International Journal of Advanced Research in Islamic Studies and Education (ARISE)
e-ISSN 2785-9088

FUN COUNTS: THE EFFECTIVENESS OF PLAY-BASED APPROACH ON PRESCHOOLERS' MATHEMATICAL SKILL ACQUISITION

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Received: 24 June 2025 *Accepted: 26 August 2025* *Published: 07 October 2025*

Abstract: This concept paper explores the effectiveness of play-based approaches for developing early mathematical skills among preschool-aged children (age 3-6 years). Despite strong evidence that early mathematical competencies predict later academic success, many preschoolers struggle to develop adequate mathematical understanding through traditional instructional methods that often misalign with children's developmental needs. The paper synthesizes research on play-based mathematical learning, exploring developmental trajectories of mathematical skills, core mathematical competencies in early childhood, and limitations of traditional approaches. Various play-based interventions are examined, including mathematical play environments, embedded mathematics in dramatic play, mathematical games, and playful problem-solving. The theoretical foundations supporting these approaches are outlined, drawing on constructivist learning theory, sociocultural theory, and cognitive development frameworks. Empirical evidence demonstrates that play-based approaches effectively develop number sense, spatial reasoning, and pattern recognition while fostering positive attitudes toward mathematics. The paper addresses implementation challenges, including teacher knowledge constraints, structural limitations, and perceived tensions between play and academic learning, while offering evidence-based strategies for overcoming these barriers. By integrating mathematical learning within developmentally appropriate play contexts, educators can create engaging learning experiences that establish strong foundations for mathematical understanding while honouring children's natural learning processes.

Keywords: Play-Based Approaches, Early Mathematics Education, Preschool Children, Early Mathematical Skill Acquisition, Early Childhood.

Cite This Article:
Nursarah Nadiah Rizam & Nurfaradilla Mohamad Nasri. (2025). Fun Counts: The Effectiveness Of Play-Based Approach On Preschoolers' Mathematical Skill Acquisition. *International Journal of Advanced Research in Islamic Studies and Education (ARISE),* 5(3), 137-153.

INTRODUCTION

Early mathematical competencies are foundational building blocks for children's academic success and cognitive development. Research consistently demonstrates that mathematical skills acquired during the preschool years (ages three to six) serve as powerful predictors of later academic achievement, not only in mathematics but across multiple disciplines (Norly Jamil, 2015). However, many preschool-aged children are struggling to develop adequate mathematical understanding, contributing to achievement gaps that persist into later education (Morgan et al. 2016; Nguyen et al. 2022).

Traditional approaches to early mathematical education have frequently relied on direct instruction methods, structured worksheets, and rote memorization techniques. While the approaches yield certain benefits, they may overlook children's natural learning tendencies, particularly their inclination to explore, experiment, and engage in play (Ompok, Ting dan Sapirai, 2021). This misalignment between pedagogy and developmental need poses challenges for early childhood educators. Developmental psychology and neuroscience suggest that the preschool years are a critical period for forming mathematical concepts (Clements & Sarama, 2018). During this stage, children naturally use mathematical thinking during this time through routine tasks like counting objects, identifying patterns, investigating shapes, drawing comparisons, and solving problems. These naturally occurring intuitive mathematical behaviours during play suggest that play-based learning has the potential to be a highly effective method for developing mathematical skills.

Despite growing interest in play-based learning, there is limited agreement on the most effective interventions, implementation strategies, and long-term outcomes (Purpura et al., 2023). Teachers always struggle to strike a balance between explicit mathematical instruction and playful learning because of ongoing conflicts between the demands of academic accountability and developmentally appropriate practices in early childhood settings (Allee-Herndon & Roberts 2020; Mohd Ikhlas et al. 2023). Although evidence supports play-based learning, there remains uncertainty regarding how to effectively implement these approaches to optimize mathematical outcomes in preschool education. Accordingly, this concept paper aims to explore and synthesize research on play-based learning in mathematics, propose a conceptual framework for its application, and provide guidance for educators seeking to integrate play into mathematical instruction.

LITERATURE REVIEW

Developmental Trajectory of Early Mathematical Skills

Research has consistently demonstrated that early mathematical skills develop along predictable trajectories, with foundational concepts serving as building blocks for more advanced mathematical thinking. According to Clements and Sarama (2018), preschoolers typically progress through developmental sequences in number sense, spatial reasoning, and pattern recognition that form the basis for later mathematical achievement. These learning trajectories provide a framework for understanding how children construct mathematical knowledge in the early years. This acquisition of mathematical concepts during early childhood is now recognized as critically important for later academic achievement. In a longitudinal study spanning from preschool to fifth grade, Watts et al. (2018) found that early mathematical competencies were stronger predictors of later achievement than reading skills or social-emotional development. Similarly, Mohd Ikhlas et al. (2023) and Zhang and Quinn (2020) demonstrated reciprocal relationships between early mathematical abilities and general cognitive development, suggesting that mathematical learning supports broader intellectual growth during the preschool years.

However, significant disparities in early mathematical knowledge exist among young children. Morgan et al. (2016) documented substantial achievement gaps in mathematical abilities among preschoolers, with these disparities often widening throughout the educational journey. Children from lower socioeconomic backgrounds typically demonstrate less developed mathematical skills upon entering kindergarten, highlighting the need for effective interventions during the preschool years.

Core Mathematical Competencies in Early Childhood

Few research studies have identified several core mathematical competencies that emerge during the preschool years and serve as foundations for later mathematical learning. Number sense, which encompasses skills such as counting, quantity discrimination, and numeral recognition, is widely recognized as a fundamental mathematical competency. In a comprehensive review, Nguyen et al. (2022) found that preschoolers' number sense was the strongest predictor of fifth-grade mathematics achievement, underscoring its developmental significance.

Beyond number sense, spatial skills represent another critical domain of early mathematical development. According to Mohd Ikhlas et al. (2023), spatial abilities in early childhood contribute uniquely to mathematical achievement and STEM readiness. These skills include shape recognition, mental rotation, spatial visualization, and geometric reasoning. Hawes et al. (2019) demonstrated that interventions targeting spatial thinking during preschool years yielded improvements in both spatial and numerical abilities, suggesting interconnections between these domains. Pattern skills comprise a third key area of mathematical competence. Zippert et al. (2020) found that preschoolers' ability to recognize, extend, and create patterns predicted later mathematical achievement, even after controlling for other cognitive abilities. These patterning skills appear to support algebraic thinking and mathematical generalization, providing an essential foundation for more advanced mathematical concepts.

Limitations of Traditional Approaches in Early Mathematics Education

Traditional approaches to early mathematics instruction have often emphasized direct instruction, structured activities, and explicit teaching of mathematical concepts. These methods' proponents contend that methodical teaching guarantees thorough coverage of mathematical material and aids in children's procedural fluency development. These approaches usually include lessons that are guided by the teacher, organized practice exercises, and a purposeful arrangement of mathematical material.

However, critiques of traditional approaches highlight their potential limitations for young learners. According to Wickstrom et al. (2019), preschoolers' innate curiosity and learning styles are frequently not captivated by highly structured mathematical instruction. Similarly, Ompok et al. (2021) noted that structured worksheet-based approaches often emphasize rote memorization over conceptual understanding, potentially undermining children's mathematical reasoning. This disconnects between traditional instructional methods and young children's developmental needs creates significant challenges for early mathematics education. Stipek (2017) documented tensions between academic accountability pressures and developmentally appropriate practice in early childhood settings, noting that mathematics instruction frequently skews toward direct instruction models that may not optimize learning for young children.

Content of Early Mathematics in Malaysian Preschools

Early mathematics skills are widely recognized as the foundation for later mathematical development and academic achievement. According to Jamilah Harun et al. (2017), the content of early mathematics includes a broad range of mathematical knowledge and skills, specifically focusing on numbers, number operations, geometry, measurement, and data analysis. Building these competencies during preschool years is crucial, as early mathematics experiences have been shown to provide a strong basis for future mathematical learning and cognitive growth (Siti Rahaimah & Farah 2017; Clements & Sarama, 2018).

In the Malaysian preschool context, the Kurikulum Standard Prasekolah Kebangsaan (KSPK) has been implemented nationally since 2010, outlining specific content areas to guide mathematical development among preschool children. The curriculum emphasizes early experiences that foster an understanding of basic mathematical ideas within meaningful and engaging contexts (Norhaizan et al., 2022). Initially, children are introduced to prenumber skills, where they engage in activities such as matching, comparing, ordering, and recognizing patterns based on attributes like size, colour, or shape. These foundational skills support the development of logical thinking and classification abilities essential for later mathematical operations.

Following this, the concept of number is systematically introduced. Five-year-old children are encouraged to develop skills in rote counting, rational counting, and recognizing numerical symbols, typically focusing on numbers from one to ten. As children progress to six years of age, the curriculum expands to include numbers up to twenty, emphasizing the ability to count forwards and backwards and to engage in skip counting. Understanding the relationship between numerical symbols, spoken numbers, and quantities is central to building strong number sense during these early stages.

The curriculum also introduces basic number operations, particularly addition and subtraction within the number range of ten. Children are guided to solve both abstract numerical problems and real-life arithmetic scenarios, such as combining groups of objects or understanding number relationships, and prepare them for more formal mathematical operations in later schooling. Additionally, KSPK incorporates elements related to the value of money, where children are exposed to recognizing different denominations, sorting coins and notes according to their value, and also performing simple purchasing activities through role-played simulations. Time concepts are also embedded within the curriculum, with five-year-olds learning to associate events with parts of the day (morning, afternoon, night) and six-year-olds extending their understanding to reading clock times and identifying days of the week and months of the year. These activities help children situate mathematical understanding within everyday life experiences.

The domain of shape and space is another important focus of early mathematics in Malaysian preschools. Children are encouraged to recognize and differentiate between various two-dimensional and three-dimensional shapes and to use spatial language such as “inside”, “outside”, “above”, and “below”. Activities involving movement, construction, and description of object positions promote spatial reasoning, essential skills closely linked to both mathematics and science learning. Although measurement and data analysis are not explicitly categorized as standalone topics in KSPK, these elements are implicitly woven into the curriculum. Activities such as seriation (ordering objects by size, length, or weight) and pattern recognition serve as early experiences in measurement and data handling, aligning Malaysian practices with international frameworks such as those proposed by National Council of Teachers of Mathematics (NCTM 2015) and the office of Superintendent of Public Instruction (OSPI, 2014).

To conceptualize the interrelationship among these domains, Clements and Sarama (2018) propose a comprehensive model of early mathematics content (see Figure 1). Their Framework identifies five principal domains (number and operations, algebra, geometry, measurement, and data analysis) with number and operations positioned at the core. The model emphasizes the essential roles of reasoning, representation, communication, and making connections across domains, suggesting that early mathematical learning is most effective when these components are integrated.

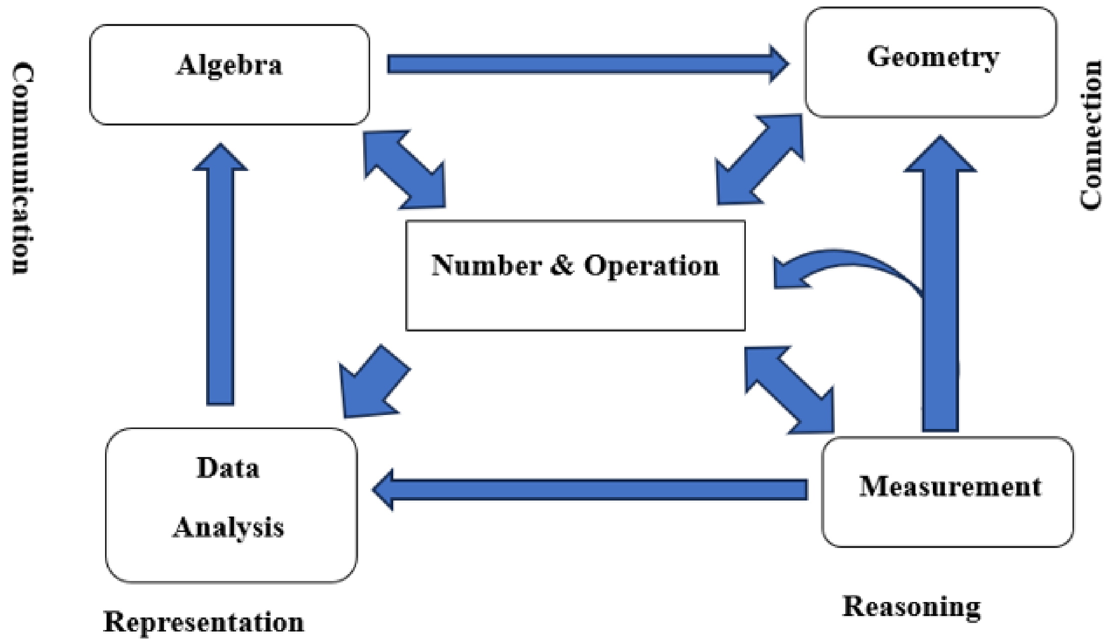

Figure 1: The Contents of Mathematics (Clements & Sarama, 2018)

Play-Based Learning as a Pedagogical Approach

Play-based learning represents a pedagogical approach that harnesses children’s natural inclination toward playful engagement to facilitate meaningful learning experiences. According to Maisarah and Syaza (2021), play-based approaches exist along a continuum from free play (child-directed, with minimal adult intervention) to guided play (maintaining playful elements while incorporating learning goals through adult scaffolding) to direct instruction (teacher-directed, with structured learning objectives). Within early mathematics education, guided play has emerged as a particularly promising approach that balances child agency with intentional learning outcomes (Fisher et al., 2022).

Numerous viewpoints in educational theory and developmental psychology are incorporated into the theoretical foundations of play-based mathematics learning. A fundamental framework is offered by Vygotskian sociocultural theory, which emphasizes how play establishes a zone of proximal development where kids can function at higher cognitive levels than they would in non-play situations (Fleer 2018). Through play, kids interact with mathematical ideas that might otherwise be incomprehensible or abstract, building understanding through social interaction and symbolic representation.

Constructivist theories emphasize how children actively construct knowledge through practical experiences and discovery, which lends additional credence to play-based mathematical approaches. Van Oers (2015) also explained how children can make meaningful connections between formal mathematical concepts and informal mathematical knowledge through play contexts. This viewpoint is consistent with ‘playful learning’ as defined by Hassinger-Das et al. (2017), in which deep conceptual development is supported by experiences that are joyful, meaningful, actively engaging, interactive, and socially interactive.

With studies showing how playful learning activates neural networks that are linked to both pleasure and executive function, neuroscience research has more recently reinforced the theoretical foundation for play-based mathematics. In order to create the best conditions for learning mathematics, Bustamante et al. (2020) discovered that play-based learning experiences engaged prefrontal cortical regions linked to attention and cognitive control while also activating dopaminergic reward pathways.

Play-Based Approaches in Early Mathematical Learning

The integration of play-based approaches into early mathematics education represents a significant shift from traditional instructional methods. Clements and Sarama (2018) identified several distinct manifestations of play-based mathematics, including mathematical play environments, mathematically rich play activities, mathematical games, and playful problem-solving experiences. These approaches share a common emphasis on active engagement, meaningful contexts, and child agency while differing in their level of structure and explicitness of mathematical content.

Mathematical play environments offer areas and resources that naturally stimulate mathematical inquiry and thought. Siti Rahaimah and Farah (2017) then showed how preschoolers’ impromptu mathematical explorations were stimulated by thoughtfully planned play areas furnished with blocks, manipulatives, and measurement instruments. The frequency and complexity of mathematical language and concepts in children’s play were also found to increase in enriched play environments with mathematically relevant materials (Vogt et al., 2018). The goal of mathematically rich play activities is to include possibilities for mathematical learning in enjoyable settings. Lewis Presser et al. (2019) showed how children’s mathematics vocabulary and comprehension were improved by including mathematical language and concepts into dramatic play scenarios. Similar to this, Cohrssen et al. (2016) then showed how teachers could use ostensibly non-mathematical play activities like constructing, cooking, and gardening to enhance mathematical learning when they identified and expanded mathematical thinking in these settings.

Mathematical games represent another significant category of play-based approaches. Ramani and Siegler (2016) developed and tested number board games that significantly improved numerical knowledge among preschoolers from low-income backgrounds. Next, Purpura et al. (2023) extended this work by designing mathematical card games targeting specific numeracy skills, finding that game-based interventions were particularly effective for children with lower initial skill levels. Playful approaches to problem-solving highlight mathematical reasoning in entertaining situations. According to a study by Park and Chang (2021), when teachers incorporated mathematical problems into entertaining situations, kids showed more advanced mathematical reasoning. In a similar vein, Clements and Sarama (2018) reported that 'puzzle play' helped preschoolers develop their geometric and spatial reasoning skills, laying the groundwork for subsequent mathematical education.

THEORIES RELATED TO THE PLAY-BASED APPROACH

Several theories and learning methods emphasize play activities in children's learning, such as Constructivist Learning Theory, Sociocultural Theory, and Cognitive Development Theories.

Constructivist Learning Theory

Constructivist theory provides a fundamental framework for understanding how play supports mathematical learning in young children. According to contemporary constructivist perspectives, children actively construct mathematical knowledge through hands-on experiences and social interactions rather than passively receiving information (Clements & Sarama, 2018). Next, Mertala (2019) extended this understanding by examining how preschoolers construct mathematical knowledge through playful experimentation with both physical and digital manipulatives. This research demonstrated that when children engage with mathematical concepts through play, they build increasingly sophisticated mental models that connect concrete experiences to abstract mathematical principles.

Neo-constructivist methods, which build on Piaget's principles, highlight how play can promote cognitive conflict and schema development (Vogt et al. 2018). Children are exposed to scenarios that test their current comprehension through engaging mathematics exercises, which encourage them to refine and broaden their mathematical ideas. According to Lee et al. (2022), young generations nowadays are able to confront and overcome cognitive difficulties pertaining to spatial relationships, measuring, and geometric concepts through constructive play with blocks and other building materials.

Contemporary constructivist frameworks also highlight the importance of representation in mathematical learning. Zippert and Rittle-Johnson (2020) examined how play supports children's development of multiple representational strategies, allowing them to move flexibly between concrete, pictorial, and abstract representations of mathematical ideas. This multi-representational flexibility has been identified as crucial for deep mathematical understanding and later mathematical achievement.

Sociocultural Theory

Vygotskian sociocultural theory offers another powerful lens for understanding play-based mathematics, emphasizing how mathematical knowledge develops through social interaction within cultural contexts. Contemporary applications of sociocultural theory highlight how play creates ideal zones of proximal development where children can engage with mathematical concepts beyond their independent capabilities (Fleer, 2018). Through playful interactions with more knowledgeable peers and adults (teachers and parents), children internalize mathematical language, strategies, and concepts that initially exist in the social plane.

Van Oers (2015) extended sociocultural perspectives on play by introducing the concept of 'mathematizing' within cultural activities, describing how children's appropriate mathematical tools and practices are developed through participation in meaningful cultural contexts. This research demonstrated how play scenarios reflecting cultural practices, like shopping, cooking, and building, provided authentic contexts for mathematical learning that connected school mathematics with children lived experiences.

Recent studies have focused especially on the role that language plays in sociocultural mathematics learning. Playful contexts stimulated rich mathematical discourse among preschoolers, according to Bjorklund and Ahlskog-Bjorkman's (2017) analysis of how mathematical language emerges and develops through collaborative play. Similar to this, Worthington and Van Oers (2016) showed how children's development of mathematical communication skills was supported by the sophisticated mathematical discussions and representations that were evoked by dramatic play scenarios. Play-based mathematics education has been better understood thanks to cultural-historical activity theory (CHAT), which builds on Vygotskian principles. In order to examine how cultural tools, rules, and the division of labor influence mathematical play in early childhood settings, Hedges et al. (2020) used CHAT perspectives. This study demonstrated how play-based mathematical learning opportunities are influenced by the larger activity system.

Cognitive Development Theories

Contemporary cognitive development theories provide an additional framework for understanding play-based mathematical learning. Executive function development, particularly important during the preschool years, has been linked to both play experiences and mathematical learning. Based on Diamond's (2016) executive function framework, play supports the development of working memory, inhibitory control, and cognitive flexibility that are critical for mathematical learning and problem-solving.

Schmitt et al. (2018) demonstrated bidirectional relationships between executive function development and mathematical play. This study found that block play interventions enhanced both executive function skills and mathematical understanding, suggesting that these processes develop synergistically through playful engagement. Similarly, Clements et al. (2020) documented how guided play activities targeting mathematical content simultaneously supported executive function development, creating dual benefits for cognitive development.

The theory of cognitive load has also influenced our knowledge of play-based arithmetic instruction. This theoretical viewpoint states that by establishing meaningful situations that support working memory resources, play might lessen unnecessary cognitive burden (Paas and Van Gog, 2021). In contrast to decontextualized problem-solving, Chen and Yang (2019) discovered that integrating mathematical issues into well-known play scenarios decreased cognitive strain and allowed kids to interact with more difficult mathematical material than they could handle in non-playful settings.

Another significant theoretical viewpoint is the evaluation of the fundamental cognitive processes that underlie mathematical reasoning. Children have neutral approximation number and spatial systems that serve as developmental foundations for subsequent mathematical learning (Feigenson et al. 2021). Play-based approaches can leverage and refine these core systems, as demonstrated by Ramani and Siegler (2016) in their work on number board games. Their research showed how playful number line activities enhanced the precision of children's mental number representations, strengthening connections between approximate and exact number systems.

TYPES OF PLAY-BASED MATHEMATICAL INTERVENTIONS

Play-based mathematical interventions encompass a diverse range of approaches that harness children's natural inclination toward play while intentionally supporting mathematical development. Mathematical play environments involve carefully designed spaces with materials that naturally elicit mathematical thinking and exploration. These environments provide opportunities for children to engage with mathematical concepts through self-directed play activities. Hanna and Angela (2024) documented how learning centres with blocks, manipulatives, and measurement tools prompted spontaneous mathematical investigations among young children. Children in these environments demonstrated increased mathematical vocabulary and concept development compared to classrooms with less intentional designed mathematical materials. Similarly, Vogt et al. (2018) also found that an enriched play environment with mathematically relevant materials increased both the frequency and complexity of mathematical language during preschoolers' play. Their research revealed that mathematical play environments were most effective when teachers periodically introduced new materials that extended children's current mathematical thinking.

Embedded Mathematics in Dramatic Play

This embedding of mathematical concepts within dramatic play scenarios leverages children's imaginative play while creating meaningful contexts for mathematical thinking. This approach integrates mathematical thinking, materials, and problems within familiar play scenarios. Lewis Presser et al. (2019) demonstrated how integrating mathematical props and vocabulary into dramatic play areas (such as grocery stores and restaurants) significantly enhanced preschoolers' numerical vocabulary and operational understanding.

After that, Fleer (2018) developed 'mathematical play worlds' where fantasy play narratives incorporated mathematical challenges and concepts. In these interventions, teachers introduced mathematical problems within ongoing dramatic play scenarios, such as helping fairy tale characters solve measurement problems. Children engaged in these play worlds demonstrated more sustained mathematical thinking and stronger conceptual understanding compared to traditional instructional approaches.

Mathematical Games

Mathematical games represent structured play activities with clear rules and objectives that target specific mathematical concepts. These games provide enjoyable contexts for practicing mathematical skills while promoting social interaction and strategic thinking. Ramani and Siegler (2016) developed number board games that significantly improved numerical knowledge among preschoolers, particularly those from low-income backgrounds. Purpura et al. (2023) later extended this research by designing mathematical card games targeting specific numeracy skills. Their intervention featured games focusing on number recognition, one-to-one correspondence, and quantity comparison. The results indicated that children who played these games demonstrated stronger gains in targeted skills compared to those who played games with similar structures but non-mathematical content. According to Zippert and Rittle-Johnson (2020), they investigated pattern-focused games and found that children who engaged in these activities demonstrated enhanced pattern recognition and extension abilities that transferred to other mathematical tasks.

Playful Problem-Solving

Playful problem-solving approaches embed mathematical challenges within enjoyable, open-ended contexts that encourage exploration and discovery. These kinds of approaches emphasize mathematical reasoning while maintaining playful engagement. Parks and Chang (2021) studied 'playful math challenges' in which teachers presented mathematical problems within imaginative scenarios. This research documented how preschoolers engage in more sophisticated mathematical reasoning when problems were framed as playful challenges rather than formal instruction. So, children have demonstrated increased persistence, mathematical vocabulary, and strategic thinking when solving problems embedded within playful contexts.

In similarly study, Hawes et al. (2019) who created a 32-week spatial reasoning intervention combining guided instruction with playful problem-solving activities. This approach has included playful spatial challenges involving mapping, perspective-taking, and geometric composition. The children who participated in this intervention showed significant improvements in both spatial reasoning and numerical operations compared to peers in traditional instructional programs.

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EFFECTIVENESS OF PLAY-BASED APPROACHES ON CHILDREN'S MATHEMATICAL SKILLS ACQUISITION

Empirical evidence increasingly supports the effectiveness of play-based approaches for mathematical skill development in preschoolers. Resulting in a meta-analysis of 16 studies, Wang et al. (2016) found that play-based mathematical interventions produced moderate to large effects on preschoolers' numerical knowledge, with guided play approaches showing the strongest outcomes. These effects were particularly pronounced for children from disadvantaged backgrounds, suggesting that play-based approaches may help reduce achievement gaps.

Numerous studies have examined particular areas of mathematics that have been impacted by play-based learning. In the area of number sense, Maisarah and Syaza (2021) demonstrated that parent-child number games greatly improved children's counting skills, number recognition, and quantity discrimination. Likewise, Cohrssen and Niklas (2019) discovered that game-based number interventions improved kids' comprehension of cardinality and one-to-one correspondence. Play-based interventions have shown a particular responsiveness to spatial reasoning skills. Children's spatial visualization, mental rotation, and geometric reasoning skills significantly improved after a 32-week spatial play intervention (Hawes et al., 2019). There may be connections between spatial and numerical cognition, as these spatial gains carried over to numerical tasks. In a similar vein, Schmitt et al. (2018) discovered that preschoolers' spatial language and spatial problem-solving skills improved with guided block play. Play-based methods have also shown promise in the areas of pattern identification and algebraic thinking. Playful patterning exercises enhanced children's recognition, extension, and creation of patterns, skills that predicted subsequent mathematical proficiency. Further evidence that pattern-focused guided play improved children's patterning abilities as well as their general mathematical reasoning skills was provided by Zhang and Quinn (2020).

Several studies have directly compared play-based approaches with more traditional instructional methods. In a randomized controlled trial, Fisher et al. (2022) compared guided play, instruction, and free play conditions for teaching geometric concepts to preschoolers. Children in the guided play condition demonstrated significantly stronger conceptual understanding and knowledge transfer compared to those in direct instruction, despite equivalent instructional time. Similarly, Wickstrom et al. (2019) found that play-based mathematics instruction yielded stronger gains in mathematical problem-solving and positive attitudes toward mathematics compared to worksheet-based approaches.

Other longitudinal studies also provide emerging evidence for the sustained impact of play-based mathematical approaches. Watts et al. (2018) have tracked children who participated in play-based preschool mathematics interventions through fifth grade, finding persistent advantages in mathematical achievement compared to control groups. These effects were mediated by both mathematical knowledge and more general learning approaches, suggesting that play-based interventions foster both content knowledge and learning dispositions. The mechanism through which play-based approaches influence mathematical learning has received increasing research attention. Bustamante et al. (2020) identified several potential pathways, including enhanced engagement, reduced math anxiety, increased intrinsic motivation, and deeper conceptual connections. Vogt et al. (2018) further suggested that play-based learning creates meaningful contexts that support knowledge transfer and application, enabling children to connect mathematical concepts across settings and situations.

IMPLEMENTATION CONSIDERATIONS FOR PLAY-BASED MATHEMATICS

Challenges in Implementation

Implementing play-based mathematics approaches presents several significant challenges for early childhood educators. Teacher knowledge and comfort with mathematical concepts are frequently identified as a primary barrier. Many preschool teachers report feeling underprepared to recognize and extend mathematical thinking that emerges spontaneously during play. At the same time, Norly Jamil (2015) found that educators often missed valuable opportunities to scaffold mathematical learning during playful interactions due to limited confidence in their own mathematical knowledge.

Next, structural constraints within educational settings also pose additional implementation challenges. Allee-Herndon and Roberts (2020) shared about how time pressures, space limitations, and resource constraints complicated efforts to implement sustained mathematical play experiences. These challenges are often compounded by large class sizes and competing curricular demands, creating practical obstacles for educators attempting to implement play-based mathematical approaches.

The perceived tension between play and academic learning represents another significant implementation barrier. Early childhood educators often feel caught between competing demands to prepare children academically while maintaining developmentally appropriate play-based practices (Stipek, 2017). This perceived dichotomy leads some educators to view play and mathematics learning as separate domains rather than complementary approaches.

Strategies for Effective Implementation

Numerous research-based tactics for successfully putting play-based mathematics ideas into practice have been identified. Promising outcomes have been observed from professional development that focuses on identifying and extending mathematical thinking in play environments. According to Norly Jamil (2015), teachers who took part in professional learning communities centred around mathematics showed noticeably better skills in promoting mathematical learning while playing, indicating that focused professional development is an important implementation tactic.

Another crucial implementation tactic is the deliberate structuring of the physical surroundings. According to Hassinger-Das et al. (2018), "mathematical play spaces" with thoughtfully chosen materials and spatial configurations encouraged mathematical inquiry and discourse. Natural chances for mathematical engagement were created by incorporating open-ended materials with mathematical affordances, such as measuring tools, collections of countable objects, and blocks of various sizes and forms.

Incorporating mathematical storytelling has been especially successful in practice. Fleer (2018) created "conceptual play worlds" that created meaningful frameworks for mathematical exploration by integrating mathematical ideas into narrative contexts. In a similar vein, Hassinger-Das et al. (2017) showed how mathematical storybooks could be used as launching pads for entertaining mathematical exercises, offering context and structure for education.

There is potential for overcoming implementation obstacles through collaborative implementation models that involve teaching teams. According to Parks and Chang (2021), teaching teams that planned and thought through play-based math activities together came up with better implementation strategies than teachers who worked alone. By working together, educators were able to overcome implementation issues and develop a common understanding of mathematics in play settings.

Conclusion

The synthesis of research presented in this concept paper highlights the significant potential of play-based approaches for enhancing mathematical skill acquisition in preschool-aged children. The evidence demonstrates that playful learning environments, when thoughtfully designed and implemented, can effectively develop foundational mathematical competencies while simultaneously promoting positive attitudes toward mathematics.

The various approaches discussed (mathematical play environments, embedded mathematics in dramatic play, mathematical games, and playful problem-solving) offer diverse pathways for integrating mathematics into young children's natural play experiences. These approaches are supported by robust theoretical frameworks, including constructivist learning theory, sociocultural theory, and contemporary cognitive development theories, which explain how play-based learning aligns with children's developmental needs and natural learning processes. Empirical evidence increasingly supports the effectiveness of play-based mathematical interventions, particularly for developing number sense, spatial reasoning, and pattern recognition skills. The research indicates that guided play approaches, which balance child agency with intentional learning goals, may be especially effective in promoting mathematical understanding while maintaining children's engagement and interest.

However, successful implementation requires addressing several key challenges, including teacher knowledge and confidence, structural constraints, and perceived tensions between play and academic learning. Promising strategies for overcoming these challenges include focused professional development, thoughtful environmental design, mathematical storytelling, and collaborative implementation models.

As educational stakeholders continue to seek effective approaches for early mathematics education, play-based learning offers a promising framework that honours children's developmental needs while promoting essential mathematical competencies. By bridging the gap between children's natural inclination toward play and foundational mathematical learning, educators can create powerful learning experiences that establish a strong foundation for lifelong mathematical understanding.

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