The relation between frequently exposed context in the early childhood settings' mathematical activities and arithmetic skills: A cross-cultural comparison of 6-year-old children in Singapore and Japan

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Abstract

In this study, the authors explored the relation between the types of contexts which young children were frequently exposed to in their early childhood setting's mathematical activities and their arithmetic skills. Addition test was administered to 35 Japanese young children (Mean age: 6 years 1 months) and 35 Singaporean young children (Mean age: 6 years 3 months) in two contexts: Written Arithmetic (WA) and Oral Arithmetic (OA). The WA problems were presented to the children on an A4-sized cardboard whereas the OA problems were read out to the children. The statistical results showed that Japanese children were more proficient in solving arithmetic by aurally instead of visually, whereas Singaporean children exhibited the opposite tendency. The authors suggested that this difference between both countries' young children was likely due to the different contexts of mathematical activities which they were frequently exposed to in their early childhood settings.

Keywords: arithmetic, mathematical activities, frequently exposed context, early childhood settings

1. Introduction

Even before formal schooling, children participate in a variety of mathematical activities in their everyday lives. Since the goals and the types of mathematical activities vary across cultures, children participate in these activities in their own culturally valued way (Saxe, 1991; Guberman, 2004). Related studies have shown that as children frequently exposed to a specific context in their mathematical activities, they developed familiarity and later expertise in solving arithmetic related to this familiar context (Saxe and Esmonde, 2005; Taylor, 2013). For example, Taylor (2013), explored the relationship between participation in tithing (giving 10% of one's earnings to a church) and children's arithmetic skills. The results revealed that children's frequent problem solving in the context of tithing could have served as a foundation for understanding operations with rational numbers. For example, using 1/10 or 10% as a basis for working out other percentages such as 5% or 20%. As a result, the children tend to solve arithmetic problems presented in the context of tithing successfully but not those in non-tithing contexts. In other studies, Brazilian candy child sellers who engaged in retail sales in their everyday lives performed better when solving arithmetic involving currency values. However, they did poorly in arithmetic presented in writing context, which was unfamiliar to them (Nunes, Schliemann, and Carraher, 1993, Rogoff, 2003; Saxe, 1991). It is of particular interest to note that the development of arithmetic skills among these children might be limited to the context that they are frequently exposed to, but the same form of development may not be reciprocated in an unfamiliar context.

The above mentioned studies are some of the studies that focused on children's out-of-school mathematical activities to examine links between the familiar contexts in these activities and their arithmetic skills (Nunes et al., 1993; Taylor, 2013). While much is now known about the influences of out-of-school mathematical activities on children's arithmetic skills, the topic of mathematical activities in early childhood settings has rarely been the issue of similar investigation. However, for two reasons we feel this issue should not be overlooked and it is worth investigating.

Firstly, the nature of mathematical activities in early childhood setting is very different from those of out-of-school mathematical activities. In fact, most of the activities in early childhood settings are designed with goals that are more geared towards developing and nurturing children's cognitive development. Besides that, young children usually only interact with their teachers or peers, guidance and assistance are often provided by the teachers to help them to achieve the different learning goals through these activities. On the other hand, out-of-school mathematical activities placed emphasis on task accomplishment in their daily lives instead of learning of mathematics. For these reasons, the findings and explanations on children's mathematical development in studies that centered on out-of-school mathematical activities might not be applicable to those young children in early childhood settings.

Secondly, early childhood setting is one of the most important platforms where children construct and develop their foundational mathematical knowledge. It is common to see young children learning and using different cultural tools such as mathematical symbols, and concrete artefacts as they participate in activities with their teachers and peers in early childhood settings. In the recent work, it has been reported that the experiences from these activities play an extremely vital role in young children's mathematical development as they form the foundation of their mathematical learning in later stage (Claessens, and Engel, 2013; Jacobi-Vessels, Todd Brown, Molfese and Do, 2016; Jordan, Kaplan, Ramineni, & Locuniak, 2009; Manfra, Dinehart, & Sembiante, 2014), and these experiences vary across cultures because even in early childhood settings young children often engage in mathematical activities which are valued by their own cultures (Tobin, Hsueh, & Karasawa, 2009). Therefore, we suggest that they are likely to go through different trajectory of mathematical development which result their mathematical cognition to situate in a specific and familiar context.

2. Mathematical activities in early childhood settings– Singapore and Japan

Now that we have established most children are exposed to mathematical activities in early childhood settings which will impact their arithmetic skills, we want to investigate this issue further by conducting a cross-cultural comparison study of Singaporean and Japanese young children. Interestingly, while Singapore and Japan seem to differ greatly in terms of the context of early childhood activities for mathematics (Ikeda, & Yamada, 2006), both countries share many similarities in terms of economic status, social issues, and the quality of education, which help to minimize confounding effects. In addition, both countries' children are often been ranked as one of the few top performers for mathematics in OECD Programme for International Student Assessment (PISA). Therefore, all these factors provide good grounds for a cross-cultural comparison study.

Singapore, a highly competitive society, places very strong emphasis on educational qualifications. Formal lessons are commonly conducted in early childhood settings to prepare young children for their elementary school education (Ikeda, & Yamada, 2006). Given that Singapore's educational system places a great emphasis on the assessment of learning and written assessment, it has influenced the pedagogy of mathematics teaching towards written arithmetical teaching and learning. Mathematical activities in early childhood settings, therefore also often revolve around paper-and-pencil tasks, written numerals on textbooks, and workbooks (Ikeda, & Yamada, 2006), suggesting that Singaporean young children might be more immersed in the written arithmetic context in these settings.

On the contrary, in Japan, mathematical activities in early childhood settings can be very diverse. For instance, mathematical concepts were embedded in activities such as taking attendance, cleaning up and playing games, and thus considered as mathematical activities (Sakakibara, 2006, 2014). Although there was a great diversity of mathematical activities, most of them appeared to take place in an oral arithmetic context. For instance, a teacher would ask the children for the number of boys and girls that were absent, and they verbally added up the total number of absentees. In another activity, before a drawing session, the teacher asked the children to verbally add up all the pink papers that she had counted and those remaining on the table (Sakakibara, 2006, 2014). These are some of the many mathematical activities in Japanese early childhood settings that require young children to rely greatly on their speech and hearing, suggesting that they were more likely to expose to the oral arithmetic in these settings.

In view of these considerations, this study seeks to explore whether the contexts of mathematical activities which both countries' young children are frequently exposed to in their early childhood settings influence their arithmetic skills differently.

3. Methodology

3.1 Participants

There were two groups of participants - first group comprised 35 Japanese young children (19 boys, 16 girls, Mean age: 6 years 1 month) and second group comprised 35 Singaporean young children (17 boys, 18 girls, Mean age: 6 years 3 months). These participants were selected through convenience sampling from four typical early childhood settings in Singapore and Japan.

Both informed consent from parents and assent from children before the study. In order to remove any potential stress in children, procedures and items in this study were slightly modified. Furthermore, all children were given the opportunity to withdraw from the study at any time, and all their information were treated confidentially.

3.2 Materials

A total of 24 arithmetic items - addition questions in two types of contexts (WA: Written Arithmetic; OA: Oral Arithmetic) with sums less than 100 were selected. Half of the items were presented in the WA format, and the remaining half in the OA format. Each WA item was printed on an A4-sized card, and displayed to the children. Whereas, OA items were read out to the children.

With reference to LeFevre, DeStefano, Coleman, & Shanahan (2005), each context was categorized into four levels (A to D) of three items each. Slight modifications were made to the complexity and structure of the items to suit the learning age of the children. The items were administered in English and Japanese languages, which are the first languages for the children in Singapore and Japan, respectively. Much attention was placed on the question techniques to ensure that the tests were parallel when presented in English and Japanese languages. In order to eliminate experimenter bias, the same researcher was deployed to conduct the experiment in both settings.

Details of WA and OA items are shown in Table 1.

The two types of items were counterbalanced across children. The design of this study was a 2 (Countries: Singapore and Japan) × 2 (Contexts: WA and OA) × 4 (Levels: A, B, C, and D) mixed factor design.

3.3 Independent variables

Three independent variables- participants' test scores, problem solving time, and strategies used were assessed in this study.

Firstly, total test scores of WA and OA problems for each child were measured. One point was awarded for each correctly solved item, with a maximum of 12 points for each context.

Secondly, the solving time of each correctly solved item was measured in seconds by the researcher. He started the stopwatch when he presented an item and stopped it when the child answered. According to Bull and Johnston (1997), one is likely to take a shorter time to solve arithmetic that were presented in familiar context than those of other contexts.

Thirdly, with reference to Bisanz, Sherman, , & Ho (2005), we categorized the solving strategies into two main types - the overt and covert strategies. If the children used concrete referents such as their fingers or circular cards, as support while solving the items, they were coded as overt strategies. In contrast, solving the items without any use of concrete referents was classified as covert strategies. And children are more likely to use covert strategies on easy or familiar problems than on difficult problems (Bisanz et al 2005).

In sum, Singaporean children are expected to employ more covert strategies and utilize a shorter time to solve more WA than OA items. Conversely, Japanese children are expected to employ more convert strategies and utilize a shorter time to solve more OA than WA items. In addition, Japanese children tend to be more proficient in solving OA items than Singaporean children whereas Singaporean children are expected to perform better in WA items than Japanese children.

3.4 Procedure

The children were tested individually by a researcher. A pretest was administered to all the children to verify their understanding of Arabic numerals and the addition '+' sign. Those who did not meet the requirement were excluded from the main task.

During the main task, a paper, pencil, and 100 circular cards (3cm in diameter) were available on the table. A blank A4 double sided printed response sheet was distributed to each child for them to fill in their answers.

WA and OA items were presented one at a time to the children starting from Level A. The task stopped once the children failed to solve or wrongly answered two items in a row. The children were encouraged to solve the items using whichever strategy was easiest for them.

4. Findings

4.1 Test Scores

Singaporean children scored an average of 8.8 out of a total of 12 for WA items, and an average of 6.6 out of a total of 12 for OA items. Conversely, Japanese children performed better in OA items than WA items, with an average score of 8.0 and 4.7 respectively (Figure 1). Two way factorial analysis of variance (ANOVA)'s results showed that there was a significant Country Groups' test scores × Context interaction, $F\ (1, 68) = 98.39$, $p < .05$. In addition, simple main effect tests were also performed to determine whether the test score of Singaporean children and Japanese children differed in each of the two contexts. In these two contexts there was a significant effect of country group's test scores: OA items, $F\ (1,68)=4.45$, $p < .05$; and WA items, $F\ (1,68)=57.73$, $p < .01$.

4.2 Problem Solving Time

Singaporean children took an average of 7.89 seconds and 5.26 seconds to solve OA and WA items respectively. In contrast, Japanese children solving time for OA and WA items were 5.18 seconds, and 6.72 seconds respectively (Figure 2). Two-way factorial analysis of variance (ANOVA) was conducted, and there was a significant Country Groups' solving time × Context interaction, $F\ (1, 68) = 8.32$, $p < .05$. In order to determine whether both countries' children's solving time differed across the two contexts, simple main effect tests were also conducted. There was a significant effect of country group's solving time found for the OA problems: $F\ (1, 68) = 5.22$, $p < .05$, but not for the WA items.

4.3 Strategy use

A chi-square test was performed to determine the strategy used by the children during problem solving across the two contexts. The test did not show any significant relationship between the children' strategy use and the contexts, except for OA's Level C ($\chi^2(1) = 5.307$, $p<.05$). In other words, only at OA's level C, were Japanese children more likely to use covert strategies than overt strategies (Table 2). Whereas, Singaporean children showed an opposite tendency. We excluded Level D in our analysis as very few children managed to solve Level D items.

5. Discussion

This study is the first of its kind to examine and reveal the contexts which Singaporean and Japanese young children were frequently exposed to in their early childhood settings' mathematical activities were likely to cause their arithmetic skills to differ not only from each other but also vary across the WA and OA contexts.

For instance, Singaporean children were more likely to be exposed to written arithmetic context in early childhood settings as their mathematical activities often revolved around written numerals on textbooks, and workbooks (Ikeda, & Yamada, 2006). The claim that children developed expertise in solving arithmetic in the context of their frequently participated mathematics activities (Ong, 2016; Rogoff, 2003; Taylor, 2013) was evident in this study as Singaporean children performed better in WA items, than OA items and the WA items by their counterparts (Figure 1). Conversely, most of the mathematical activities in the Japanese early childhood settings tend to require young children to rely greatly on their speech and hearing (Sakakibara, Hatano, & Inagaki, 2001). Therefore, Japanese children performed better in OA items, than WA items and the OA items by Singaporean children.

Similar to the above reason of the frequent exposure to written arithmetic context, Singaporean children, on average, took a shorter time to solve WA items, than OA items and the WA items by Japanese children. On contrary, Japanese children took a shorter time to solve OA items, than WA items and the OA items by their counterparts (Figure 2). Since solving arithmetic items requires one to correctly identify, and transfer the information from the stimulus to the working memory for processing (DeStefano, & LeFevre, 2004), this finding suggests that Singaporean children correctly identified and processed visually presented problem information faster than aurally presented information, whereas, Japanese children tend to exhibit the opposite tendency.

Next, prior to the experiment, we expected Singaporean children to use more overt strategies to solve OA items and more covert strategies for WA items, while Japanese children will exhibit the opposite tendency. Unexpectedly, young children in both countries used more covert strategies than overt strategies to solve both OA and WA items at Level A and B. This could be due to the fact that both levels of problems are easy to solve for a six-year-old child, and easy problems are usually solved by covert strategies (Bisanz et al 2005).

The only distinct difference between these groups of young children was at Level C’s OA items where the problems became more challenging hence children used a different approach to resolve this. Japanese children who were more proficient with OA items used more covert strategies than overt strategies, whereas, Singaporean children took the reverse strategy by using more overt strategies instead.

As for Level C’s WA problems, Singaporean children who were more proficient with WA items used covert strategies more than overt strategies. Unexpectedly, although Japanese children were less proficient with WA items, they used more covert strategies instead of overt strategies. During the study, many reported that they might get teased by their peers for using fingers or circular cards to count (overt strategies), therefore they tried to avoid using overt strategies even though concrete referents are helpful as a form of support to solve difficult WA items. This therefore led them to make more mistakes when solving those items. This unexpected finding could also suggest that besides arithmetical abilities, social factors such as peer pressure might also influence the types of strategies a child chooses to solve the arithmetic problems.

6. Implication

In this study, we administered the addition tests to the young children visually and aurally in order to determine how their arithmetic skills fare in each context. Taking into consideration all the data from both countries' preschoolers, there was concrete evidence that Singaporean children were more proficient in solving arithmetic visually instead of aurally, whereas Japanese children displayed the opposite tendency. These findings are beneficial for Singaporean and Japanese early childhood educators and also elementary school teachers because we had identified which context the children were less proficient or more proficient when dealing with arithmetic. Since WA and OA are two of the most basic and important contexts in which children learn mathematics in schools, being less proficient in any one of the contexts is likely to hinder children's learning of mathematics. Therefore, in order to ensure both countries' preschoolers become equally proficient in both contexts as they proceed to elementary school, early childhood educators can integrate more elements related to the less proficient context into their mathematical activities with the children. In addition, elementary school teachers can make the mathematical content easier to understand when teaching in the less proficient context.

Next, although this study centered on Singaporean and Japanese children, the findings can also be beneficial for other early childhood educators in countries where their early childhood education systems share similar frameworks with those of Singapore and Japan.

Furthermore, through this study, it is advantageous for other countries' early childhood educators to understand that the context and also the types of mathematical activities which their young children were frequently exposed to in their early childhood settings, may also influence the children's arithmetical competencies. This may help to raise an even higher awareness level among early childhood professionals on the importance of their roles in designing of mathematical activities and supporting young children in these activities.

7. Limitation and Future research directions

Firstly, as with other studies, this study also had some limitations. For instance, data was collected from a relatively small number of young children in Singapore and Japan, and therefore, it was not possible to generalize the results. A much larger sample size of young children would be required. In addition, it might be more insightful and interesting if other countries' young children are also included as participants for investigation in future studies.

Secondly, this study suggested that the contexts of mathematical activities which Singaporean and Japanese young children were frequently exposed to in their early childhood settings influence their arithmetic skills differently. However, in order to further strengthen the above findings, future study that investigates the degree of exposure to the written and oral arithmetic contexts by both countries' children in their early childhood setting's mathematical activities is required. For instance, future study might want to expand their area of investigation beyond arithmetic to other aspects of mathematics, such as counting, measurement, geometry, and pattern since young children do not only deal with arithmetic in their mathematical activities.

Another area which is worth investigating to strengthen the above outcome is the issue on the link between young children's mathematical development and their social interaction with teachers and peers in early childhood settings. Although Vygotskian theory holds that children's development is shaped by social interactions with others and how children co-construct their knowledge through symbols, and artefacts with the guidance from the adults (Carruthers & Worthington, 2006; Ong, 2016; Rogoff, 2003), little is known about the process of how young children's social interactions in early childhood settings influence their mathematical development. As we look deeper into this progressive issue, it leads us to ponder upon a number of key questions, such as how do these young children learn and share meanings of mathematical symbols and artefacts during their engagement in joint mathematical activities with teachers or peers, and how does this process shape the way young children construct their mathematical knowledge in their own culturally valued way. In order to advance our understanding of young children's mathematical development, especially in the context of early childhood settings, it is therefore crucial to answer these key questions in future studies.

Finally, we believe work addressing early childhood settings still plays a very important role in contributing evolving, exceptional and progressive insights into the discussion of young children's mathematical development. This topic continues to leave lots of room for researchers, teachers, and other education stakeholders to debate further.

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Table 1.

Descriptions of the WA and OA problems

Level	Written Arithmetic (WA)	Oral Arithmetic (OA)	Details
A	3+4, 7+1, 2+6	2+3, 5+1 3+6	Single digit operands, sum less than 10
B	5+10, 9+10, 10+12	2+10, 10+8, 14+10	At least one operand which is 10
C	16+12, 13+11, 21+17	12+13, 17+11, 23+14	Absence of carrying operations
D	17+16, 23+19, 36+28	15+17, 25+16, 33+29	Presence of carrying operations

Table 2.

Frequency and Percentage of Covert and Overt strategies

	OA		**WA**	
	Japan	Singapore	Japan	Singapore
Level A				
Covert Strategy	78	69	70	88
(%)	(75.73)	(72.63)	(77.78)	(86.27)
Overt Strategy	25	26	20	14
(%)	(24.27)	(27.37)	(22.22)	(13.73)
Total	103	95	90	102
(%)	(100.00)	(100.00)	(100.00)	(100.00)
Level B				
Covert Strategy	70	57	46	79
(%)	(73.68)	(67.06)	(76.67)	(79.80)
Overt Strategy	25	28	14	20
(%)	(26.32)	(32.94)	(23.33)	(20.20)
Total	95	85	60	99
(%)	(100.00)	(100.00)	(100.00)	(100.00)
Level C				
Covert Strategy	44	19	9	50
(%)	(70.97)	(46.34)	(64.29)	(66.67)
Overt Strategy	18	22	5	25
(%)	(29.03)	(53.66)	(35.71)	(33.37)
Total	62	41	14	75
(%)	(100.00)	(100.00)	(100.00)	(100.00)

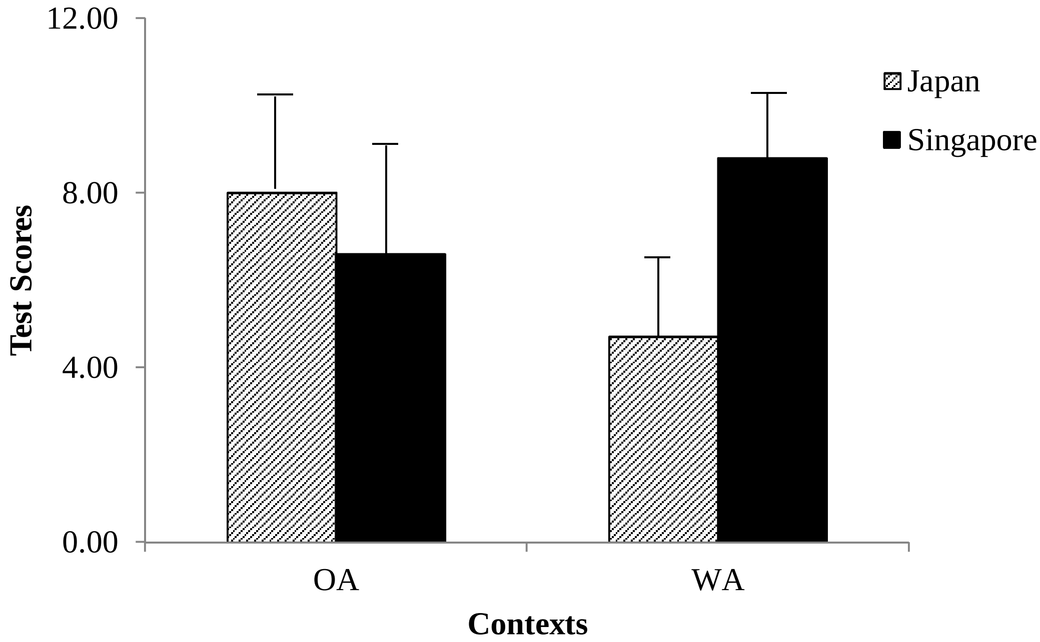

Figure 1.
Test scores over the two contexts

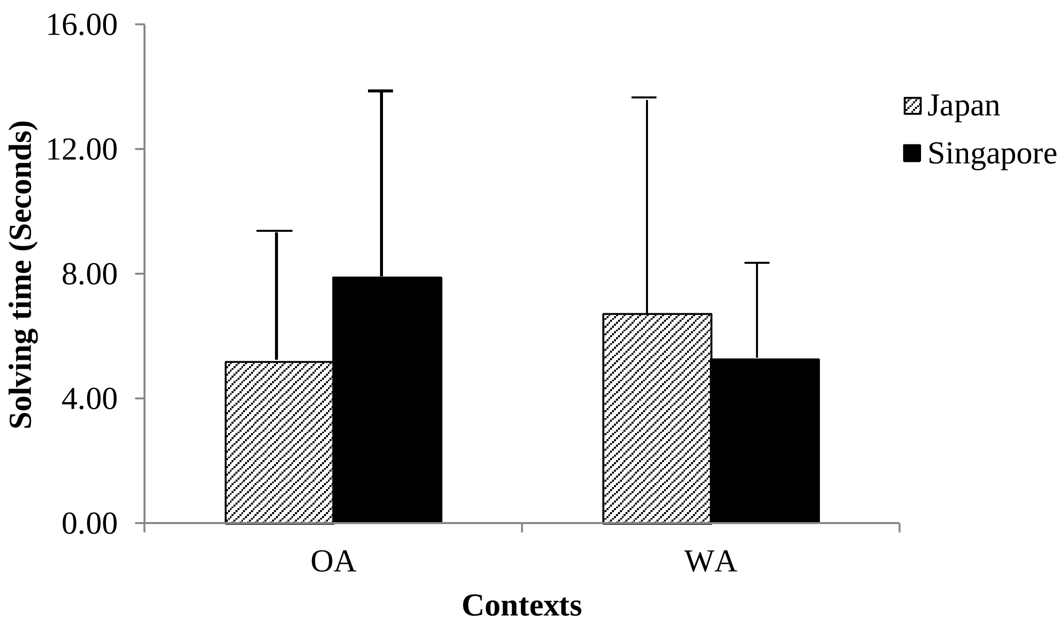

Figure 2.
Solving time over the two contexts

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