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A Proposed Early Childhood Mathematics Program in Japan

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Abstract

In recent years, the importance of early childhood mathematics education has become increasingly evident globally. Despite its acknowledged significance in Japan, the importance of mathematics is not always recognized. However, both exposure to mathematics from early childhood and the experience of learning and enjoying this subject enhance the future enjoyment and significance of learning mathematics. This study proposes an early childhood mathematics program that connects preschool education in Japan—which currently lacks a formal mathematics curriculum—with elementary school education. Our program framework was developed with reference to Wiles' model based on the following three elements: the five key areas of focus in Japanese kindergarten education, children's basic mathematical competencies developed in Japanese elementary schools, and the mathematical literacy Japanese children should acquire. To test the effectiveness of our proposed program, we assessed the mathematical performance of 150 five- and six-year-old children who participated in both the pre- and post-surveys at 23 private preschools in the Tokyo metropolitan area. The results indicate a significant increase in the test scores of the participating children (N = 150) after taking part in playful mathematical activities within our proposed program, with the children showing an increased ability to propose their own ideas. This suggests that participating in such an early childhood mathematics program can build a foundation for learning mathematics in elementary school as well as make future mathematics learning meaningful, even if the subject is learned informally in preschool.

Keywords

Preschool, Mathematics Program, Program Framework, Playful Mathematical Activities, Elementary School, Japan

1. Introduction

Recognizing the increasing global importance of mathematics and technology, numerous researchers have focused on early childhood mathematics teaching and learning for preschool and younger elementary school students (Duncan et al., 2007: pp. 1428-1446; Presser 2015: pp. 399-426; Gasteiger & Benz, 2018: pp. 109-117; Björklund et al., 2020: pp. 607-619; Clements et al., 2023). However, few studies have focused on this subject in Japan. The foundational research that informed early childhood education in Japan considered preschool children to have limited cognitive abilities; additionally, owing to a unique sociocultural perspective, Japanese policymakers, curriculum developers, and educators have concentrated less on mathematics education in preschool than in elementary school (Inagaki, 1996: pp. 59-86; Gelman, 2006: pp. 147-166). Consequently, scant scholarly research on preschool mathematics teaching and learning exists in Japan because of the lack of a coordinated national early childhood mathematics program, which is defined as a series of playful mathematical activities and includes objectives, mathematical content, a classroom environment, activity procedures, and evaluations. An additional factor is the lack of emphasis on structured mathematics instruction in the classroom, as stressed by Whitburn (2003: pp. 155-179).

Contemporary international studies on teaching and learning have demonstrated that younger children have sophisticated mathematical minds and a natural eagerness to engage in various mathematical activities (Brandt, 2013: pp. 227-248; English & Mulligan, 2013: pp. 1-4). Furthermore, they can develop complex mathematical knowledge and abstract reasoning significantly earlier than previously believed (Nakamichi, 2005: pp. 1-11; Gelman, 2006: pp. 147-166). Thus, experts on the transition from preschool to elementary school have proposed various types of elementary school curricula and programs (McClelland et al., 2006: pp. 471-490; Romano, 2010: pp. 995-1007; Jang, 2024), particularly in mathematics (English & Mulligan, 2013: pp. 1-4; Clements & Sarama, 2014; Perry et al., 2015: pp. 1-12; Mulligan et al., 2020: pp. 663-676).

However, Matsuo (2013: pp. 245-254) noted that Japanese teachers do not concentrate on teaching elementary school mathematics in preschool. One exception is Funakoshi (2011: pp. 1-15), a Japanese mathematician and educator who proposed a preschool curriculum based on teaching elementary school mathematics as a subject rather than embedding mathematical components into daily preschool play activities, which is considered preferable in Japan (MEXT, 2018). Recently, the expert panel of Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) proposed a bridge program between preschool and elementary school (MEXT, 2021). Local governments are now attempting to implement this program; however, it addresses general education, and mathematics education specialists were not involved in the program development.

The foundation for elementary school mathematics lies in the various play activities through which children learn in preschool (Vygotsky, 1978; Froebel, 2015). Play activities in early childhood learning are ubiquitous across cultures, not only in mathematics, but also in other subjects. Studies have demonstrated that embedded mathematical activities can facilitate learning in early childhood (Hirsh-Pasek et al., 2008; van Oers et al., 2010: pp. 23-37; Thomas et al, 2011: pp. 69-75; Fisher et al., 2011: pp. 342-360; Cohrssen et al., 2016: pp. 159-189; Björklund et al., 2018: pp. 469-480; Zhang et al., 2024: pp. 765-780).

In this study, we examine whether playful mathematical activities can enrich children's interest in learning elementary mathematics. Moreover, we complete the foundation for learning after elementary school by connecting these playful activities with mathematics teaching and learning in elementary school. The playful activities are developed based on our proposed mathematics program framework and differ from the structured activities conducted in elementary school, such as solving mathematical problems, reflecting on the solution, and forming and systematizing concepts. Our proposed early childhood mathematics program aims to connect preschool education with elementary school mathematics education. To examine its effectiveness, we tested the program with Japanese children aged five and six years who have not formally learned mathematics in preschool. The construction of the program framework and development and implementation of a mathematics program based on this framework can provide high-quality early childhood mathematics education. Accordingly, we aim to answer the following research questions:

1) Which elements in an early childhood mathematics program lay the foundation for post-elementary school mathematics education?

2) How does our early childhood mathematics program promote young children's mathematical performance in the absence of a formal early childhood mathematics education curriculum?

The research process is presented in **Figure 1**. First, we review preschools in Japan. Next, referring to Wiles' (2009) curriculum development process, we present the framework of our proposed early childhood mathematics program, indicating some of the mathematical education problems. The framework is based on the five key areas of children's social development in Japanese preschools (i.e., health, human relationships, environment, language, and expression) (MEXT, 2018), basic mathematical competencies that students are expected to acquire in elementary school in Japan (MEXT, 2017), and mathematical literacy (Science for All Project, 2008). Based on this framework, we then propose *sugoroku* (similar to Western backgammon) as an example of proposed playful activities within the developed program. Next, we present the results of testing the effectiveness of the entire program with a sample of preschool students in Japan. We conclude with a discussion of our survey results and the study's implications and limitations.

This study contributes to the mathematics education literature by presenting a program that uniquely balances the sociocultural aspects of Japan's preschool curriculum with the country's elementary school curriculum. It also assesses whether such a program used by teachers inadequately trained for teaching mathematics in early childhood is effective for children who do not formally learn mathematics in preschool.

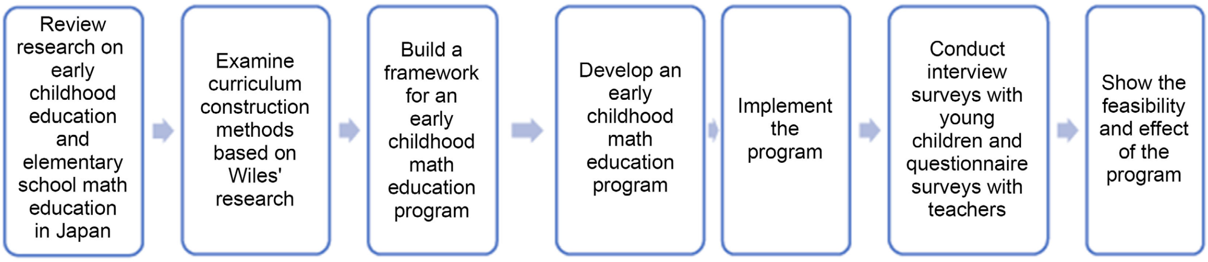


Figure 1. The research process.

2. Early Childhood Education in Japan

Three main types of preschools exist in Japan—kindergartens (*yochien*), nursery schools (*hoikuen*), and mixed schools (*kodomoen*). Children usually attend preschool until the age of six. This study focuses on kindergartens and mixed schools because almost the entire enrollment of young children in both kindergartens and mixed schools is based on the kindergarten national curriculum. According to the *School Basic Survey*, in 2023, 758,000 and 862,000 children attended Japanese kindergartens and mixed schools, respectively (MEXT, 2023).

As Whitburn (2003: pp. 155-179) noted, the philosophy of preschools varies by facility. However, a child-centered approach—influenced by Western approaches such as the Reggio Emilia Approach®, Montessori Method, and developmentally appropriate practices—remains the prevailing philosophy in Japanese preschools (Research Center for Child and Adolescent Development and Education, 2004). The MEXT's *Course of Study for Kindergartens* (MEXT, 2018), Japan's national curriculum standard for kindergartens, states that "Education during childhood is extremely important for cultivating a foundation for lifelong character building." It also states that kindergarten curricula should be designed to "cultivate the foundation for compulsory and further education" (MEXT, 2018). These statements emphasize kindergarten education's focus on children's social development and on laying a foundation for their elementary school education rather than concentrating on school subjects, particularly mathematics.

As mentioned above, kindergarten education in Japan integrates five interrelated key areas of children's social development: health, human relationships, environment, language, and expression (MEXT, 2018). This focus facilitates children's acquisition of various experiences. The curriculum content is delivered comprehensively through specific activities developed according to children's learning environment and development stage. This differs from elementary school education in Japan, where the curriculum comprises separate subjects, such as Japanese, mathematics, and social studies (MEXT, 2017). For example, in kindergarten, the key area of environment is integrated into mathematical activities "to enrich children's understanding of the nature of things, the concepts of quantities, written words, etc. through observing, thinking about and dealing with surrounding things and experiences" (MEXT, 2018). MEXT (2018: p. 7) adds, "Children should be encouraged to place importance on their experiences based on the necessities of their own lives so that interest, curiosity and an understanding of the concepts of quantities and the written word can be fostered".

Nonetheless, extant literature does not sufficiently examine how kindergarten education in Japan lays a foundation for children's mathematical learning in elementary school. In theory, Japanese kindergarten teachers focus on both supporting children's social development and laying a foundation for learning mathematics in elementary school, given children's needs and interests. However, they are not clearly shown how to build a foundation for understanding the concepts of numbers and geometric figures. Accordingly, when embedding mathematics into everyday activities in preschool, teachers are expected to integrate mathematical content into other areas while considering children's cognitive and affective development. However, Matsuo and Nakawa (2021: pp. 345-348) found that Japanese preschool teachers seldom teach children about numbers, quantities, or geometric figures to develop children's interest in the mathematical aspects of their activities.

3. Proposed Early Childhood Mathematics Program

Wiles' (2009) curriculum development theory continues to be cited in many recent curriculum development studies (Albayrak & Akgün, 2022: pp. 161-182; Algani & Eshan, 2023). Hence, Wiles' model was useful for developing our early childhood mathematics program, as it enabled us to focus on constructing a new program for Japanese preschools that meets the changing needs of those preschools, elementary schools, and society. Wiles (2009) noted that scholars consider the concept of a curriculum from four main perspectives: as a subject or series of written documents, such as books and syllabi; in terms of school experiences; as a dynamic plan tied to the goals and related objectives of the school program; and in terms of outcomes or results.

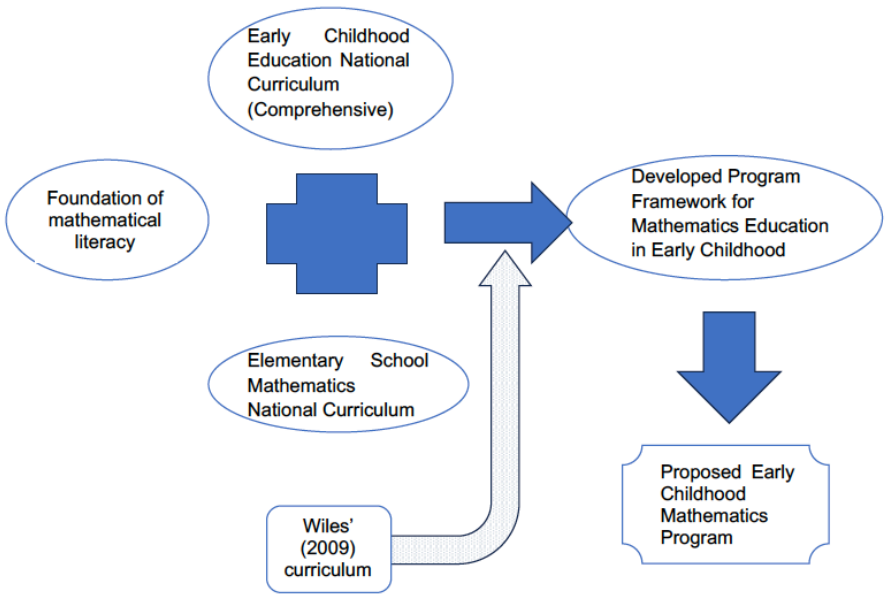


Figure 2. How we created our early childhood mathematics program.

Our proposed program was designed to create a foundation for mathematics education at the preschool level, leading to higher-quality elementary school mathematics education as well as achieving the goals and objectives of the school curriculum, resulting in successful teaching and learning. Our program was based on a framework built by integrating the kindergarten curriculum, which does not explicitly include mathematics, into elementary school mathematics curricula (**Figure 2**). Therefore, following Wiles (2009), our early childhood mathematics program was developed from the perspectives of goals and objectives. However, standards, content, and lesson plans will be added, as they are necessary to reinforce each playful mathematical activity.

3.1. Goals

Our program relates the five key areas of kindergarten education to elementary school mathematics education as well as the mathematical competencies essential for elementary school students. According to McMahon and Whyte (2020: pp. 48-76), the PreK-3 curriculum relies on terms like continuity, coherence, and alignment, but studies in this area tend to consider these concepts in different ways. Our program is designed to maintain continuity and alignment by maintaining an awareness of the five key areas of kindergarten education while connecting them to the elementary school mathematical content. Additionally, an individual's mathematical literacy, including basic mathematical knowledge, is related to mathematical content and methods to meet the coherence requirement. Moreover, since the program's basic idea is the comprehensive achievement of early childhood education goals by focusing on teaching through play as a spontaneous activity for young children (MEXT, 2018), the playful mathematical activities that are concretized based on the proposed program also incorporate the perspective of Japanese play (e.g., competitions, games, puzzles, and personal creativity).

3.2. Objectives

To create our early childhood mathematics program, we adopted two perspectives: 1) social and emotional development and 2) mathematical literacy. Therefore, the program framework was established by considering the five key areas of the kindergarten curriculum in Japan, basic mathematical competencies in elementary school, and Japanese mathematical literacy proposed by the literature (Matsuo, 2014: pp. 169-176).

First, the program content integrated the five key areas of the Japanese kindergarten curriculum with each child's social and emotional development. In particular, the area of environment is connected to elementary school mathematical content. In this area, teaching should relate to mathematical content, particularly quantities, and diagrams (MEXT, 2018); however, since this content is vague, it is not possible to connect it to concrete play activities. The area of health involves selecting an activity corresponding to elementary school mathematical content. In Japan, a strong relationship exists between mathematics and sports activities (e.g., counting points in sports games). Moreover, sports may be considered a form of play that helps children maintain good mental health. However, not all early childhood programs include sports that help children maintain good physical health. Therefore, in this study, health is understood as both physical and mental health, including the consideration shown and joy experienced in relationships with others. The areas of language and expression involve the methodological elements necessary to learn mathematics in elementary school, while the area of human relationships involves all of children's activities in preschool. If the proposed program does not correspond to these five key areas, implementing it in preschools in Japan will be impossible. Therefore, this is a condition that will increase the feasibility of our study.

Second, we considered students' basic mathematical competencies in elementary school. When constructing a school curriculum, the evaluation criteria of a lesson or learning unit include knowledge and understanding of numbers, quantities, and geometric figures; mathematical thinking; mathematical skills; and interest, willingness, and a positive attitude toward learning mathematics (MEXT, 2017). Therefore, the aims and evaluation criteria of mathematics education in elementary school indicate where mathematics learning in early childhood will lead, highlighting the importance of creating these programs.

Third, we considered mathematical literacy (Botha & Reyneke, 2013: pp. 160-171). The preschool mathematics curriculum in Japan relates to future mathematics learning and teaching in elementary schools for coherence. Thus, we considered how the program should relate to mathematical literacy. According to the MEXT's Mathematical Science Expert Committee, children require basic knowledge of science and technology, particularly mathematical knowledge (Science for All Project, 2008). Learning the basics of mathematics before entering elementary school is grounded in the idea that mathematical literacy is important for Japanese children's future. To develop our program, we considered the content of mathematical learning, including numbers, quantities, and geometric figures; variations and relations; data; and probability. These are areas similar to those of the Organisation for Economic Co-operation and Development's PISA assessment of the four major concepts of mathematical literacy (OECD, 2000). We also considered two perspectives on applying mathematical methods: using mathematical language and mathematical problem-solving. The link between Japanese children's early childhood learning and their lifelong learning will be clarified through the mathematical literacy that they should acquire and by designing programs based on this goal, because implementing such programs will give them the opportunity to understand how to learn.

We created our early childhood mathematics program based on the above considerations. In the area of health, we selected the theme of preschool children's activities related to elementary school mathematical content (e.g., sports events and rulemaking in a game). The area of expression encompasses mathematical problem-solving, where children use various expressions related to mathematics. The area of language is not only related to representing children's thinking using words or sentences but also to communicating with others using words or sentences. Finally, the central part of the framework is embedded in the areas of environment and human relationships. The environmental content in the *Course of Study for Kindergartens* (MEXT, 2018) is directly related to mathematics, while children learn various activities through human relationships. Figure 3 (modified from the figure presented in Matsuo (2016: pp. 299-306)) presents the framework used to construct our early childhood mathematics program.

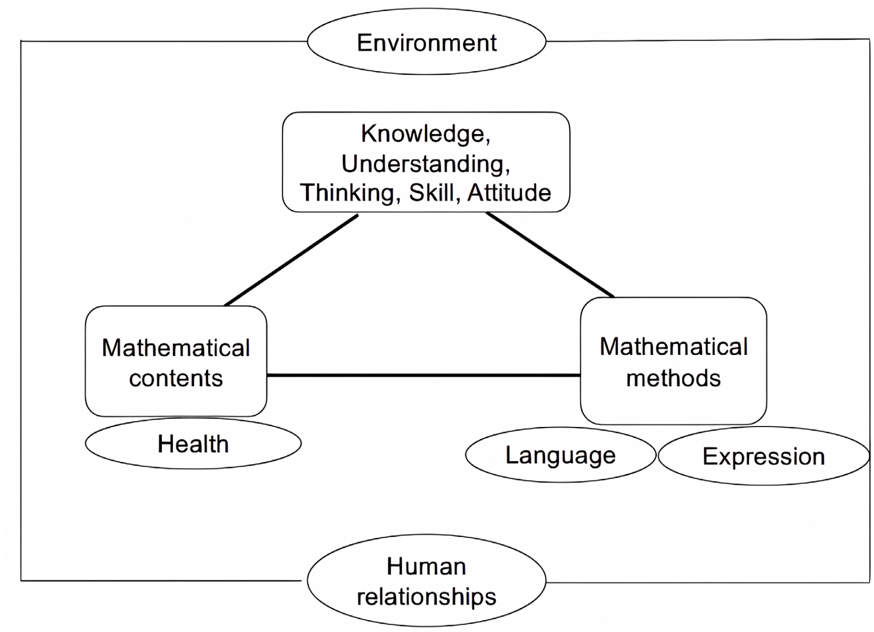


Figure 3. Framework for constructing our early childhood mathematics program.

3.3. Standards and Contents

Our proposed program for playful mathematical activities was related to the Grade 1 learning content in elementary schools in Japan. This content includes counting, subitizing, adding and subtracting, recognizing ordinal and cardinal numbers, measuring and comparing length, recognizing shape patterns, and embedding. Table 1 includes the standards to which each activity aspires.

Table 1. Content of the early childhood mathematics program.

S/N	Name of the activity	Mathematical content	Standards	Objectives	Lesson plan
1	Let’s go to the fruit/ vegetable shop	・Recognizing ordinal numbers ・Recognizing cardinal numbers	・Observing the difference between ordinal and cardinal numbers	・Children are expected to use the skills and fundamental ideas related to numbers, especially ordinal and cardinal numbers, in a given context. ・Children can communicate with each other through their relationships.	1) There is a shop where fruits and vegetables are arranged in a cross formation. 2) Teachers ask children where a certain fruit or vegetable is located, asking them to describe the direction and cardinal/ordinal numbers. The teachers also tell them the location of a certain fruit/vegetable and ask them to identify the fruit/vegetable. 3) The game is repeated multiple times.

Continued

2	Rabbit and Turtle	・Counting ・Subitizing ・Adding ・Subtracting	・Subitizing the number of dots on the dice ・Counting numbers up to 6 ・Adding and subtracting numbers (if possible)	・Children are expected to use the skills and fundamental ideas related to numbers, counting, addition, and subtraction in a given context. ・Children can communicate with each other through their relationships. ・Children can read the number of dots on the dice, say the number, count, point to the number, and perform these mathematical expressions through gestures, speech, and demonstrations of interest.	1) Narrate the story of the "Rabbit and Turtle" and let the children understand the story's context. 2) Show *Sugoroku* (a Japanese board game similar to Western backgammon) with points ranging from 1 to 20. 3) Two teams can compete with each other. Both teams start at 10 and move in different directions. The game ends when one team reaches the home of the rabbit or the turtle at 1 or 20.
3	Which is longer?	・Length ・Measurement	・Comparing the length ・Measuring length using different materials	・Children are expected to use the skills and fundamental ideas related to comparing and measuring in a given context. ・Children can communicate and discuss with each other when measuring things.	1) Teachers show objects (e.g., pencils) and ask children to compare their lengths. 2) Task children to compare the length of the pencils drawn on a paper through direct comparison. The children are given a clip, which they can use for indirect comparison. 3) Children are asked to measure the length of different things (e.g., a desk, paper, and a snake made of clay).
4	Let's make a fish!	・Embedding ・Disembedding	・Combining different shapes to make another shape ・Knowing a variety of shapes	・Children are expected to use the skills and fundamental ideas related to embedding and disembedding, and manipulate shapes. ・Children can talk and present in front of others to show the product.	1) Distribute the mounts to embed the color plates (e.g., right-angled isosceles triangles, squares, parallelograms, and trapezoids) and color plates to make the fish shape. 2) Line up the colored plates and fit them into the fish-shaped frame (embedding/disembedding). Children can create various patterns if they wish. 3) Fix one pattern of a fish and make a presentation, paying extra attention to patterns, colors, and so on. They can also present their impressions.
5	Let's plant a bell pepper!	Planting bell pepper seedlings and creating a stamp using the cut surface of vegetables	・Designing shape ・Classifying ・Measuring length ・Knowing quantity relationships	・Children can design some shapes using stamps made from cut vegetables. ・Children are expected to measure length. ・Children are expected to compare different quantities.	1) Make plans to plant vegetables. 2) When engaged in planting activities, children focus on shapes, numbers, and measurement. When planting vegetables, children can measure the distance between vegetables and count the number of seeds/plants. 3) When they see the growing plants, they can compare the size of each plant by direct/indirect comparison. 4) When finishing the activity, they can make a stamp using the cut surface of vegetables and then use the stamp to create geometrical patterns on a piece of paper.

We concretized the early childhood mathematics program comprising the five activities shown in **Table 1**. Each activity within the program includes mathematical content: counting, subitizing, recognizing ordinal and cardinal numbers, adding and subtracting, measuring and recognizing shape patterns, and comprehensive contents.

3.4. Lesson Plans

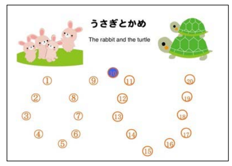
Our program's lesson plans were developed according to the following: structure of the learning units; theme of the activity; preparation and material; objective of the activity; method of the activity; rules and procedures; questions to confirm understanding, reflection, and connection to mathematics learning in elementary school; desired activity for younger pupils; and relation to the proposed program. The plans were reviewed following trials in preschools.

3.5. Example of a Learning Unit in Our Proposed Early Childhood Mathematics Program

In Grade 1 of elementary school in Japan, six-year-old children begin learning the basic concepts of numbers. According to interviews with preschool teachers (Matsuo & Nakawa, 2021: pp. 345-348), many people in Japan believe that younger children cannot count or add numbers before entering elementary school. However, inside and outside preschool, children learn about using numbers in their daily lives, such as by counting concrete objects, reading numerals, playing monetary activities (e.g., buying things and paying money), and understanding which object relates to another. In the first semester of Grade 1, children are expected to learn how to count to 10, read and write, understand the structure of numbers, and use numbers in reference to concrete and semi-concrete objects. In the area of numbers, we developed a learning unit on counting, subitizing, adding, and subtracting. Consequently, we created a backgammon game with 1 to 20 points as an example of a culturally specific preschool play activity based on our program framework. According to Vygotsky (1978), the primary activities of young children from about three years of age are characterized as playful activities; therefore, the curriculum in the early years is a play-based curriculum. The learning unit structure is presented in **Table 2**. In the learning unit, activities can be improved by modifying or developing some of them. Further, tailoring activities for four-year-olds and other younger children is considered desirable for these pupils. Based on the recommendations shared in this study, we expect teachers to consider various possibilities of customizing the way the game is played according to the children's actual situation.

The program we propose includes three elements embodied in the Rabbit and Turtle activity. First, it relates to the five areas emphasized in Japanese kindergarten education, as follows: Mathematical learning will take place in the area of environment because it involves numbers and calculations. It will also take place in the area of expression, because of the various expressions related to mathematics

Table 2. Example of the structure of the learning unit: rabbit and turtle.

Learning unit	Example: Rabbit and Turtle
1. Theme of the activity	This activity requires dividing the students into Rabbit and Turtle teams, and having them play a backgammon game in which one team goes from 10 to 20 and the other team from 10 to 1. The students place magnets on the game sheet of the whiteboard or blackboard in place of a rabbit and a turtle. This game is based on the original ideas of a preschool teacher. 
2. Preparation and material	The activity consists of a traditional number of dice rolls (to practice reading the number of dots from 1 to 6), a masking tape, the backgammon game, and pictures of a rabbit and a turtle.
3. Objective of the activity	To play the game, the children are required to count up and down, perform simple addition and subtraction (numbers from 10 down to 1 in the first class, numbers from 10 up to 20 in the second class), and read the number of dots on the dice.
4. Method of the activity	The children take turns looking at the dice and read the number of dots. The teacher checks whether they are counting up or down. The teacher focuses on situations in which every child is engaged in an activity.
5. Rules and procedure	1) In the Rabbit and Turtle game, the teacher states, "There is a rabbit and a turtle. After playing together, they return to their house. Using the dice, which one of them can return home faster? Let's split into rabbit and turtle groups." One by one, the children go to the front and, roll the dice and then tell the teacher the numbers on the dice. The child then moves forward or backward as many times as the number on the dice. 2) Divided into Rabbit and Turtle teams, the children take turns rolling the dice and moving the tops of the frames one by one. The order of the children is from oldest to youngest. 3) The game is won when one of the players reaches the mountain or sea (after passing through points 1 and 20, respectively). When the mountain and sea are close, the teacher asks, "With which number do you think the rabbit (turtle) will win?" The teacher gives them a chance to think about how many more dots on the dice are needed to reach the goal and what the number of dots is. 4) Playing with older children: If the children return to 10 several times and the teacher finds that they are comfortable with the rules of the game, they can end the game quickly by changing the so-called special rule to allow them to advance the number of dice rolls twice (i.e., two dice rolls). 5) Playing with younger children: Some younger children may say 50 instead of 15 or may only be able to move one at a time; teachers should be patient.
6. Rules and procedure	Teachers ask the children what they think about the game. The teacher also checks how well the children can read the number of dots on the dice and the numbers from 1 to 20 written on the game sheet.
7. Reflection	If children's performance does not improve, teachers consider the reasons for their performance and think about how to improve it in the future. Teachers also observe and reflect on the differences in the results for both older and younger children.
8. Connection to mathematics learning in elementary school	The concepts of numbers and addition and subtraction are introduced in Grade 1 of elementary school (MEXT, 2017).
9. Desired activity for younger pupils	Some children may not know numbers up to 20. In this case, they are taught to count up and down by one and move the frame using their fingers. Even if they do not know the numbers, teachers ensure that they can participate in the game in a fun way so that the game does not become a burden for young children.
10. Relation to the proposed program	The learning unit can foster knowledge, understanding, thinking, skills, and attitudes regarding the sequence and magnitude of numbers from 1 to 20 and simple arithmetic. Children are expected to use the skills and fundamental ideas related to numbers, counting, addition, and subtraction in a given context. In the area of human relationships, as there are multiple participants, children can communicate with each other through their relationships, such as cooperating and competing with each other. In the areas of health, language, and expression, children can read the number of dots on the dice, say the number, count, point to the number, and express these mathematical concepts through gestures, speech, and demonstrations of interest.

in play, for instance, if you move three places from 2, you can reach 5. It will also occur in the area of language because of the inclusion of games that use mathematical terms. Furthermore, regarding the area of human relationships, considering that children participate in games by cooperating with their peers on the same team or competing with other teams, children's social skills can be developed. In addition, concerning the area of health, by having fun while playing games, children can maintain their mental health and realize learning. Second, the program is designed to help students develop a foundation for the mathematical skills they will learn in elementary school, including the basic competencies of numbers, counting, subitizing, adding, and subtracting. Third, activities are designed so that students acquire the mathematical literacy necessary to live as Japanese citizens; this includes the knowledge and skills related to numbers, calculations, and mathematical problem solving, which are required to achieve the goals of the game.

4. Research Design

4.1. Sample

To test the effectiveness of our proposed program, we first assessed 379 five- and six-year-old children at 23 private preschools in the Tokyo metropolitan area (pre-surveys hereafter). We then assessed 169 five- and six-year-old children (post-surveys hereafter). Although we had originally planned to survey all 379 children in the pre- and post-surveys, there were many absences. We were unable to conduct activities on the dates and times when many young children could participate, and the COVID-19 pandemic resulted in a difference in the number of pre- and post-survey participants. Twenty-three preschools participated in both the pre- and post-surveys. We analyzed the assessment data for the 150 participants who participated in both the pre- and post-surveys. The ages of the children ranged from 5 years and 1 month to 6 years and 2 months. All participants lived in Tokyo and the surrounding areas and came from middle- and upper-middle-class families in Japan. Altogether, 75 boys and 75 girls participated in the study. We did not have access to academic performance records for each school, as unlike preschools in other countries, most preschools in Japan lack subject-based learning.

In addition, we surveyed the 39 preschool teachers in charge of implementing the program. The survey (presented via a Google Form) asked for specific examples of observed behavioral and emotional changes in children after the implementation of this program, selected from a list of options. The 379 parents of the children participating in the program and 39 teachers were informed about the project as well as its related studies and aims, data collection processes, use of the results, and their rights as participants (e.g., guaranteed anonymity and secure storage of their data). They were asked to provide informed consent, which they could withdraw without explanation. The protocol was approved by the Ethics Committee of Chiba University, Faculty of Education (No. 126).

4.2. Data Collection

The verbal pre- and post-assessments were conducted in June 2021 and March 2022, respectively. They were both conducted in the preschools, mainly by the class teacher. Participation was voluntary, and no child refused to participate. All assessments were administered individually. The data were aggregated and analyzed, with each teacher entering the results into Google Forms. The assessment content was limited to the basic skills Grade 1 students need to learn mathematics in elementary school. The assessments comprised 16 questions, and the interview responses were scored; children obtained 1 point for every correct response and 0 points for incorrect responses. The total possible score of the question items for each pre- and post-assessment was 16 points.

5. Results and Discussion

We calculated the total scores of the 150 children participating in the pre- and post-surveys as well as the mean percentage and standard deviation. The mean pre-survey (post-survey) score was 11.27 (13.40). The paired t-test results showed that the improvement was statistically significant ($p < 0.01$, $t = -11.379$). **Table 3** presents the assessment items and mean percentage of correct answers for the pre- and post-surveys.

According to Welch's t-test results, the scores on multiple items improved between the pre- and post-surveys. Specifically, the results of Q2.1 and Q2.3 (marked with one asterisk in **Table 3**) showed a statistically significant improvement at the 5% level, and those of Q1, Q2.5, Q2.6, Q4, Q5, Q6.2, Q7.1, Q7.2, Q8, and Q9 (marked with two asterisks in **Table 3**) showed a statistically significant improvement at the 1% level. We inferred that the improvement reflected the significant enhancement of the children's performance between the pre- and post-surveys. Furthermore, the post-survey results demonstrated that the children's mathematical performance improved significantly from the pre-survey (**Table 4**), indicating the effectiveness of the proposed program. By area, the children significantly increased their scores regarding numbers, calculation, quantities, measurement, and shapes by participating in the program. Therefore, implementing the proposed program led to a transformation in mathematical performance (i.e., a significant increase in scores) for the young participants, indicating the program's effectiveness. This result is consistent with that of previous research showing that a well-defined, age-appropriate curriculum based on playful learning may strengthen children's preschool mathematics skills in a play-based early childhood education curriculum context (Størksen et al., 2023: pp. 36-46).

In addition, we asked the teachers to provide us with specific examples of observed behavioral changes in the children after the implementation of the program. In response to the question, "Please give specific examples of behavioral changes in children that you have observed through the implementation of the program," 17 teachers (43.6%) stated that the children could do simple calculations, while 13 (33.3%) stated that the children could count. These results suggest that, from the teachers' perspective, the program effectively enhanced the children's abilities related to numbers and calculations. In response to the question, "Can you give us specific examples of psychological changes in children that you have seen through the implementation of the program? (multiple answers allowed)," 18 teachers (46.2%) selected, "They have become interested in various things," while 12 (30.8%) said, "The children have been able to work on it in a creative way." Thus, many teachers recognized the children's mental development. Consequently, the children's participation in the program improved not only their skills, but also their interest in mathematical activities. They could also propose their own ideas rather than simply imitating what they were told.

Table 3. The assessment items and percentage of correct responses.

Item	Question	Intent of the problem	Pre	Post
			Mean score (Standard deviation)	Mean score (Standard deviation)
Q1**	Count aloud the number of marbles indicated.	The number of objectives studied in the first six months of Grade 1 is 20.	52.67% (0.50)	94.00% (0.24)
Q2.1*	Read out the number of 1s on the die.	Children subitize the number of dots on the die.	97.33% (0.16)	100% (0.00)
Q2.2	Read out the number of 3s on the die.		96.67% (0.18)	99.33% (0.08)
Q2.3*	Read out the number of 5s on the die.		90.67% (0.29)	96.67% (0.18)
Q2.4	Read out the number of 2s on the die.		97.33% (0.16)	98.67% (0.12)
Q2.5**	Read out the number of 4s on the die.		90.00% (0.30)	98.67% (0.12)
Q2.6**	Read out the number of 6s on the die.		90.67% (0.29)	98.67% (0.12)
Q3	Take the number of marbles corresponding to the number 6 on the die.	Children determine the number of marbles by subitizing.	91.33% (0.28)	95.33% (0.21)
Q4**	Calculate the sum of two dice (5, 3).	Children add two numbers.	68.00% (0.47)	84.67% (0.36)
Q5**	Find the difference between two dice (5, 3).	Children subtract one number from the other.	30.67% (0.46)	64.67% (0.48)
Q6.1	Show three blocks from the top of a tower of blocks.	Children understand the concept of a cardinal number.	60.67% (0.49)	62.67% (0.49)
Q6.2**	Indicate the third block from the bottom of the tower of stacked blocks.	Children understand the concept of an ordinal number.	66.00% (0.48)	80.00% (0.40)
Q7.1**	Find the longest of four pencils with slightly different lengths.	Children compare the lengths of pencils.	70.67% (0.46)	90.00% (0.30)
Q7.2**	Look at the picture of four pencils of slightly different lengths and answer in order of length.	Children compare the lengths of pencils without moving them.	40.00% (0.49)	58.67% (0.49)
Q8**	Based on this pattern of shapes, answer the following.	Children identify a rule in the repeating pattern.	70.67% (0.46)	83.33% (0.37)
Q9**	When fitting the appropriate shapes to the left triangle, which shape or shapes do you choose?	Children fit the color board within the specified frame (i.e., embedding).	14.00% (0.35)	34.67% (0.48)

Table 4. Results of the t-test.

	Pre-survey	Post-survey
Mean	11.27333333	13.4
	7.099284116	4.617449664
Number of observations	150	150
Pearson correlation	0.565708476	
Difference from hypothesized mean	0	
Degrees of freedom	149	
T	−11.37956783	
p (T ≤ t) (one side)	2.7552E−22	
t boundary value (one side)	1.655144534	
p (T ≤ t) (both sides)	5.51039E−22	
t boundary value (both sides)	1.976013178	

In summary, the proposed program is structured based on the following three elements: the five key areas of focus in Japanese kindergarten education, children's basic mathematical competencies developed in Japanese elementary schools, and the mathematical literacy that Japanese children should acquire. The five key areas provide comprehensive coverage and consistency with early childhood education, and children's basic mathematical competencies developed in Japanese elementary schools provide consistency with mathematics courses. As our program is developed based on both, it not only maintains a continuous relationship with them but also aligns with their content. To ensure coherence, the mathematical literacy that Japanese children need to acquire is consistent with the goals for both the early childhood and elementary school stages.

The proposed early childhood mathematics education program improved the children's mathematical competencies. Further analysis revealed that this improvement occurred because of the content characteristics and program structure. First, the proposed program is compatible with Japanese culture, notably the purpose, content, and methods of traditional early childhood education. In Japan, educators have maintained the perspective that learning by subject (e.g., mathematics) is unnecessary in early childhood; hence, preschool teachers do not know what kind of mathematical content to teach. Therefore, it would not be an exaggeration to say that the current emphasis of early childhood mathematics education is on the development of teaching materials.

Second, this program was designed to be a comprehensive approach to early childhood education in Japan and to be implemented in a manner comparable to that in regular preschools. Implementation involved incorporating mathematical elements into play, which allowed teachers to implement the program easily. Moreover, the children did not know that they were learning mathematics; however, they experienced joy as they engaged in the activities. We demonstrated that children can learn mathematics through play in an environment that does not intentionally provide mathematics education in early childhood. Play-based learning is essential for young children (Ginsburg et al., 2008: pp. 1-24; Miller, 2018; Nakawa et al, 2019: pp. 121-128; Samuelsson & Björklund, 2023: pp. 309-323; Størksen et al., 2023: pp. 36-46) because as children play, they engage in extensive thinking, sometimes noticing important mathematical concepts and using mathematical reasoning to devise new ways of thinking. Thus, teachers should understand the importance and viability of early childhood mathematics education. Teacher training should help teachers understand the need for early childhood mathematics education and encourage them to notice mathematical knowledge and reasoning in children's activities and suggest areas of learning accordingly.

5.1. Novelty and Significance

Our program includes the following novel factors. First, it can be integrated into daily preschool activities, as the framework was developed according to the five key areas of focus in the *Course of Study for Kindergartens* (MEXT, 2018) in Japan. Second, we clarified the connection between preschool and elementary school education based on the principles upon which the elementary school mathematics curriculum is constructed. Third, our program framework connects with mathematical literacy, which is considered important for learning mathematics in Japan. Fourth, our program, based on Wiles' (2009) principles of curriculum development, differs from the elementary school curriculum because of its different objectives and the difficulty of content, even though the content seems similar. Fifth, our program is designed to address the key concepts of continuity, consistency, and alignment (Stein & Coburn, 2023: pp. 840-872) that link the early childhood and elementary stages.

Our proposed program is significant for the following reasons. First, we clarified the importance of matching play with learning, which allowed us to show the importance of children's interest in learning mathematics. The balance between play and learning is important, and this program was considered to have achieved a good balance between the two (United Nations, 1989). Even in the absence of an early childhood mathematics curriculum, as is the case in Japan, with an appropriate program in place, children can develop mathematical competencies (Sancar-Tokmak, 2015: pp. 5-20; Miller, 2018; Nakawa et al., 2019: pp. 121-128). In Japan, a distinction is made between play and learning; in the former, children's spontaneity is emphasized, and teacher intervention is not permitted. However, in Western countries, even activities that involve adult intervention and lead to certain behaviors may be categorized as play (Weisberg et al., 2016: pp. 177-182). Accordingly, we developed and implemented a mathematics learning program associated with play and confirmed the improvement in children's performance. This demonstrates the effectiveness of attempting to incorporate mathematics learning with play in a country that does not implement mathematics education in early childhood.

Second, the early childhood mathematics program proposed in this study is different from Funakoshi's (2011: pp. 1-15) curriculum. Our program links mathematics education with lifelong learning because it is constructed based on the principles of each educational level to connect preschool education with elementary school education.

5.2. Limitations

Nonetheless, our study has some limitations. First, the participants were children living in one metropolitan area in Japan. Future research must verify whether the same effect can be found for children in other regions in Japan or elsewhere. Second, since the program was conducted throughout the year, the children's assessment data were largely influenced by their participation in the program; nevertheless, other influences, such as mathematical play at home and children learning math through private tuition, cannot be ruled out. Third, in addition to the quantitative analysis of the assessment data, the changes in children and their factors based on detailed video recordings of them performing each activity could have been analyzed. Fourth, the program we developed could not verify the continuity of learning. Fifth, the learning units were not streamlined. These points can be explored in future studies.

6. Conclusion

In this study, we proposed an early childhood mathematics program based on the five key areas of Japanese kindergarten education: children's basic mathematical competencies in elementary school and the mathematical literacy that Japanese children should acquire. We demonstrated its effectiveness using a sample of Japanese preschool children. The study revealed the effects of implementing the early childhood mathematics education program in Japan, where mathematics education is not conducted in preschools and teacher training for the same is not provided (MEXT, 1998). The research findings clarify the feasibility and effectiveness of the program and are consistent with the findings of many previous studies that have demonstrated the relationship between play and learning (Hirsh-Pasek et al., 2008; Sancar-Tokmak, 2015: pp. 5-20; Størksen et al., 2023: pp. 36-46). The effectiveness of the program in the underdeveloped context of early childhood mathematics education in Japan represents the novelty of this study.

Ethics Approval

All procedures performed in the current study were approved by the Bioethics Committee in the Faculty of Education at Chiba University for the participants in Japan (No. 126). This study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent to Participate

Informed consent was obtained from all individual participants included in the study. Written informed consent was obtained from the parents. Verbal informed consent was obtained prior to the interview.

Data Availability

The datasets generated and/or analyzed during the current study are available.

Authors' Contributions

Both authors (Nanae Matsuo and Nagisa Nakawa) contributed to and reviewed the main manuscript text.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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