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Learning Process of Developing Subitising, Counting, and Reasoning Skills among Jamaican Preschool Children

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Abstract

This study investigated the developmental aspects of subitising, verbal and object counting, and reasoning skills among young Jamaican children within a guided play environment that incorporated gestures. It employed a comprehensive intervention for mathematics education, involving pre- and post-interviews with a cohort of 10 children aged 5 to 6 years. Employing a mixed-method approach, transcriptions of the children's utterances and gestures were meticulously analysed to identify pivotal moments in their mathematical skill acquisition. The findings underscored the intricate relationship between subitising, counting, and cardinality, asserting the fundamental role of these skills in facilitating numerical development during early childhood. Notably, the study highlights the significance of gestures, particularly using fingers, for augmenting reasoning skills and nurturing a profound conceptual understanding of numerical concepts. By highlighting the symbiotic relationship between cognitive processes and physical gestures in mathematical development, the study contributes valuable insights into educational practices, emphasizing the multifaceted nature of learning in young children and advocating for the incorporation of guided play enriched with gestures in early mathematics education.

Keywords

Early Childhood Mathematics Education, Subitising, Counting, Reasoning, Jamaica, Gesture

1. Introduction

In recent decades, the global mathematics education community has significantly prioritised mathematics education in early childhood (Björklund et al., 2020), recognising the pivotal role of numeracy skills in shaping a solid foundation for primary and advanced mathematics in later educational stages (Duncan et al., 2007; Gable et al., 2020). This emphasis underscores the crucial need to enhance the quality of early mathematical learning as a significant step toward future educational success.

In Jamaica, children's numeracy skills lag behind those in other Caribbean countries, which reveals shortcomings in primary school education (Bourne, 2019). Despite integrating mathematics into the early childhood curriculum (The Dudley Grant Memorial Trust in Collaboration with the Ministry of Education and the Early Childhood, 2010), well-educated individuals in Jamaica struggle to apply mathematics in their professional lives after graduation (Ministry of Education in Jamaica, 2013). Several educational reports also highlighted the lower mathematics skills among Jamaican students (e.g., George, 2023; Ministry of Education in Jamaica, 2013). However, few studies scrutinise learning processes and specific challenges Jamaican students face in mathematics, particularly in early childhood education, necessitating further exploration.

Counting and subitising skills are crucial aspects of mathematical development (Björklund et al., 2018; Clements & Sarama, 2014a). While counting involves enumerating objects, subitising is the instant recognition of the number of objects without the need for counting (Clements & Sarama, 2014a). These skills are interconnected and vital for numeracy development, and the connection between subitising, counting, and reasoning skills has been highlighted (Clements & Sarama, 2014a). Though the importance of these skills has been recognised, they are not incorporated into the curriculum for Jamaican pre-primary mathematics education, and a paucity of research on this topic in the Jamaican context leaves gaps in understanding how to support and enhance these skills among young learners.

This study explores the learning processes of young Jamaican children, specifically focusing on the development of subitising and counting skills in relation to reasoning skills. Key research questions include investigating how Jamaican children develop these skills using verbal expressions and gestures and understanding the relationship between subitising, counting, and cardinality in the context of early childhood mathematics development. This study also explores ways to inform the development of the Jamaican curriculum based on children's learning processes. By analysing socio-cultural discussions on children's understanding of numbers, particularly through the perspective of gestures, this research contributes valuable insights to the field.

2. Literature Review

Focusing on subitising and counting, Learning Trajectories (LT) offer valuable insights, constituting a sophisticated theoretical and empirical framework. LT is based on developmental steps and offers developmental paths (Baroody et al., 2019: pp. 25-26). It provides guidelines for defining goals for meaningful instruction, identifying children's current developmental levels and subsequent instructional steps and designing instructions to facilitate their advancement to the next level (Baroody et al., 2019: p. 26). LT serves as a useful integrative tool within a Neo-Piagetian cognitive framework for understanding children's thinking processes. It covers various mathematical areas, including numbers, quantity, geometry, compositions of shapes and patterns, measurement, estimation, ordering, and algebraic thinking. Several studies have highlighted the importance of LT (Clements & Sarama, 2014b; Jacobi-Vessels et al., 2014). As subitising and counting are integral components of LT, we utilise it as our conceptual framework.

2.1. Subitising

Subitising is individuals' ability to instantly recognize the number of objects without needing to count them individually. Clements and Sarama (2014a) introduced two types of subitising: perceptual and conceptual. Perceptual subitising allows individuals to recognize the number of objects intuitively and simultaneously in a very small collection. In contrasting, conceptual subitising involves recognizing parts and combining them to understand the total number of objects. Developing conceptual subitising skills can help children develop numerical and arithmetic strategies. Clements and Sarama (2014a) stated that 5-year-old children can perceptually subitise up to 5 and conceptually subitise up to 5, sometimes even extending to 10. Numerous studies have highlighted the importance of subitising in the development of various number concepts (Feza, 2015; Logan & Zbrodoff, 2003; Mandler & Shebo, 1982; Starkey & Cooper, 1995). Several others have explored the relationship between subitising and multiple object tracking, including eye-tracking (Chesney & Haladjian, 2011; Li et al., 2010). Additionally, investigations into how subitising relates to other skills, such as understanding cardinality (Paliwal & Baroody, 2020) and arithmetic units (Wilkins et al., 2022), have expanded the understanding of the role of subitising in mathematical cognition. These studies reveal that subitising is closely linked with various aspects of numerosity. The current study contributes to this ongoing research trend, further investigating the relationship between subitising and other numeracy skills.

2.2. Verbal and Object Counting

Verbal and object counting are crucial for composing and decomposing numbers (Nakawa et al., 2020). Verbal counting refers to saying number words in the correct order and helps children understand the principle of the number system and patterns (Baroody, 1987). Clements and Sarama (2014a) emphasized verbal counting over rote counting, as it allows children to use mathematical structures and patterns without relying on rote memory. They also emphasized that verbal counting helps the development of quantitative thinking. Conversely, object counting requires children to verbally enumerate while coordinating their fingers with the objects being counted. As Clements and Sarama (2014a) pointed out, this method not only is a fundamental mathematical skill but also serves as an algorithm. Object counting is particularly useful for quantifying groups and is an alternative to subitising the collections of objects. Clements and Sarama also observed that 5-year-old children can count and produce quantities with objects more than 10. The crucial roles of verbal and object counting in early mathematical development underscore the importance of ongoing research in these areas, making this study critical in enhancing effective educational practices.

Numerous studies have highlighted the importance of reasoning skills in mathematical development for your children (Jacobi-Vessels et al., 2014; Lee & Md-Yunus, 2015). Lee and Md-Yunus (2015) observed that assessments tend to focus only on evaluating children's answers as correct or incorrect. However, they argued that determining whether children can rely on the reasoning behind their answers is crucial. They further emphasised that evaluations should incorporate reasoning questions such as "Why did you do this?" and "How did you do that?" to effectively assess young children's numerical knowledge and skills. Additionally, several studies have emphasized the importance of language in mathematical thinking. Van Oers (2013) proposed paying close attention to children's narratives to better understand their mathematical thinking, highlighting the need to explore how young children communicate about numbers and quantities.

Furthermore, Mix et al. (2005) asserted that children develop numerical skills through verbal and non-verbal interactions. Specifically, many studies have explored the role of gestures, a form of body action categorized non-verbal expression (e.g., Nakawa et al., 2023; Johansson et al., 2014; Radford, 2008). However, few studies specifically investigated the link between young children's gestures and their learning and thinking processes. Therefore, this study analysed both verbal expressions and gestures to understand the development of children's numerical skill, focusing on counting and subitising.

2.3. The Jamaican Context

The Jamaican educational system for early childhood education involves two phases: one for 0 - 2 years old and another for 3 - 5 years old. The curriculum framework emphasises an integrated curriculum; therefore, children aged 3 - 5 years learn numeracy and mathematics-related concepts in integrated lessons rather than subject-specific lessons (The Dudley Grant Memorial Trust in Collaboration with the Ministry of Education and the Early Childhood, 2010). For instance, 5 years old are targeted for "intellectual empowerment", among six developmental objectives. They are expected to engage in mathematical activities, such as counting objects up to 20, writing numerals up to 20, and performing basic addition and subtraction (The Dudley Grant Memorial Trust in Collaboration with the Ministry of Education and the Early Childhood, 2010: pp. 123-124). While counting is a component of the pre-primary mathematics education, the curriculum does not specifically mention subitising despite its recognized importance in numerical development. Thus, the current review highlights a gap in the Jamaican early childhood education system, especially in the area of subitising, illustrating the need for investigating, and contributing to, the enhancement of early numeracy education strategies.

3. Methodological Framework

Data Collection

The study was conducted from April to May 2021 in Port Antonio, Jamaica, selected for its reported weaker mathematical performances than other regions. Author 2's involvement in a non-profit organisation programme supporting educational activities during the COVID-19 pandemic further motivated the location choice. Given the rural nature of Port Antonio, educational challenges intensified during the pandemic. To address these constraints, we prioritised participants with established relationships, particularly those engaged in Author 2's support activities. This pre-existing rapport facilitated trust, ensuring more reliable data collection. Informed written consent was obtained from all participants' guardians after the study's purpose, procedures, and potential risks were comprehensively explained to them.

The research comprised a pre-interview, a 10-day intervention, and a post-interview. During the intervention, each child participated in individual interviews in a designated space, engaging in play and responding to prepared questions (see the appendix). Based on the schedule shown in the appendix, we provided each child with a similar task and modified the level of the tasks according to their competencies. Each child was called to a small room for 10 - 15 minutes daily. Within the guided play setting, Author 2 asked the children some questions while playing with each. Owing to COVID-19 precautions, only one child was accommodated at a time. After Clements and Sarama's (2014a) framework was tailored for preschool children, sessions were adapted based on each child's competency level, as assessed by Author 2. Conversations and physical movements were recorded and transcribed for thematic analysis. This study employed a mixed-method design (Bakker & van Eerde, 2015; Bikner-Ahsbahs et al., 2015: p. 429), incorporating qualitative analysis of transcriptions to identify mathematically significant moments in children's development. Author 2 conducted interviews in both Patois, the local Jamaican language, and English, accommodating children with varying language proficiency. **Table 1** presents interview questions categorised under each theme, addressing verbal counting, object counting, subitising up to 5, and subitising up to 10 (Q 1 - 3, Q 4 - 6, Q 7 - 15, and Q 16 - 20, respectively).

Table 1. Pre-/post-interview items.

No. of interview items	Questions
1	Can you count numbers up to 10?
2	Can you count numbers up to 20?

Continued

3	Can you count backwards from 5 to 1?
4	Can you count these blocks? (3)
5	Can you count these blocks? (5)
6	Can you count these blocks? (8)
7	How many dots do you see? (1)
8	How many dots do you see? (3)
9	How many dots do you see? (4)
10	How many dots do you see? (2)
11	How many dots do you see? (5)
12	How many dots do you see? (2 diagonal)
13	How many dots do you see? (3 diagonal)
14	How many dots do you see? (5 square)
15	How many dots do you see? (4 square)
16	How many dots do you see? (6)
17	How many dots do you see? (8)
18	How many dots do you see? (7)
19	How many dots do you see? (10)
20	How many dots do you see? (9)

4. Result

Table 2 and Table 3 present the results of the pre- and post-interviews. The horizontal numbers show each question item and the vertical ones each child.

Table 2. Result of the pre-interview.

Questions / Children	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	0	1	1	0	1	1	1	0	0	1	1	1	1	0	0	1	1	0
2	1	0	1	1	1	0	1	1	1	1	0	1	1	0	1	0	0	0	0	0
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
4	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	0	0
5	1	0	0	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0
6	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0
7	1	0	0	1	1	0	1	1	0	1	0	1	1	0	0	0	1	0	0	0
8	1	0	0	1	1	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0
9	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0

Table 3. Result of the post-interview.

Children \ Questions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
7	1	0	1	1	1	0	1	1	1	1	0	1	1	0	0	0	0	0	0	0
8	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
9	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0
10	1	0	0	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0

Given the small number of participants, a statistical analysis would not be valid. Therefore, we focused on changes in the total score and the average percentage per child and per question item. Table 2 and Table 3 show the improvement observed in each child.

4.1. Analysis

During the intervention programme, we analysed the process and development of counting and subitising in relation to reasoning skills. We divided pupils into three groups based on their performance in the activities. In the first group (No. 1 - 4), children successfully enhanced their subitising skills up to 10 and their reasoning skills. They were proficient in both verbal and object counting. In the second group (No. 5 - 6), children showed slight improvement in Q1 - 16 but almost no improvement in more advanced questions Q17 - 20. The third group (No. 7 - 10) demonstrated significant improvements in verbal and object counting and subitising skills up to 5, although their skills did not reach the level achieved by the other two groups.

Focusing on two children from the first and third groups as case studies, we examined in depth how one child could develop their skills during the intervention. We used pseudonyms for the children, as detailed below. Using transcripts and recording, two authors highlighted the scenes which related to their mathematical thinking and determined which part showed their improvement in different skills focused on in this study. Furthermore, we chronologically checked how these changes were intertwined qualitatively.

4.2. Karen's Case: A Child in the Higher Performing Group

In the first group, all 4 children demonstrated their ability to subitise up to 10 at the post-interview, showing improvements from the pre-interview. We took one child's (Karen, a 5-year-old) process of learning, focusing on subitising along with her language and gestures in guided play.

Change of Subitising and Reasoning Skills

In the pre-interview, Karen could not subitize 6, 8, and 9. Additionally, she failed to explain her thoughts as follows:

T: How much is this? {In Q16, Author 2 shows a flash card with 6 dots}

S: 8.

T: 8. All right. Why do you think it was 8?

S: Because it looks like 8.

T: Because it looks like 8? Okay.

T: How about this one? {In Q17, Author 2 shows a flash card with 8 dots}

S: 9.

T: Why do you think this is 9?

S: Because I know.

As shown above, Karen could not subitise and provide a logical explanation. On the second day, during the game in which she had to identify the numbers of fingers Author 2 held up, she could subitise numbers, though she could not explain how she arrived at answers. Author 2 attempted to show her the combination of 5 and 2 with his fingers.

T: How about this one? {Author 2 holding up 7 fingers}

S: 7; I got it because I have thrown 7 balls.

T: Oh, because you have thrown 7 balls, you remembered it?

T: So, how many over here? {Author 2 moving the right hand with 5 fingers}

S: 5.

T: How many over here? {Author 2 moving the left hand with 2 fingers}

S: 2.

T: So, 5 and 2 make?

S: 7!

T: 7, that's right. Then what about this one? {Author 2 holding up 9 fingers}

S: 9.

T: You didn't even count it. How did you know that?

S: Because I have thrown 9 balls.

T: Oh, you have thrown 9 balls and you remembered that.

S: {Child nods}

T: So, how many over this side? {Author 2 moving the right hand with 5 fingers}

S: 5.

As seen above, Author 2 explained using a group of 5 and the remaining numbers with fingers.

On the third day, Author 2 showed cards displaying various numbers of apples and asked her to identify the numbers. When Author 2 showed a card with 8 apples, she could not subitise 8 and instead counted all 8 apples. However, she could explain as Author 2 had demonstrated on the second day and as previously shown. Her gestures clearly indicated that she had a sense of decomposing 5 and 3 to make 8 in her mind. The following transcript corresponds to Figure 1.

T: How many are these? {A flashcard with 8 apples on it is shown}

S: {Looking at the card (Figure 1(1-1)). She is counting the number of apples on the flashcard by looking (Figure 1(1-2))} 8.

T: 8, How did you know that?

S: Because 3 apples {Showing her hand wide (Figure 1(1-3))} and 5 apples {Clapping her hands and putting them on her left side (Figure 1(1-4))} make 8 {Showing her clapped hand at the centre and opening them (Figure 1(1-5))}.

T: Oh, where is 3? {Child points to the bottom row of apples on the card} Oh, these are 3? Where is 5? {Points to the top row of apples on the card} Oh, this is 5? So…

S: 5 is a bigger number than 3, so it could make 8.

T: Oh, 5 is bigger than 3 and that makes...?

S: 8.

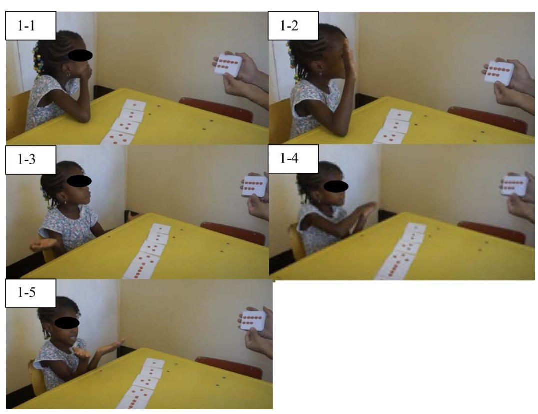


Figure 1. Karen's logical explanation for her answer, 8 (including Figures 1(1-1)-(1-5)).

The transcript indicated that Karen spoke as Author 2 had demonstrated the previous day, although she used 'count all' strategies and did not use subitising. Moreover, her gestures, such as displaying her fingers, putting her hands together, and leaning them to one side, helped reinforce her understanding that the two numbers combined to make 8, which relates to the concepts of number composition and decomposition. On the fifth day, she could finally subitise numbers correctly and explain how she arrived at the answers.

T: Can you find 8?

S: {Child takes cards with 8 dots and 8 apples on the table}

T: So, how did you know that it is 8?

S: Because you said 8.

T: Because I said 8?

S: Because it is 5 and 3.

On the ninth day, she applied reasoning skills to different numbers using her fingers, demonstrating development in reasoning skills. Her skills appeared stable, and with different numbers, her fingers supported her thinking, allowing her to explain the conceptual subitising process. Her improvement in reasoning skills was evident in an activity where she had to match the number of her fingers to the amount requested by Author 2.

T: Can you show me 2?

S: {Holds up 2 fingers}

T: All right, can you show me 4?

S: {Holds up 2 sets of 2 fingers}

T: Ah, this is very interesting. Is this 4?

S: {Nods} 2 and 2 make 4.

T: Oh, this is also 4 {Holds up 4 fingers} and this is also 4 {shows 2 sets of 2 fingers}. All right, can you show me 3?

S: {Holds up 3 fingers (**Figure 2**)}

T: Ah, that's 3. Okay, can you show me 3 in a different way?

Figure 2. Karen gestures to show 3.

S: {Holds up 2 fingers of one hand and 1 of the other hand (**Figure 3**)}

Figure 3. Karen gestures in another way.

T: Ah! So how many over here? {Gestures to her left hand}

S: 2

T: And how many over—{Gestures to her right hand}

S: 1

T: So, 2 and 1 make?

S: 3

T: 3. Very good. Can you show me 5?

S: I'm going to make it a different way.

T: Ah.

S: {Holds up 3 fingers of one hand and 2 of the other (**Figure 4**)}

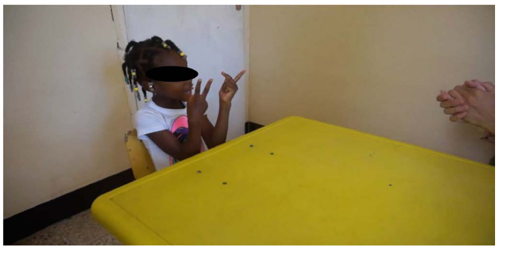


Figure 4. Karen demonstrates 5 in another way.

T: Okay.

S: 1, 2, 3, 4, 5.

T: Aha! So, 5 can be what and what?

S: 3 and 2.

T: 3 and 2 can be 5. Can you come up with any other way to make 5?

S: {Nods} Hmm. {Holds up 5 fingers of one hand}.

T: Ah! That is 5, right?

S: {Nods}

These conversations and gestures indicate that Karen applied previously acquired reasoning mechanisms to different numbers. Before this activity, she had explained her reasoning only for numbers larger than 5. However, once she learned to logically explain her reasoning, she spontaneously applied this method to smaller numbers.

Furthermore, after becoming accustomed to this type of reasoning, she further deepened her understanding of number decomposition across various numbers, making her subitising more stable. Interestingly, she spontaneously closed her eyes during this practice as shown in the following transcripts, which helped her focus on the numbers on each of her hands, thereby facilitating her understanding of number decomposition.

S: I can make it without looking.

T: Oh, you can do it without looking! That's very good. How about 8?

S: {Holds up 8 fingers with her eyes closed}

Figure 5. Karen demonstrates 8 with her eyes closed.

T: 8 is…?

S: 3… 5 and 3 (**Figure 5**).

T: Very good. How about 9?

S: {Holds up 9 fingers with her closed eyes}

T: 9 is…?

S: 5 and 4.

T: 5 and 4, very good. 10! How much—How about 10?

S: {Holds up 10 fingers with her closed eyes}

T: 10 is…?

S: 5 and 5.

T: 5 and 5. Very Good!

Regarding numbers larger than 5, she used one hand to represent 5 and expressed the remainder of the number with her other hand, demonstrating a technical understanding of the concept. On the final day of the practice, she successfully subitised numbers without counting during the flashcard activity and consistently repeated this skill. Furthermore, she explained how she arrived at the numbers in her answers and successfully identified the number of dots in various groups, showing a significant improvement from the pre-interview and the first day.

In the final interview, she could not only subitise numbers but also explain her actions by stating the composition of two numbers and explaining original numbers. By the time of the post-interview, her subitising skills had become very stable.

4.3. Antony's Case: A Child in the Third-Performing Group

At the stage of the pre-interview, Antony did not understand the concept of cardinality, as later transcripts clarify. Owing to this lack of understanding, when asked to subitise cards displaying dots, Antony could not identify the number but resorted to counting them.

T: How many is this? {Flashcard of 1 dot is shown}

S: 1.

T: Mhmm. {Flashcard of 3 dots is shown (Figure 6)}

S: 1, 2, 3.

T: Mhmm. {Flashcard of 4 dots is shown}

S: 1, 2, 3, 4.

T: Mhmm. {Flashcard of 2 dots is shown}

S: 1, 2.

T: Mhmm. {Flashcard of 5 dots is shown}

S: 1, 2, 3, 4, 5.

T: Mhmm, all right.

Figure 6. Antony's object counting.

In Figure 6, Antony's eyes moved from left to right, and he counted the dots one by one instead of identifying the total number of dots immediately.

On the first day of practice, when asked to count the number of balls in a basket, Antony could state the number of balls, such as "1, 2, 3". However, when Author 2 asked him about the total number of balls, he repeatedly recounted from 1 instead of directly stating the total number, indicating that he lacked an understanding of cardinality.

T: How many balls did you get so far?

S: 1, 2, 3.

T: How many?

S: 1, 2, 3.

T: So, how many in all? {Gestures towards the basket with large red balls}

S: 1, 2, 3.

T: Hmm... These are 3 balls, right? So, you have 3 balls (See **Figure 7**).

Figure 7. Antony says 1, 2, 3 while touching.

Antony's responses indicate that he did not yet grasp the concept that the last counted number represents the total quantity of those objects. He could not connect the counting process with the overall quantity of objects.

However, interestingly, when asked to subitise the number of fingers displayed by Author 2, Antony could do so without counting them, even though he could subitise dots in the previous interviews.

T: How many are these? {4 fingers are shown}

S: 4.

T: How many are these? {2 fingers are shown}

S: 2.

T: Oh, you are so smart. How many are these? {5 fingers are shown}

S: 5!!

Figure 8 illustrates that the child responded "5" when asked "how many?", showing his 5 fingers. The primary reason he could subitise fingers, even though he failed to do so with dots, is supported by Clements and Sarama (2014a). They

Figure 8. Antony subitises while seeing the number of fingers.

argued that subitising with fingers involves unique spatial patterns, which can be easier for children to recognize. Therefore, Antony may have internalized the spatial patterns of fingers corresponding to numbers in his mind, enabling him to subitise without counting.

On the fifth day, during the activity of counting blocks, Antony finally learned to identify the number of blocks by using his ability to recognize finger patterns, as follows:

T: So how many blocks are there?

S: 1, 2, 3.

T: So how many blocks? That's…? (**Figure 9**)

S: 3! (**Figure 10**)

T: Yeah, you don't have to count them again. You can just say 3. Right, how much is this?

S: 1, 2.

T: So that's 2! Yes, that's correct! How many are these?

S: 1, 2, 3, 4.

T: So that's…?

S: 4 blocks.

T: Yes, 4 blocks. That's perfect! Let us try just one more. How many are these?

S: 1, 2, 3, 4, 5.

T: So that's…?

S: 5 blocks.

In **Figure 9**, the interviewer placed three blocks on the desk and asked Antony for the number. After he counted the blocks once, the interviewer repeated the question "How many?" Antony was about to count them again "1, 2, 3", as he had done previously. However, this time, the interviewer showed three fingers, mirroring as many objects on the desk, as illustrated in **Figure 9**, to help Antony connect the counting process with the quantity of the blocks by using spatial finger patterns. Thus, Antony stopped recounting and displayed his 3 fingers, saying "3!" excitedly, as shown in Figure 10.

Figure 9. Antony wants to count the number of the objects.

Figure 10. Antony shows his three fingers corresponding with those of Author 2.

This improvement was also observed with different numbers. When asked to count 2 blocks, he touched them one by one, saying "1, 2", and then displayed 2 fingers, looking at them (Figure 11).

Figure 11. Antony corresponds with his fingers to the objects.

Following this, Antony said "2!", confirming the total number of blocks to the interviewer and expressing his excitement (Figure 12). This time, he could specify the total number without attempting to recount the blocks. Here, Antony appeared to have understood the concept of cardinality, recognizing that the last counted number represented the total quantity of the objects.

On the seventh day, Antony finally learned subitising up to 5, helped by his finger patterns. Previously, in the pre-interview and earlier conversations, when

Figure 12. Antony confirms 2 with the Author 2.

asked to subitise cards with dots, he would count each dot, such as "1, 2, 3". However, at this stage, he stopped counting and instead stated the total number directly, displaying the same number with his fingers as follows:

T: How many apples are these? {Shows flashcard}

S: 1? (Figure 13(13-1))

T: Apple, yes. 1 apple. How many apples are these?

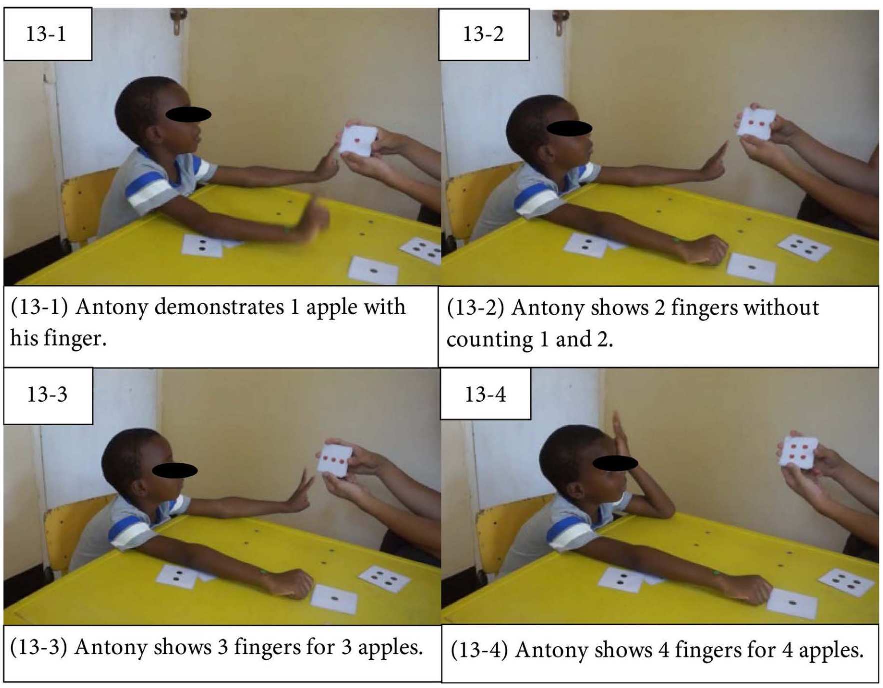
S: 2 apples. (Figure 13(13-2))

T: 2 apples. Very good. How many apples are these?

S: 3 (Figure 13(13-3))

T: 3 apples, very good. I'm proud of you! How many apples?

S: It's… 4! (Figure 13(13-4))



(13-1) Antony demonstrates 1 apple with his finger.

(13-2) Antony shows 2 fingers without counting 1 and 2.

(13-3) Antony shows 3 fingers for 3 apples.

(13-4) Antony shows 4 fingers for 4 apples.

Figure 13. Antony's unique way of expressing the number of apples with his fingers.

T: 4 apples, right. The next one is kind of tricky. How many apples are these?

S: 6?

T: That's very close. Right. 1, 2, 3, 4, 5. So that is…

S and T together: 5 apples!

Given his ability in identifying finger patterns and associating them with numbers, Antony utilized his fingers, displaying the corresponding number with his fingers to subitise the cards with dots. Thus, he used his finger patterns as a mediating tool to facilitate subitising.

After continuous practice, Antony's skills of subitising numbers up to 5 became increasingly stable. In the post-interview, he could subitise up to 5 accurately and confidently.

T: All right. How many...are these?

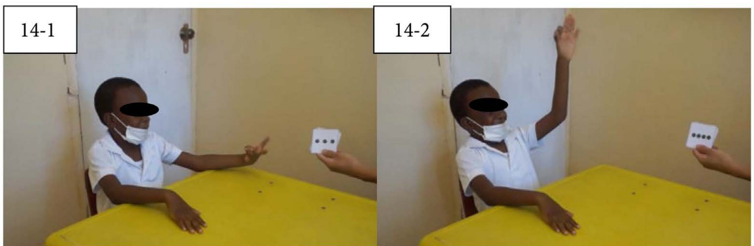
S: 3 dots on the card! (Figure 14(14-1))

T: 3 dots on the card. All right. How many are these?

S: 4…

T: How many are these?

S: 4 dots on the card! (Figure 14(14-2))



(14-1) Antony subitises 3 with 3 fingers. (14-2) Antony excitedly subitises 4 with 4 fingers.

Figure 14. Antony subitising numbers.

Initially, Antony struggled with the concept of cardinality and relied on counting each object, even in subitising tasks. Over time, his ability to subitise improved significantly, supported by his recognition of finger patterns. His use of finger patterns as a mediating tool was instrumental in this development, reflecting a substantial growth in his understanding of cardinality.

5. Discussion and Findings

5.1. Verbal and Object Counting

Analysis of interviews revealed that some children, as exemplified by Antony, encountered challenges in grasping cardinality, impacting their object-counting abilities. Antony's struggles to articulate the total quantity, though he verbally counted objects, underscore the necessity for teachers to assess counting levels and pose follow-up questions. Antony's progress, shown by a gradual improvement in his ability to identify total quantities through consistent inquiry, highlights the crucial role of teacher guidance in fostering children's mathematical development.

5.2. Relationship between Subitising, Counting, and Cardinality

Observations of Antony's play revealed interconnections between subitising, counting, and cardinality. Although lacking cardinality initially, Antony demonstrated proficiency in subitising fingers, suggesting a connection between spatial patterns and numbers, as described by Clements and Sarama (2014a). This subitising ability, potentially influenced by Jamaican educational practices of incorporating finger patterns and use, served as a mediating tool for understanding object counting and developing cardinality. Once he developed cardinality, Antony's subitising skills significantly improved and became stable. This symbiotic relationship between cardinality and subitising skills was evident, aligning with Paliwal and Baroody's (2020) findings, emphasising the mutual reinforcement of these skills.

5.3. Subitising and Reasoning Skills through Gestures

Significant improvement in subitising skills, particularly through gesture integration, was observed among the children, exemplified by Karen. Initially unable to provide logical explanations, Karen's progression involved verbal reasoning strengthened by gestures. Her use of gestures, such as displaying fingers, mirrored her verbal explanations, displaying the integration's impact on deepening conceptual understanding. Karen's flexibility in applying learned skills to different numbers underscored the depth of her conceptual understanding, facilitated by the fusion of gestures and verbal reasoning. This aligns with Johansson et al.'s (2014) assertion that language alone is insufficient for fully expressing mathematical understanding.

Similarly, Antony's use of fingers as a mediating tool in subitising clearly highlighted the role of gestures in mathematical learning, resonating with Nakawa et al.'s (2023) suggestions. Li et al. (2010) claim regarding the benefits of pointing or nodding during counting was reinforced. These findings underscore the importance of observing children's gestures to comprehend their learning process and encouraging physical actions to deepen conceptual understanding. However, further exploration is warranted to understand the diverse roles of various gestures across cultures and regions in impacting learning processes.

6. Implications for Jamaican Mathematics Curriculum Development

This section addresses our third research question, drawing from our findings.

The research demonstrated a significant connection between counting and subitising, exemplified by Antony's understanding of cardinality through finger subitising. This underscores the potential of subitising to accelerate children's understanding of counting and numbers. Despite its importance, subitising is currently absent in the Jamaican curriculum and lacks widespread recognition among educators. Therefore, integrating subitising, alongside counting, into the curriculum could enhance numerical understanding among Jamaican children. Introducing playful subitising activities with a competitive element may prove effective, as they enhance motivation, making learning more engaging.

Furthermore, our study emphasizes the value of utilizing finger patterns to bolster numerical understanding in the Jamaican context. While finger use is commonplace in Jamaican education, our research showcases the efficacy of employing fingers, specifically as patterns for subitising. Introducing finger patterns as an initial step to understanding subitising can be a powerful tool, supporting further learning. We propose incorporating the use of finger patterns into the curriculum guide and teaching resources, facilitating easier integration of subitising activities into teaching practices and strengthening children's mathematical foundations.

Our study also revealed how gestures, as demonstrated by children like Karen, contribute to deepening understanding and applying numerical concepts. Integrating gestures into teaching methods has the potential to enhance children's reasoning skills. This highlights the need for teachers to observe children's physical actions, tailoring approaches to individual learning processes. Although reasoning skills are underscored in the curriculum guide, specific methodologies are insufficiently outlined. We recommend incorporating gesture-based instruction in the curriculum and teacher resource books, providing practical tools and examples for educators. As observed in the interviews, children effectively express their thoughts using gestures, particularly when subitising with fingers, making the explanation process more accessible and contributing to conceptual understanding.

Incorporating these insights into curriculum documents and supplementary resources can enhance the effectiveness of mathematics education in Jamaica, establishing a robust foundation for future mathematical learning and reasoning.

7. Conclusion

This study presents novel findings with two prominent implications. First, recognising the robust interconnection between subitising, counting, and cardinality is crucial for curriculum development. Given the lack of emphasis on subitising in Jamaican textbooks, redirecting focus towards this skill could fortify children's foundational understanding of cardinality and number recognition. Second, educators should meticulously observe children's reasoning processes, particularly attending to gestures, to enhance their conceptual understanding of numbers. By incorporating these insights into educational practices and curricula, teachers stand to significantly improve the effectiveness of mathematics teaching in Jamaica. However, the study has limitations. The participant selection, driven by pre-existing relationships imposed by the COVID-19 constraints, may introduce selection bias and limit sample diversity. Additionally, one-on-one interviews, implemented as a COVID-19 precaution, lack social and peer interaction, potentially influencing children's reactions. Consequently, the insights may not fully encapsulate the broader experiences of preschool children in more typical settings. Acknowledging these limitations, future research should employ diverse sampling strategies, engage more children, and explore how children's multimodal expressions relate to numerical understanding and skills.

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Conflicts of Interest

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

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Appendix: Contents of Interventions

Week 1 (V: Verbal counting; O: Object counting; S: Subitising)

DAY 1

V: Children should be able to count 1 - 5 verbally.
- Let children count up to 5.
- Ask children if they can count showing their fingers.

O: Children should be able to count balls.
- Roll five balls on the table and let children catch the ball using the basket.
- Ask how many they were able to catch.
- Let children count the balls while moving them from the basket onto the table.

O: Children should be able to count blocks (3, 4, 5).
- Let children count up to five blocks on the table.
- Show how to count the blocks if children do not count properly.

S: Children should be able to subitize the number of blocks on the board.
- Show up to five blocks on the board and let children answer the number of the blocks quickly.
- Let children count the blocks if they do not subitize them correctly.

DAY 2

V: Children should be able to count 1 - 10 verbally.
- Let children count up to 10.
- Ask children if they can count showing their fingers.

O: Children should be able to count balls.
- Let children roll five balls into the basket on the table and count the number of balls in the basket.
- Increase the number of the balls to 10 if they are able to count them correctly.

O: Children should be able to count blocks (3, 5, 7, 9).
- Let children count up to ten blocks on the table.
- Show how to count the blocks if children do not count properly.

S: Children should be able to subitize the number of fingers.
- Show up to five fingers and let children answer the number of the fingers quickly.
- Let children count the fingers if they are not able to subitize them correctly.
- Increase the number up to 10 if they are able to subitize them correctly.

S: Children should be able to subitize the number of blocks on the board.

- Show up to five blocks on the board and let children answer the number of the blocks quickly.
- Let children count the blocks if they do not subitize them correctly.

DAY 3

V: Children should be able to count 1 - 10 verbally.

- Let children count up to 10.
- Ask children if they can count showing their fingers.

V: Children should be able to jump the number shown with the teacher's fingers.

- Let children jump as many as the number the teacher shows with fingers.
- Show children how to do it by jumping with them if they are not able to do it.

O: Children should be able to place the same number of blocks.

- Tell a number up to 5 and let children put the same number of blocks on the table.

S: Children should be able to subitize the number of apples on the cards.

- Show cards with up to five apples on them and let children answer the number of apples on the cards quickly.
- Increase the number of apples to 10 if they are able to subitize them correctly.

DAY 4

V: Children should be able to count 1 - 10 verbally.

- Let children count up to 10.
- Ask children if they can count showing their fingers.
- Let children count up to 20 they are able to count 10.

V: Children should be able to count to 10 while lifting a balloon.

- Let children lift the balloon while counting numbers to 10.
- Let children catch the balloon when the count reaches 10.

O: Children should be able to place the correct number of blocks in a 10 frame.

- Tell numbers up to 5 and let children put the number of blocks in the 10 frame.
- Increase the number of blocks to 10 if they are able to do it correctly

S: Children should be able to subitize the number of dots on the cards.

- Show cards with up to five dots on them and let children answer the number of dots on the cards quickly.
- Increase the number of dots to 10 if they are able to subitize them correctly.

DAY 5

V: Children should be able to count 1 - 10 verbally.

- Let children count up to 10.
- Ask children if they can count showing their fingers.
- Let children count up to 20 if they are able to count to 10.

V: Children should be able to count backwards from 5 to 1.

- Let children count backwards from 5 to 1.
- Count backwards with children showing fingers if they are not able to count correctly.

O: Children should be able to count the number of blocks while building a tower.

- Let children stack up the blocks
- Let children count the blocks

S: Children should be able to identify the cards with the correct numbers of objects on them.

- Tell numbers up to 5 and let children take cards with the same numbers of dots or apples on them.
- Play the game with children to encourage them to take cards quickly.
- Increase the number to 10 if children are able to do that correctly.

Week 2

DAY 6

V: Children should be able to count 1 - 20 verbally.

- Let children count up to 20.
- Let children count up to 10 if they are not able to count to 20.

V: Children should be able to jump as many times as the teacher claps.

- Clap hands and let children jump as many times as the number of the claps.
- Jump with them if they are not able to do that.

S: Children should be able to subitize the number of fingers.

- Show up to five fingers and let children answer the number of fingers quickly.
- Let children count the fingers if they are not able to subitize them correctly.
- Increase the number up to 10 if they are able to subitize them correctly.

S: Children should be able to find cards with the correct number of dots.

- Roll a die and let children take cards with the same number of dots on them.
- Play the game with children to encourage them to take cards quickly.

DAY 7

V: Children should be able to count 1 - 20 verbally.

- Let children count up to 20.
- Let children count up to 10 if they are not able to count to 20.

O: Children should be able to count the number of bottles they knock out.

- Place 10 bottles on the table and let children throw a ball to knock the bottles out.
- Ask children how many bottles they knock out.
- Ask children how many bottles they fail to knock out.

S: Children should be able to find pairs of cards.

- Place cards with up to five apples and dots on the table and let children find pairs.
- Ask why they think those cards can be pairs.
- Increase the number of apples and dots to 10 if children are able to find pairs properly.

DAY 8

V: Children should be able to count 1 - 20 verbally.

- Let children count up to 20.
- Let children count up to 10 if they are not able to count to 20.

V: Children should be able to count backwards from 5 to 1.

- Let children count backwards from 5 to 1.
- Count backwards with children showing fingers if they are not able to count correctly.
- Let children count backwards from 10 to 1 if they are able to do that.

O: Children should be able to place the same number of blocks as the teacher shows with the blocks on the board.

- Show children up to five blocks on the board.
- Let children place the same number of blocks on the table.
- Increase the number of blocks to 10 if children are able to do that.

S: Children should be able to move an object forward as many times as the number a die shows.

- Let children roll a die and move a character forward on the course as many times as the number the die shows.
- Play the game and compete to reach the goal with the children.

DAY 9

V: Children should be able to count 1 - 20 verbally.

- Let children count up to 20.
- Let children count up to 10 if they are not able to count to 20.

V: Children should be able to count backwards from 5 to 1.

- Let children count backwards from 5 to 1.
- Count backwards with children showing fingers if they are not able to count correctly.
- Let children count backwards from 10 to 1 if they are able to do that.

O: Children should be able to put up as many fingers as the number the teacher tells.

- Tell numbers up to five and let children put up the same number of their fingers.
- Increase the number to 10 if they are able to do that correctly.

S: Children should be able to match cards with the same number of dots.

- Place cards with up to five dots face-down.
- Let children turn over two cards and take them if they have the same number of dots. If they are not the same, those cards should be put face-down again.
- Increase the number to 10 if they are able to do that properly.

DAY 10

V: Children should be able to count 1 - 20 verbally.

- Let children count up to 20.
- Let children count up to 10 if they are not able to count to 20.

V: Children should be able to count backwards from 10 to 1.

- Let children count backwards from 10 to 1.
- Count backwards with children showing fingers if they are not able to count correctly.
- Let children count backwards from 5 to 1 if they are not able to do that.

S: Children should be able to subitize the number of dots on the cards.

- Show cards with up to five dots on them and let children answer the number of dots on the cards quickly.
- Play the game with the children to encourage them to answer quickly.
- Increase the number of dots to 10 if they are able to subitize them correctly.

S: Children should be able to move forward as many times as the cards show with dots on them.

- Let children take a card with up to six dots randomly and move forward on a hopscotch course as many times as the number the card shows with the dots.
- Play the game with the children and compete to reach the goal first.