

Developing Early Childhood Mathematical Thinking Through Play-Based Learning and Assessment

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Abstract: This study investigates the development of mathematical thinking in early childhood through play-based learning and task assessment. Data were collected from observations of block play in a kindergarten setting and a one-to-one assessment interview with a 4–5-year-old child. The findings indicate that block play facilitates the development of spatial structuring, pattern recognition, and early quantitative reasoning, while the assessment interview reveals children’s competencies in number sense, sequencing, and problem-solving. The study also identifies the role of language comprehension in shaping mathematical performance.

Keywords: Early childhood mathematics, Mathematical thinking, Play-based learning, Assessment.

1. Introduction

Early childhood is a crucial period for the development of mathematical thinking, during which children begin to construct foundational concepts of number, space, and pattern through everyday experiences. In contemporary early childhood education, increasing attention has been given to play-based learning as a meaningful context for supporting mathematical development, particularly in relation to children’s spontaneous exploration and interaction with materials. At the same time, assessment practices are essential for making children’s thinking visible and informing pedagogical decisions. This study aims to examine how young children develop mathematical thinking through both play-based experiences and structured assessment tasks. Drawing on observations of block play and an individual assessment interview in a kindergarten setting, the paper explores the ways in which children demonstrate emerging competencies in spatial structuring, number sense, and problem-solving. By linking empirical observations with the Victorian Curriculum and relevant literature, this study contributes to a deeper understanding of how integrated approaches to play and assessment can support early mathematical learning.

2. Methodology

2.1. Observation of Block Play

Observations were made in the kindergarten's outdoor area. The outdoor area is divided into a painting area, a block building area, and kitchen play. The block area is a spacious open area with a large basket in the center filled with blocks of various shapes and colors, including squares, rectangles, triangles, and cylinders.

At first there was only one child in the block area, her name is Abby (all names are alias). Abby was building a castle, she picked all the rectangles, some cylinders and arch shapes from the frames that held the blocks. Then Abby neatly lined up one rectangle after another, making two rows in all, and then took the three extra rectangles and placed them on top of the bottom two rows of rectangles and kept them aligned. Abby placed the arch-shaped block in front of all the rectangles and went back to the basket with the blocks to look for other

blocks. At this time, two children, Billy and Cindy joined in. On enquiry it was learnt that all three children were aged 3-4 years. Billy and Cindy asked if they could join Abby in her castle building activity and Abby immediately said yes. They whispered around the castle Abby had already built, and then Cindy started pulling some squares and cylinders out of the frame, trying to stack two cylinders on top of each other and put squares on top. Abby saw Cindy's movements and suggested that they could compete to see who could stack the blocks higher, so they toppled all the existing buildings, and start to place each block on top of the tower of the previous one and tried to build higher and higher. During the building process, the three children's “towers” kept collapsing, so they would immediately start over and repeat the actions.

2.2. Interview-Based Assessment

This interview consists of some math quizzes with a four-and-a-half-year-old child to analyze and observe the child's mathematical thinking and logic, and to make some suggestions. The child we interviewed is a girl called Nadia (pseudonym). In question F1, she finished all questions very quickly without repeating any instructions. At the beginning of F2, Nadia was asked to place different colored bears in the orientation instructed. After listening to the question, Nadia asked us: “Is it just one?”, and after receiving an affirmative answer, she quickly completed the instruction. In the F2 c-question (match pattern), Nadia used the same colors for the placement (i.e., the first one was green, the second one was yellow, and so on) based on the sample pattern we showed her. In question d (continue pattern), Nadia completed the first two correctly without any questions, but in the third bear, Nadia placed only one blue bear (the pattern called for two), and quickly corrected her placement after we prompted her for an error.

Nadia spent more time on the b problem (match numbers) in F3 than on the other questions, but she still managed to complete the question very well. And when it came to question c-e (order numeral number), after we read the instructions, Nadia's teacher came over and repeated the instructions in a different way. The teacher told us that maybe the kinder kids didn't understand some of the vocabulary on the instructions, so they needed to explain it in a different way. Nadia finished the questions quickly after the teacher

explained them. When it came to question f (show 6 fingers in different ways), Nadia first made a gesture of “6” and we gave her an example so that she could better understand what we meant. Nadia then counted 6 fingers in one way and shook her head when we asked her if there were other ways. In question h (“less than” numbers), Nadia didn't understand the meaning of less. After we replaced the word with “smaller”, Nadia made the question. All other questions were completed quickly and accurately by Nadia, who was able to fully understand the meaning of the number “0”).

3. Results and Analysis

3.1. Mathematical Thinking in Block Play

During free time in kindergarten, the children who are building blocks stack them upwards and say that the competition is to stack them higher and higher. According to Victorian curriculum foundation level B, In Level B, Statistics and Probability, students can recognize “one” and “many” objects and understand “more” in familiar contexts. “more” in familiar contexts [1]. Children in the block group manipulate objects to build towers by using 'more' block sets, knocking down the original blocks and starting again. When children build block towers, they need to recognize and select blocks of different shapes, such as squares, rectangles, triangles, and cylinders. By selecting and arranging these shapes, they unconsciously perform shape recognition and categorization. They involved their concept of height when they competed to see whose tower was taller, more than that, the children move the blocks around to balance them better to stack the towers higher. Children react and respond to objects and experience measured attributes in real-world situations, and students can explore space by moving and changing positions and locations. As a result, children who play with blocks also achieve Victorian Curriculum and Assessment foundation level A standards [1]. According to a study of piaget cognitive theory found that in preoperational stage, children are prone to perceive one object while ignoring another dimension [2]. For example, Abby knows that stacking blocks increases the height of the “tower,” but she does not realize enough to realize that stacking a rectangle on top of a cylinder may cause the “tower” to collapse. But when children keep repeating the action of stacking the blocks high, it will keep reinforcing the concept of shapes in their minds, from helping children form mathematical thinking.

Building blocks help young children in the building of their mathematical knowledge, especially in developing higher order thinking, and contribute to the geometric area of spatial sense in future children [3]. Research has shown that free play where children are given blocks and build designs of their own choosing stimulates imagination and the ability to produce complex relationships without prompting [4]. Spatial Construction Skills and Number Sense in Young Children The above research suggests that spatial construction skills are an important factor in the development of number sense, especially the ability to gain insight into number relationships [5]. The progress of kindergarten children in maths depends largely on the extent to which teaching and learning in schools is successfully related to children's level of understanding [6]. The kindergarten has a block area in the children's outdoor area where the children go to build blocks during free play, in line with Foundation Level B of the Victorian Curriculum. Combined with the above findings, the children's participation in block building is in line with the age-

appropriate curriculum and largely helps the development of mathematical thinking in spatial structures.

3.2. Mathematical Thinking in Assessment Tasks

The purpose of this assessment is to increase children's desire to learn math and to provide a quantitative apples-to-apples measure of young children's math skills, which will make it easier for teachers to adjust their children's instructional programs [7].

In this interview, F1 focused on the children's concepts of number of items and 'more or less'. This part of the task corresponds to foundation level A in the Victorian Curriculum [1]. Students were able to compare the number of teddy bears and were able to increase and decrease, place and move teddy bears. Nadia performed very well in F1, so she achieved Foundation Level A.

Task F2 focuses on children's understanding of location, pattern, and ordinal numbers. F2 The child can match the same familiar objects and is able to manipulate his or her position relative to the objects according to the instructions given by the interviewer. Nadia was able to repeat the teddy bear in F2 according to the sample we gave her and understood orientation instructions such as “blue in front of green” very well. Therefore, Nadia has also achieved Victorian Curriculum Foundation Level B. It should be noted that when carrying out the instruction to continue following the teddy bear pattern we had already placed, Nadia did not do so successfully. “Continuing the pattern” is considered to be a Foundation Level D instruction, so Nadia met the Level B criteria.

F3 examines a child's ability to perceive numbers, match numbers to quantities, sequencing, and one-to-one correspondence. The content examined in F3 matches the content of Victorian curriculum foundation levels C and D. Nadia has also met the requirements for both levels. Although she did not complete the process very well and was missing one way of counting the 6 fingers instruction, Victorian Curriculum did not require the child to use more than two ways to complete it, and there is no requirement for the vocabulary used by the interviewer.

3.3. The Role of Language in Mathematical Understanding

Nadia's ability to understand and follow mostly instructions quickly without repetition shows that she has strong word comprehension skills, which will help Nadia solve complex math problems in the future. The results showed that performance on math's word problems was strongly related to performance in reading comprehension [8]. Nadia's good comprehension helped her to develop a mathematical mind. One study emphasizes the importance of schema and spatial skills in addition to early numeracy, that is the child's students' patterning and analogical reasoning skills, for future equivalence and functional mathematical thinking [9]. Nadia has mastered the law of finding but hasn't quite been able to perpetuate it. However, this skill is moderately developed as the samples who mastered the skill in the above study was 6-year-old. This is evidenced by Nadia's initial mistakes in continuing this pattern, but her ability to correct herself shows potential for growth. Regarding Nadia's need for a separate explanation of the “language of mathematics” from the teacher, it is highly likely that young children's ability to count may indeed be more limited than that of adults, and that in the

absence of language, numbers are approximated, but that accuracy increases with age [10]. In Summary, in this interview, Nadia demonstrates good mathematical thinking and ability for her age, and she has ability to think beyond just repeating instructions.

4. Pedagogical Implications

According to Sarama and Clement [11], encouraging Math Wise Play in Daily Play Parents and teachers watch their children play and make thoughtful interventions. If they don't see any new block structures, they could upload images in the block center or exchange books that show various block structures. Cognitive and Blocks When parents witness children comparing sizes, they could provide a variety of measuring tools, such as rulers, cubes, and thread [11].

4.1. Implications for Educators

Teachers can talk through and clarify concepts when students' arithmetic reasoning stalls. When a youngster raises a question, for instance, regarding the height of a block, the teacher can answer it by asking other students in the class, gathering differing perspectives, and then explaining it to the student [11]. It is crucial for the instructor to be present during block play and to encourage the children's ideas and ways of thinking while they construct their blocks. This entails becoming genuinely interested in the children, lowering yourself to their level, and posing open-ended queries or making observations about the structure [11].

One thing to keep mind is that adults should also verify that they are treating them fairly, including parents and teachers. In the sand, building, and block areas, early childhood educators often spend more time with males than with girls [12]. Adults need to understand that equal time should be spent by boys and girls on developing mathematical thinking. The teacher should apply a range of instructional tactics to help youngsters learn. Nadia can benefit from a smart blend of well-planned activity sequences and integrated methods throughout the day. Successful early childhood instructors focus on children's informal knowledge and daily activities while taking into consideration their cultural backgrounds, language, mathematical concepts, and methods [11].

4.2. Implications for Parents

For Nadia's parents, they can often be found opportunities in math to help their child reflect on and extend the math that occurs in everyday activities, conversations, and play, as well as to build environments that support these activities [6].

Based on these, I thought it would be more engaging to introduce the concept of comparison to children through games. For example, using scales to compare the weights of different items allows children to visualize the magnitude of quantities. Younger children can understand abstract concepts more quickly when they are more concrete and relevant.

5. Conclusion

This study highlights the significant role of play-based learning and assessment in supporting the development of mathematical thinking in early childhood. Findings from both block play observations and the assessment interview demonstrate that young children can develop early competencies in spatial reasoning, pattern recognition, and number sense when provided with appropriate learning environments and support.

The integration of informal play experiences with intentional assessment practices enables educators to better understand children's thinking and to provide responsive pedagogical support. In addition, the findings emphasize the importance of language in shaping children's mathematical understanding. Overall, this study reinforces the value of combining play and assessment as complementary approaches to fostering early mathematical development in educational settings.

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Appendix – Interview Note Paper

MAI Assessment Interview Record Sheet – Detour (for use by Monash pre-service teachers in EDF5829, 2021)

Cr: _____
 Age: 4.5
 Date: 8-13 / 1

Relevant factors (language difficulties, integration/special needs)	<input type="checkbox"/> not attempted
	<input checked="" type="checkbox"/> correct
	<input type="checkbox"/> incorrect

DETOUR FOR YOUNGER CHILDREN	Other relevant notes
<p>E1) Simpler counting tasks/more or less/conservation</p> <p>a. Sort by one attribute (colour) <input checked="" type="checkbox"/></p> <p>b. Count a collection of 4 <input checked="" type="checkbox"/></p> <p>c. Identify one group out of two as 'more' <input checked="" type="checkbox"/></p> <p>d. Make a set, cardinal number 5 <input checked="" type="checkbox"/></p> <p>e. Conserve number: (i) Teddies moved <input checked="" type="checkbox"/> (ii) Hiding <input checked="" type="checkbox"/></p> <p>f. How many blue teddies (5+3) screened <input checked="" type="checkbox"/></p> <p>g. How many blue teddies (5+3) not screened <input checked="" type="checkbox"/></p>	<p>quiet</p> <p>→ no first, then ✓. quick pick up, → counting correctly. thinking.. need to count and quote</p> <p>when green, ask 'just one?'</p> <p>→ use blue first. put under the sample pattern. yellow second. yellow green.</p> <p>↓ in third, she put wrong but modify later.</p> <p>→ quiet reaction.</p> <p>Her teacher come and help she to understand the question then she give answer without more guidance.</p> <p>don't understand of 'less' → '0 is smaller than 3'.</p> <p>just answer question without saying other things.</p>
<p>E2) Location/pattern/ordinal number</p> <p>a. Follow directional language instruction beside <input checked="" type="checkbox"/> behind <input checked="" type="checkbox"/> in front of <input checked="" type="checkbox"/></p> <p>b. Name colour pattern <input checked="" type="checkbox"/> yellow ✓ blue ✓</p> <p>c. Match pattern <input checked="" type="checkbox"/></p> <p>d. Continue pattern <input checked="" type="checkbox"/> say no first then green yellow green.</p> <p>e. Explain pattern <input type="checkbox"/> 'I can think'</p> <p>f. Ordinal number (i) 3rd <input checked="" type="checkbox"/> blue (ii) 5th <input checked="" type="checkbox"/> green</p>	
<p>F3) Subitising/matching numerals to quantities/ ordering/one-to-one correspondence/part-part-whole</p> <p>a. Recognise quantities without counting (subitising)</p> <p>2 <input type="checkbox"/> 4 <input checked="" type="checkbox"/> 0 <input type="checkbox"/> 5 <input type="checkbox"/> 3 <input type="checkbox"/> 0 <input checked="" type="checkbox"/> 2 <input checked="" type="checkbox"/> 3 <input type="checkbox"/></p> <p>b. Match numerals to quantities</p> <p>2 <input checked="" type="checkbox"/> 4 <input checked="" type="checkbox"/> 0 <input checked="" type="checkbox"/> 3 <input checked="" type="checkbox"/> 9 <input checked="" type="checkbox"/> 4 <input checked="" type="checkbox"/> 3 <input checked="" type="checkbox"/></p> <p>c. Order numeral cards 1-5 <input checked="" type="checkbox"/> biggest → smallest</p> <p>d. Order numeral cards 1-9 <input checked="" type="checkbox"/></p> <p>e. Order numeral cards 0-9 <input checked="" type="checkbox"/> She know 0 least.</p> <p>f. Show 6 fingers <input checked="" type="checkbox"/> gesture</p> <p>another way? <input checked="" type="checkbox"/> another way? <input type="checkbox"/> need help.</p>	
<p>g. Identify 'more than' numbers</p> <p>(i) 1 more 4 <input checked="" type="checkbox"/> (ii) 1 more 10 <input type="checkbox"/> (iii) 1 more 15 <input type="checkbox"/></p> <p>h. Identify 'less than' numbers</p> <p>(i) 1 less 3 <input type="checkbox"/> (ii) 1 less 12 <input type="checkbox"/> (iii) 1 less 20 <input type="checkbox"/></p> <p>i. One to one correspondence of straws and cups prediction <input checked="" type="checkbox"/> correct sharing <input checked="" type="checkbox"/></p> <p>j. Order shortest to longest candles (with 3) <input checked="" type="checkbox"/></p> <p>k. Order shortest to longest candles (with 4) <input checked="" type="checkbox"/></p>	