also emphasized to make the subject more relatable and develop critical thinking skills. Educational management insights

from participants highlighted the importance of modeling positive behavior to mitigate math anxiety and enhance motivation. Fostering success through tailored learning activities was seen as crucial for building a positive attitude towards math and ensuring continuous engagement. These strategies collectively aim to create a supportive and effective learning environment for improving early numeracy skills.

Analysis

This presents an overview of the study and discusses the implications based on the findings. The study aimed to investigate the challenges teachers face in improving early numeracy skills among struggling kindergarten learners. By examining these challenges, the study identified effective coping strategies and provided valuable insights into educational management.

Emerging Challenges

Inadequate Motivation and Low Self-Confidence. Learners often exhibit diminished motivation and self-confidence, negatively impacting their retention of math concepts. Insufficient motivation results in incomplete engagement with the material, leading to a weaker understanding of mathematical concepts. Similarly, low self-confidence hampers problem-solving abilities, making learners more prone to giving up or avoiding challenging tasks in mathematics.

Limited Instructional Time. Teachers face a conflict between covering extensive content and the limited instructional time available. They feel compelled to address a wide range of math concepts quickly, limiting in-depth exploration and individualized support for struggling learners. This adversely impacts the academic progress of struggling learners.

Diverse Classroom Setting. The diverse skill levels within a classroom pose a significant challenge in personalizing instruction for struggling learners. The instructional pace often caters to average or high-achieving students, unintentionally disadvantaging those needing extra support. Struggling learners in mixed-ability classes may hesitate to seek help, contributing to a widening gap in numeracy skills.

Limited Resources and Technology Access. Teachers face challenges incorporating hands-on activities to enhance learner understanding due to limited access to suitable materials and technology tools. Despite aiming for an engaging and interactive math learning experience, the shortage of resources hinders their efforts, posing a significant obstacle to delivering dynamic and comprehensive math education.

Coping Strategies

Setting Achievable Goals for Students. Teachers break tasks into achievable goals, offering a clear path for learners. They guide learners in achieving these goals through continuous guidance and ample practice.

Providing Extended Learning Opportunities. Teachers offer extra learning opportunities, such as optional assignments or additional resources for struggling learners. These opportunities help teachers overcome time constraints and cater to diverse learning styles and math abilities.

Linking Math to Real Life. Teachers prioritize linking math concepts to real-life situations to nurture essential competencies beyond subject-specific content, including communication, critical thinking, and problem-solving. These skills can be cultivated with minimal reliance on external learning resources.

Educational Management Insights

Modeling Positive Behavior. Teachers play a crucial role as role models for learners. When they exhibit a positive attitude and behavior toward math, struggling learners are inclined to adopt these positive traits. Modeling such behavior fosters a genuine love for the subject and nurtures self-esteem.

Fostering Success. Teachers emphasize the importance of letting struggling learners experience success. They customize learning activities to suit diverse learning styles and varying levels of mathematical proficiency. Feeling successful leads to a positive attitude toward math and sustained engagement with the subject.

Approaching Teaching Practically. Teachers believe that education extends beyond the classroom, preparing learners for real-world applications of their knowledge. They serve as models, showcasing the significance of creativity and innovation in addressing real-world challenges.

These emerging themes provide a framework for educational managers to support teachers in improving the numeracy skills of struggling learners in kindergarten. Through effective educational management, educational leaders can help teachers create a better learning environment and opportunities for children in mathematics education.

Future Directions

For Policymakers. Policymakers may develop and implement comprehensive training initiatives designed to equip teachers with specialized strategies for addressing the diverse needs of young learners in numeracy. They should review the impact of policy changes related to curriculum design, resource allocation, and support systems for teachers to foster an environment conducive to improving numeracy skills in early education.

For School Administrators. School administrators may incorporate specialized coaching or mentorship programs to provide ongoing support for teachers in implementing effective strategies to improve kindergarten learners' numeracy skills. They should design and execute targeted training programs aimed at equipping teachers with effective strategies for addressing diverse learning needs within kindergarten classrooms.

For Teachers. Teachers may engage in collaborative action research projects to share best practices and collectively address challenges related to improving numeracy skills. This collaborative approach could involve peer observation, joint lesson planning, and the development of a supportive professional learning community within the school.

For Future Researchers. Future researchers should explore the interrelationships between numeracy development and other areas of early childhood education, such as socio-emotional development or language acquisition. They should investigate and assess the effectiveness of innovative teaching strategies, such as gamified learning approaches, blended learning models, or project-based activities, in improving numeracy skills among kindergarten students.

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