International Journal of Education in Mathematics, Science and Technology (IJEMST)

www.ijemst.com

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ISSN: 2147-611X

To cite this article:

Jung, E., Zhang, Y., & Chiang, J. (2019). Teachers' mathematics education and readiness beliefs, and kindergarteners' mathematics learning. *International Journal of Education in Mathematics, Science and Technology (IJEMST), 7*(2), 137-154. DOI:10.18404/ijemst.552416

IJEMST International Journal of Education in Mathematics, Science and Technology

Volume 7, Number 2, 2019 DOI:10.18404/ijemst.552416

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Article Info

Article History

Received:
18 January 2019

Accepted:
23 March 2019

Keywords

Mathematics education
Kindergarten children
Mathematics learning

Abstract

This study investigates kindergarten children's mathematics learning with a focus on the role of teachers' mathematics education and readiness beliefs, and home learning environment. Using structural equation modeling to estimate the individual differences in early mathematics learning, data from 5,845 kindergarteners was evaluated. Findings show that teachers' beliefs regarding what is important for children's preparation in mathematics selectively influenced what they taught in the classrooms for mathematics education and what children experienced in kindergarten. The results also reveal that children who were provided ample experiences in reading and singing activities at home, and more frequent math learning practices, problem-solving activities, and arts or life-related materials within the classroom showed greater math thinking skills and higher math achievement scores than those who were not provided such experiences. More reading and singing activities at home, math learning practices, problem solving activities, and use of art or life-related materials during the kindergarten year are encouraged to highlight kindergarteners' mathematics instruction and learning. What has a greater impact on mathematics learning in kindergarteners appears to be the kind of instruction that is planned and delivered, rather than teachers' beliefs regarding mathematics readiness.

Introduction

Children begin their kindergarten year equipped with different mathematics ("math") skills, and they progress in diverse ways during their kindergarten year through a variety of experiences (Edens & Potter, 2013; Kinzer, Gerhardt, & Coca, 2016; Ready, 2010; Wang, Shen, & Byrnes, 2013). Although all children are capable of learning math, some have the opportunity to engage in pertinent early experiences, while others do not (Cross, Woods, & Schweingruber, 2009). Researchers have noted that early math skills are one of the consistently significant predictors in children's later school outcomes (Bargagliotti, Gottfried, & Guarino, 2017; Duncan et al., 2007). A better understanding of the math learning experiences with regards to math skills development continues to be an important area of investigation in the field of early childhood education. Exploring the contributing factors to children's math skills is crucial.

Given the importance of math learning in children's development, numerous studies have highlighted the roles of teachers' beliefs and instructional practices on children's learning, separately or in combination. An array of research supports the argument that teacher beliefs are related with their instructional practices (Archambault, Janosz, & Chouinard, 2012; Hu, Fan, Yang, & Neitzel, 2017; Šapkova, 2014). Researchers have found that teachers' beliefs serve as an important educational environment for children, directly impacting students' academic experiences (Archambault et al., 2012). In contrast, there has been another set of studies that argue that teacher beliefs are not related with teaching practices (Francis, 2015; Graham et al., 1997; Raymond, 1997; Skott, 2001). These scholars report that teacher beliefs do not significantly influence kindergarten math teaching practices. With these mixed findings on this rarely investigated yet important issue, it is not yet clear in the educational field as to whether teacher beliefs matter or not in kindergarten math learning.

With regards to teachers' instructional practices, scholars have found that certain math instructional practices, such as involving students in math related verbal communications and math vocabulary usage, were stronger predictors than others for kindergarteners' math achievement (Firmender et al., 2014; Gottfried, 2016). Likewise, there could be certain practices that may be more helpful than others to children's math learning in

their kindergarten years. While no one would argue against the idea that the early math experiences that teachers and families provide for children serve as important factors in children's math learning during early childhood (Geist, 2009), the relationship between teacher beliefs in their practices and children's math learning, and the efficacy of certain instructional practices and family activities on children's math learning have not yet been frequently investigated. Even though teachers' beliefs and practices—as well as families' roles in children's learning—in early math learning have been studied separately or with older children, studies have rarely investigated these variables in combination to provide a clearer picture of the early mathematics learning experiences to understand the longer term impacts on math related achievement. If certain teacher practices and home activities are more helpful for children's math learning than others, and if these practices have a continuing impact on children's math achievement over time, then these practices have the potential to be important in children's math skills development. The current investigation has been designed to address this practical and pressing issue.

Teacher Beliefs regarding Math Readiness and Practices

Researchers have defined school readiness as the "pre-kindergarten child characteristics and skills that have predicted positive academic and behavioral adjustment to school" (Bierman, Domitrovick, & Darling, 2013, p. 148). This concept of school readiness has been extensively documented in the previous literature, given its significance in children's learning (Quirk, Grimm, Furlong, Nylund-Gibson, & Swami, 2016; Farran, 2011; Quirk, Nylund-Gibson, & Furlong, 2013). However, these studies have tended not to focus on teachers' beliefs, with specific regards to math readiness, classroom practices, and children's learning. Beliefs guide and determine behaviors (Pajares, 1992). Especially, teachers' beliefs guide their educational planning, instructional decisions and teaching practices in the classroom (Tondeur, Hermans, Van Braak, & Valcke, 2008). However, what teachers believe in children's readiness in math and what these teachers actually do in classrooms to teach math to children remains mostly unknown.

Teacher beliefs can be interpreted using cognitive constructivism framework, as beliefs are regarded as an influence on the way in which teachers believe, act, and implement their beliefs through their interactions with their environment (Haney & Bissonnette, 2011; Hegde & Cassidy, 2009). Cognitive constructivism here indicates that individuals' beliefs construct what they observe and interpret, and how they behave (Hegde & Cassidy, 2009). As cognitive constructivism theory implies, teacher beliefs regarding math readiness are expected to influence their teaching practices (Echevarria & Graves, 2007; Eggen & Kauchak, 2010). Teachers may believe that children's need to be prepared in math skills and developing good problem-solving skills is important for readiness for school math. With regard to specific math knowledge and skills that children are expected to learn in kindergarten, the National Council of Teachers of Mathematics (NCTM) has suggested focal points for kindergarteners that emphasize numbers and operations, geometry, and measurement (Geist, 2009; NCTM, 2000). Proficiencies in math skills that are expected upon kindergarten entry include representing, comparing, and ordering whole numbers (i.e., numbers and operations), describing shapes and space (i.e., geometry), and ordering objects by measurable attributes (i.e., measurement). These skills commonly serve as a guide for teachers' beliefs regarding math readiness and what is important for children to be ready for math (NCTM, 2006).

Scholars have suggested that there are close relations between teachers' beliefs and the instructional approaches that they employ (Hu et al., 2017; Kukliansky, Shosberger, & Eshach, 2016; Lambert, Abbott-Shim, & Sibley, 2006; Wilkins, 2008). Teachers who have specific beliefs regarding what are important elements in readying children for school math may offer different math-related approaches and practices, depending on their beliefs. Wilkins (2008) noted that teachers provided different experiences to their students according to their different beliefs about children. He showed that teachers' beliefs were significantly related to the curriculum employed by the teachers and to the instructional approach that the teachers utilized. Sarama and DiBiase (2004) also indicated that teachers' beliefs are related to how specific content was delivered in the classroom. Teachers' beliefs are related to how long they have provided math-related activities or how frequently they employed math instruction (Cassidy & Lasrence, 2000; Lambert et al., 2006; Wilkins, 2008). Šapkova (2014) further demonstrated that teachers' beliefs are related to their teaching practices in math, and that teaching practices are related to a diverse set of students' math achievement in different ways.

Other researchers have suggested that there may be a disconnect between teachers' beliefs and their classroom practices in math (Francis, 2015; Graham et al., 1997; Mohamed & Al-Qaryouti, 2016; Skott, 2001). For example, Graham et al. (1997) showed that teachers believed in the importance of children having relevant math knowledge for successful learning, yet these teachers' actual classroom practices did not include much math

instruction. The possible disconnect between teachers' beliefs and classroom practices in math may be reflected in math-related practices in kindergarten classrooms, including the amount of time, types of practices, and the frequency and duration of time devoted to instructional methods with math content (Boonen, Van Damme, & Onghena, 2014). Yet the possibility of a connect or disconnect has thus far not been studied in detail. The current study seeks to obtain clarity on this issue.

Early Experiences and Children's Math Learning

Children may have different experiences depending upon the nature, duration, materials and resources that teachers and parents employ. A broad range of research suggests that classroom routines and practices, technology use, math manipulatives, and home activities, among others, are generally regarded as important variables in kindergarten children's math learning (Clements, 2002; Furner & Berman, 2003; Geiger, Goos, & Dole, 2015; Hitchcock & Noonan, 2000; Jacinto & Carreira, 2017; Kinzer et al., 2016; Sarama & DiBiase, 2004). For children to become effective problem solvers and have proficient math abilities, they require time to consider problems, attempt various strategies, and discuss the problems with their peers, teachers, and other adults (Charlesworth & Lind, 2013; Hou & So, 2017). Ecological perspectives have indicated that an individual's learning occurs in myriad ways and in various contexts (Hayslip, 2014; Leu, 2008; Pelech & Pelech, 2013). Classroom and home learning environments, among others, are critical contexts that need to be carefully considered in combination, as children engage in diverse learning experiences (Cozza & Oreshkina, 2013; Gottfried & Gee, 2017; Hampden-Thompson & Galindo, 2017; Schütte, 2014). In a microsystem of the ecological system, families and classrooms are one of the most proximal environments, and this environment closely interacts with children at home and in school settings to promote their learning and development (Bronfenbrenner & Morris, 1998). Through interactions among home, classrooms, and children, children are influenced by this proximal environment to learn basic skills including math skills (Eccles & Roeser, 2011).

Researchers have noted that the frequency and duration of math instruction is important to children's math learning. They have also noted that improving math concepts and operations in kindergarten is associated with children's math learning (Fuson & Briars, 1990; Jung, 2014; Rittle-Johnson, Fyfe, & Loehr, 2016). Young children performed better when they learned in classrooms where teachers used a concrete-spatial approach, such as involving manipulatives and math related games in their practices (Heshmati, Kersting, & Sutton, 2018). This use of a concrete-spatial approach over time and in the early stages of development can associate meanings and build connections for kindergarten students (Jung, 2014). Given that children learn more effectively in classrooms where teachers provide more opportunities for using manipulatives during math learning (Furman, 2017; Saam & Nowak, 2005), researchers have suggested that teachers consider the concepts and skills that are necessary to make clear connections between mathematical ideas and manipulatives, which will provide opportunities for improved achievement in math (Ball & Bass, 2003).

The influences of classroom resources and the materials or physical elements of a classroom have been studied separately in relation to children's learning outcomes; for example, several researchers have examined classroom materials including art- and life-related materials, music and movies (Beyer & Davis, 2008; Clemens & Hamakawa, 2010; Guerrettaz & Johnston, 2013; Schaefer, 2016), and classroom technology (Blackwell, Lauricella, Wartella, Robb, & Schomburg, 2013; Kenworthy-U'Ren & Erickson, 2009; Ozerbas & Erdogan, 2016). However, the classroom practices in conjunction with classroom resources and materials have rarely been studied (Logan & Sachs, 1992; Mashburn et al., 2008). This is another important issue that the current investigation seeks to address.

There are various activities that parents engage in with their children at home before they enter formal schooling that influence children's learning (Foster, Froyen, Skibbe, Bowles, & Decker, 2016; Pianta, LaParo & Hamre, 2008). Studies have shown that shared family activities are major contributors to children's growth and learning (Cannon & Ginsburg, 2008; Duncan et al., 2007). The benefits in children's development are evident when parents and children spend more time together and are involved in activities such as reading, singing, or engaging in physical activities (Benson & Mokhtari, 2011; Bryant & Zick, 1996; Ferretti & Bub, 2017). Family economic status is also known to strongly correlate to child outcomes, as it influences the quality of living, learning environment, parenting practices, and parent-child activities (Bradley & Corwyn, 2002; Crampton & Hall, 2017). Children from less affluent homes experience different teaching practices and instructional materials, compared to children from relatively affluent backgrounds. Bodovski and Farak (2007) showed that children from economically disadvantaged families or families with a low socioeconomic status (SES) have a relatively low level of instructional activities, as well as a lack of learner focused instructional practices. Thus, poverty may adversely impact children's math acquisition (Georges, 2009; Rittle- Johnson, Fyfe, Hofer, &

Farran, 2017). Although it is well established that parents contribute significantly to their children's early development through family involvement, it is not yet clear whether specific family activities, when coupled with teacher beliefs and practices at school, are related to children's math skills in kindergarten.

The purpose of this study, therefore, was to investigate whether teachers' beliefs regarding what is important for children to know to be ready for kindergarten math relates to their instructional approaches in kindergarten classrooms, and how children's early experiences at home and their kindergarten math experiences are related to their math performance in kindergarten and first grade.

Method

Participants

The children in this study participated in a large longitudinal study, the Early Childhood Longitudinal Study-Kindergarten (ECLS-K). This dataset focused on children's school education, development, and achievement starting in kindergarten and ending with eighth grade, thereby examining children nationwide from kindergarten through middle school (Tourangeau, Nord, Le, Sorongon, & Najarian, 2009). The data was collected using multiple methods with multiple informants, including parents, principals, teachers, and students (National Center for Education Statistics, 2009).

This sample included 5,845 children who were attending kindergarten at the time of data collection. We examined only kindergarten children who did not change schools or repeat grades for the duration of the study to avoid any confounding effects from school changes (M_{age}= 5.8 years, *SD* = 4.89 months, 3,239 boys, 2,606 girls, age range: 4.5-6.6 years). In this sample, 63.2% of children were White, 13.3% were Black or African American, 14.4% were Hispanic, and 4.6% were Asians. The rest (4.7%) were Native Hawaiians, American Indians, or identified as more than one race. Among the children, 85.1% of them indicated their native language was English, while 10.1% reported English was not their native language. The majority of the children (88.4%) attended public schools while 21.6% attended private schools.

Regarding family economic backgrounds, one third (31%) of the families were living in poverty, another third of the families (32%) were working class, approximately 29% of the families had a yearly income greater than $50,000 but less than or equal to $100,000, and 7.7% of the families had a yearly income over $100,000. The study also included information regarding children's teachers (74 men, 5,130 women, M_{age}= 35.65 years, *SD* = 9.91 years, age range: 18-52 years). Among the teachers, 31.1% reported they had a high school degree, associate degree, or bachelor's degree, 30.9% stated they had one year beyond a bachelor's degree, and 27.2% had a master's degree. Table 1 presents detailed information regarding the demographics of the children, families, and teachers who participated in this study.

Measures

A set of scales assessing kindergarten teachers' math readiness beliefs, math teaching, math activities and materials for teaching in the classroom, and children's math thinking skills were included in the study. These variables were drawn from teachers' questionnaire in ECLS-K dataset and served as the predictors of children's math achievement. Another scale on home activities was drawn from parents' questionnaire. Home activities were also hypothesized to predict children's math achievement. Family income served as a control variable.

Kindergarten Teachers' Math Readiness Beliefs

Kindergarten teachers' math readiness beliefs (teacher beliefs hereafter) were measured when the children were near the end of kindergarten year and reflected the teachers' beliefs, reported by teachers, regarding what is important for children to know to be ready for kindergarten math. Teachers' responses were on a 5-point scale (1 = *not important* and 5 = *essential*). Thirteen items reflecting teachers' beliefs on what is important for children to know to be ready were drawn from teachers' questionnaire in ECLS-K dataset. We executed a factor analysis on this 13-item scale to identify items relevant to math readiness. Based upon the results from the factor analysis, two factors were derived via Varimax method in exploratory factor analysis. One factor reflected socio-emotional and language readiness, and the other factor reflected math readiness beliefs. Five items related to math readiness with factor loadings over 0.50 (Costello & Osborne, 2005) were derived (i.e., whether or not

students: “finish tasks,” “can count to 20 or more,” “have good problem-solving skills,” “are able to use pencils and paint brushes,” and “can identify primary colors and shapes”). The reliability coefficient for the 5-item scale was $\alpha = 0.79$.

Table 1. Demographic information of children, family and teachers

Variable	*n*	*%*
Child		
Gender		
Boys	3,239	55.4
Girls	2,606	44.6
Composite race		
White, non-Hispanic	3,694	63.2
Black or African American, non-Hispanic	775	13.3
Hispanic, race specified	420	7.2
Hispanic, race not specified	418	7.2
Asian	267	4.6
Native Hawaiian, other Pacific Islander	22	0.4
American Indian or Alaska native	117	2.0
More than one race, non-Hispanic	126	2.2
Not ascertained	6	0.1
Language speaking		
English speaking	4,974	85.1
Non-English speaking	593	10.1
Not ascertained	49	0.8
Family Backgrounds		
Family income (yearly)		
Less than $25,000	1812	31
$25,000 to $50,000	1870	32
$50,000 but less than or equal to $100,000	1695	29
Over $100,000	450	7.7
Teachers Backgrounds		
Gender		
Male	74	1.4
Female	5,130	97.6
Composite Race		
White	4,653	86.7
Black or African American	323	6.02
Hispanic or Latino	276	5.15
Asian	54	1.07
Native American or Pacific islanders	58	1.08
Educational Attainment		
High school, associate degree, or bachelor	1,547	31.1
One year beyond a bachelor’s degree	1,538	30.9
Master’s degree	1,353	27.2
Education specialist or professional diploma	259	5.2
Doctorate degree	16	0.3
Not ascertained	257	5.2

Frequency and Duration of Math Teaching

The frequency and duration of math teaching was assessed through the teachers’ reports on the questions “How often and how much time do children in class typically work on lessons or projects in math related areas, whether as a whole class, in small groups, or in individualized arrangements? “This question was measured at the end of the children's kindergarten year. Teachers reported on a frequency based on a 5-point scale (1 = *never* and 5 = *daily*). The response scale for the duration of math teaching was on a 4-point scale (1 = *1-30 minutes a day*, 2 = *31-60 minutes*, 3 = *61-90 minutes*, and 4 = *more than 90 minutes*).

Classroom Math Activities

The items regarding classroom math activities were measured at the end of the children's kindergarten year. Teachers were asked to respond regarding the frequency of math activities in class using a 6-point scale (1 = *never* and 6 = *daily*). Three items examined manipulative activities related to learning math concepts, such as "work with geometric manipulatives," and "work with counting manipulatives to learn basic operations." The reliability coefficient for this 3-item scale was $\alpha = 0.72$. Another three items examined kindergarteners' ability to solve math problems such as "explain how a math problem is solved," and "solve math problems in small groups or with a partner." The reliability coefficient for this 3-item scale was $\alpha = 0.72$. The final two items examined the use of music and movements when learning math concepts in kindergarten, such as "use music to understand math concepts," and "use creative movement or creative drama to understand math concepts. "The reliability coefficient for this 2-item scale was $\alpha = 0.76$.

Classroom Materials or Resources

To examine the class materials or resources in the classroom that teachers generally utilized in class, teachers were asked to respond regarding the frequency of children using the materials or resources in class using a 6-point scale (1 = *not available* and 6 = *daily*). The measure was assessed as children were nearing graduation from kindergarten. In the ECLS-K data set, nine items were included for the classroom materials or resources battery. The factor analysis indicated that the following four items constituted one factor regarding arts or daily life materials in kindergarten: "art materials," "musical instruments," "costumes for creative dramatics/theater," and "cooking or food-related items." Another two items measured the frequency of using technology for watching broadcast programs. These were referred to as technology resources. The reliability coefficient for this 2-item scale was $\alpha = 0.54$. The remaining three items were not loading to any factor and therefore the current study does not include them. Given that alpha coefficients below 0.5 should be avoided (Kline, 1998) or improved upon before use in research, the reliability of these measures was acceptable.

Home Activities

We used seven items from parent interviews asking about a typical week in their home, including "how often do you or any other family member do the following things with the child." This measure was assessed when children were first entering kindergarten. There were three items about reading and singing activities at home: "reading books," "telling stories," and "singing songs." Responses were based on a 4-point scale (1 = *not at all* and 4 = *every day*) on a weekly basis. The reliability coefficient for this 3-item scale was $\alpha = 0.51$. The other four items were directly or indirectly related to physical play with children such as "playing games or doing puzzles with the child," and "building something or play with construction toys with the child." The reliability coefficient for this 4-item scale was $\alpha = 0.59$.

Math Thinking Skills

The ECLS-K data set provided an instrument battery assessing children's mathematical thinking skills (math skills, hereafter). Teachers reported their evaluations of each child based on their experiences with them, rating children's math thinking skills on a 5-point scale (1 = *not yet* and 5 = *proficient*). Six items were included in the study such as "sorts, classifies, and compares math materials by various rules and attributes, "orders a group of objects," and "solves problems involving numbers using concrete objects. The study included these items in two time points: the entrance of their kindergarten reflecting children's pre-knowledge in math (pre-math skills, hereafter), and the exit of their kindergarten to reflect the end of children's kindergarten year's knowledge in math (post-math skills, hereafter). Reliability coefficients for the 6-item teacher reported scales were $\alpha = 0.81$ for the pre-math skills and $\alpha = 0.90$ for the post- math skills.

Math Achievement Scores

Children's math achievement was measured using direct assessment and standardized math scores of IRT (Item Response Theory) scores. This instrument reflects children's overall math performance. Specifically, it was designed to assess children's understanding of numbers, properties, their spatial sense, and other math related concepts (National Center for Education Statistics: NCES, 2002). In the present study, the math IRT-based

scores ranged from 0 to 174 (NCES, 2002). The study drew child's math achievement scores at three time points: representing the kindergarten year (pre-math scores hereafter); the end of the kindergarten year (post-math scores hereafter); and a year later when children were in 1st grade (math scores in 1st grade hereafter). The reliability coefficients for the observed scores for the assessments of pre math scores, post math scores, and math scores in 1st grade were α = 0.91, α = 0.93 and α = 0.94, respectively. A more detailed description of the math test used in the current study can be found in the ECLS-K psychometrics reports (NCES, 2002).

Control Variable

The study included family income as a control variable. Each household was asked to report detailed-range income questions, and the detailed income ranged from $5,000 or less to $200,001 or more. ECLS-K data transferred the detailed income range into composite variables with mean of 0 and a standard deviation of 1.

Analytic Approach

This study applied a structural equation modeling (SEM) approach to address the research questions and to examine the hypothesized model. Figure 1 provides a visual representation of the present study's hypothesized model regarding the relationship between children's early math experiences and achievements. This approach is used to test the inter-correlations among latent variables simultaneously, which is also called path analysis (Kline, 2005). Before testing the variable association within the model, we used exploratory factor analysis (EFA) with Varimax rotation to first evaluate the measurement as a model component (Kline, 1998). Later in path analysis, we applied the maximum-likelihood (ML) method of estimation.

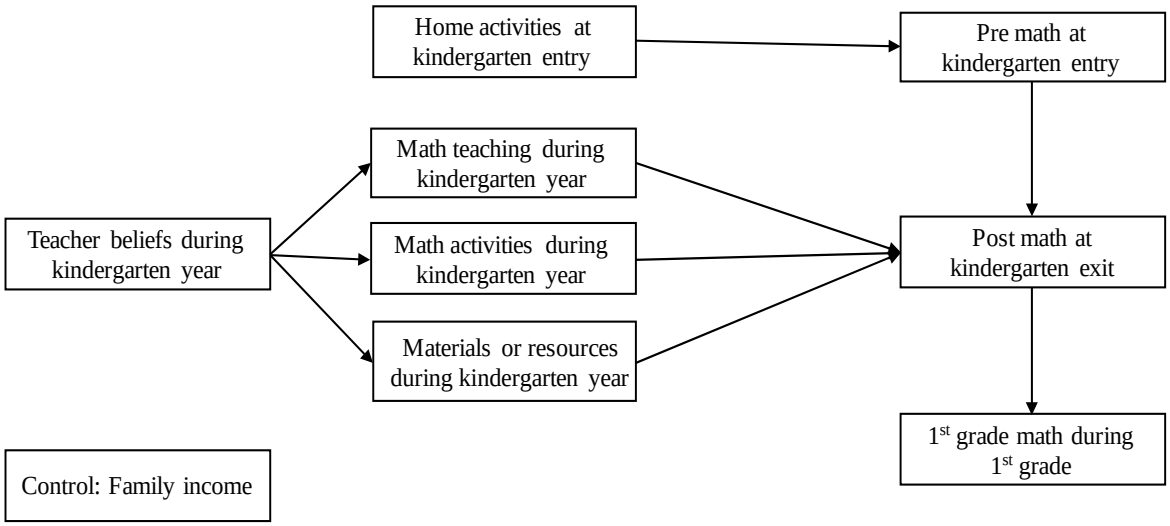

Figure 1. Hypothesized model of children's early mathematics experiences and achievements

The missing data for the current study variables were estimated using an Expectation Maximization (EM) imputation algorithm in SPSS (version 21). Given that, on average, 11% of the cases among each main variable were missing, this method is an appropriate strategy since it allows researchers to include all cases and it provides the least biased estimates (Little & Rubin, 2002; Widaman, 2006). The structural equation models were evaluated using several goodness-of-fit indices, including the goodness-of-fit-index with a Chi-square and the corresponding p-value, the Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA) (Hu & Bentler, 1999). However, as Chi-square can easily exceed the critical value in large samples, we also used fit indices that were less sensitive to sample size, including the Normed Fit Index (NFI) and the Tucker-Lewis Index (TLI) as other evaluations of model fit.

Results

Descriptive Analysis

The current sample showed that teachers believed finishing tasks, counting to 20 or more, problem-solving, and other items included in the study were somewhat important for children to be ready for kindergarten math (*M* = 3.11, *SD* = 0.63). Teachers, on average, indicated their frequency of math teaching as four times a week to daily (*M* = 4.59, *SD* = 1.70), and the duration as more than 30 minutes, but less than 60 minutes (*M* = 1.44, *SD* = 2.09). Regarding classroom math activities, teachers, on average, reported they had manipulative activities more than twice a week, but less than four times a week (*M* = 4.50, *SD* = 0.86); solved math problems around three times a month to once a week (*M* = 3.71, *SD* = 1.17); and applied music and movement to learn math more than once a month but less than three times a month (*M* = 2.60, *SD* = 1.28). For classroom materials or resources, teachers reported they used arts- or life- related materials approximately two or three times a month (*M* = 3.14, *SD* = 1.31), and almost never used TV or VCR (*M* = 2.22, *SD* = 1.40). For home activities, parents reported they did reading or singing activities with their children three to six times a week (*M* = 2.98, *SD* = 0.63) and physical play more than twice, but less than six times a week (*M* = 2.59, *SD* = 0.59).

Table 2. Means, standard deviations, and bivariate correlations of study variables

Variables	1	2	3	4	5	6	7	8
1. Family income	1							
2. Teacher beliefs	-.025	1						
3. Math teaching frequency	-.046***	.019	1					
4. Math teaching duration	-.057***	-.002	.406***	1				
5. Manipulative activities	-.057***	-.007	.031*	.066***	1			
6. Solving problems	-.029*	.044**	-.015	.021	.430***	1		
7. Music and movement	-.069***	.036**	-.033*	-.056***	.369***	.331***	1	
8. Arts or life materials	.088***	-.048***	.099***	.042**	.159***	.140***	.196***	1
9. Technology	-.055***	.089***	.025	.028*	.093***	.111***	.166***	.292***
10. Reading or singing	.171***	.004	.019	-.013	-.015	-.009	-.011	.023
11.Physical play	.079***	.008	.004	-.006	.016	.01	.007	.026*
12.Pre math skills	.181***	-.016	.005	-.015	-.134***	-.117***	-.125***	.021
13.Pre math scores	.424***	-.001	-.009	-.024	-.047***	-.021	-.067***	.043**
14.Post math skills	.277***	.019	-.006	.002	-.014	.045**	-.018	.037**
15.Post math scores	.411***	.007	.001	-.021	-.041**	.011	-.056***	.058***
16.Math scores in1st grade	.392***	-.004	.008	-.017	-.026*	.003	-.043**	.068***
M	0.00	3.11	4.59	1.44	4.50	3.71	2.60	3.14
SD	0.82	0.63	1.70	2.09	0.86	1.17	1.28	1.31
Range	0-1	1-5	1-5	1-3	1-6	1-6	1-6	1-6
Variables	9	10	11	12	13	14	15	16
9. Technology	1							
10. Reading or singing	-.013	1						
11.Physical play	.012	.460***	1					
12.Pre math skills	-.041**	.037**	.029*	1				
13.Pre math scores	-.031*	.135***	.065***	.259***	1			
14.Post math skills	-.042**	.083***	.023	.305***	.451***	1		
15.Post math scores	-.028*	.112***	.064***	.245***	.813***	.470***	1	
16.Math scores in1st grade	-.015	.097***	.057***	.216***	.697***	.445***	.763***	1
M	2.22	2.98	2.59	3.43	28.33	3.88	39.33	64.81
SD	1.40	0.63	0.59	1.49	10.94	1.02	13.63	19.15
Range	1-6	1-4	1-4	1-5	0-96	1-5	0-96	0-96

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

In terms of children's math achievement scores, the sample set indicated an average math score of 28.33 (*SD* = 10.94) at the start of kindergarten year, 39.33 (*SD* = 13.63) at the end of kindergarten year, and 64.81 (*SD* = 19.15) in first grade. According to the report from the National Center for Education Statistics (2002), the national representative data on children's math achievement scores in the same standard tests at these three time points are 30.02 (*SD* = 10.87) at the start of the kindergarten year, 43 (*SD* = 11.55) at the end of the kindergarten year, and 62.72 (*SD* = 13.06) in first grade. Compared to the national data on math standard scores for kindergarteners, the sample set in this study indicated slightly lower math achievement at these three time points. Table 2 presents the means, standard deviations, and correlation matrix among the study variables.

Associations between Key Study Variables

An examination of all of the main variables in the current study revealed an overall trend suggesting that there was a positive relationship between kindergarten teachers' beliefs and teachers' math instructional practices in class; however, the results did not indicate a significant association between teachers' beliefs and children's math skills, as reported by teachers, or math achievement scores based on a direct assessment. The frequency and duration of teaching for math in the classroom was not significantly correlated with children's math skills (post-math skills) or achievement scores (post-math scores) at the end of kindergarten or 1st grade (math scores in 1st grade). Children's participation in reading and singing activities at home was significantly correlated with their post math skills and post achievement scores. Children's pre- math skills were significantly correlated with their subsequent math skills and achievement scores. More detailed relations between the selected variables are presented in the following section, based on the structural equation model.

Teachers' beliefs showed no association with math teaching frequency ($r = 0.02$, $p > 0.05$) or duration ($r = 0.00$, $p > 0.05$). Teachers' belief showed no association with manipulative activities ($r = -0.01$, $p > 0.05$), but did indicate a positive association with solving math problems ($r = 0.04$, $p < 0.01$), and music and movement activities ($r = 0.04$, $p < 0.01$). Regarding classroom materials and resources, teachers' beliefs showed a negative relationship with the use of arts- or life-related materials ($r = -0.05$, $p < 0.001$); and a positive association with using technology (e.g., TV and VCR) ($r = 0.09$, $p < 0.001$). Home reading and singing showed a positive association with both children's pre-math skills ($r = 0.04$, $p < 0.01$) and pre-math achievement scores ($r = 0.14$, $p < 0.001$). Home physical play showed a positive association with pre-math skills ($r = 0.03$, $p < 0.05$) and pre-math achievement scores ($r = 0.07$, $p < 0.001$). At the end of the kindergarten year, both math teaching frequency and math teaching duration showed non-significant association with children's post-math skills or post-math scores. Manipulative activities were non-significantly associated with post-math skills, but they were negatively associated with post-math scores ($r = -0.04$, $p < 0.01$). Solving problems was positively associated with post-math skills ($r = 0.05$, $p < 0.01$), but it was non-significantly associated with post-math scores ($r = 0.01$, $p > 0.05$). Music and movement was non-significantly associated with post-math skills, and was negatively associated with post-math scores ($r = -0.06$, $p < 0.001$). Using arts or life materials was positively associated with both post-math skills ($r = 0.04$, $p < 0.01$) and post-math scores ($r = 0.06$, $p < 0.001$), while using technology was negatively associated with both post-math skills ($r = -0.04$, $p < 0.01$) and post-math scores ($r = -0.03$, $p < 0.01$). Children's pre-math skills and scores were positively associated with their post-math skills ($r = 0.31$, $p < 0.001$) and scores ($r = 0.81$, $p < 0.001$).

Testing the Structural Model

The model showed a good fit for the data: χ^2 (1,409, $N = 5{,}845$) = 5806.49, $p < 0.001$; NFI = 0.97; CFI = 0.98; TLI = 0.97, RMSEA = 0.023, 90% CI = [0.022, 0.024]). Although we expected a non-significant Chi-square value, given the sensitivity of the Chi-square with large samples, a significant Chi-square was also acceptable. Other model fit criteria indices, including the root mean square error of approximation (RMSEA) (< 0.06), CFI (> 0.95), and TLI (> 0.95), all indicate that the model provides a reasonable fit for the data (Hu & Bentler, 1999). As shown in Figure 2, we presented the focal associations between classroom variables and children's math skills and achievement, as well as the associations between home activities and children's math skills and achievement after controlling for family income. Table 3 presents the standardized factor loadings for each latent variable. Most of the factor loadings for the observed variables to the underlying latent variables were statistically significant ($p < 0.05$) with factor loadings greater than 0.45 in the anticipated direction (Costello & Osborne, 2005).

Relations between Teachers' Math Readiness Beliefs and Their Practices

Examining the structural components of this model, the results indicated that kindergarten teachers' math readiness beliefs were only selectively related to teachers' practices in the classroom, and thus children's experiences in the classroom. Teachers' math readiness beliefs were positively related to children's math problem-solving activities ($\beta = 0.04$, $p < 0.01$) and their use of the technology to watch broadcast programs ($\beta = 0.13$, $p < 0.001$), whereas this variable was negatively related to children's use of the arts or daily life materials ($\beta = -0.06$, $p < 0.001$). These results suggest that when kindergarten teachers have strong beliefs regarding the importance of preliminary math skills, they are more likely to have children participate in math problem-solving activities and use materials such as VCRs or TVs. Teachers' math beliefs, however, were not significantly

associated with their frequency and duration of math teaching (β = 0.01, p = 0.35), manipulative activities (β = -0.02, p = 0.09), or their use of music and movement activities to learn math (β = 0.02, p = 0.11).

Table 3. Factor loadings for scales in current study

Scales	***β***
Kindergarten teachers' math readiness beliefs	
Finish tasks	.50
Can count to 20 or more	.76
Has good problem-solving skills	.57
Is able to use pencils and paint brushes	.71
Identifies primary colors and shapes	.73
Frequency and duration of math teaching	
How often children work on lessons or projects in math topic areas in class	.72
How much time children work on lessons or projects in math topic areas in class	.56
Manipulative activities	
Work with geometric manipulatives	.63
Work with counting manipulatives to learn basic operations	.70
Play math-related games	.71
Solving problems	
Explain how a math problem is solved	.64
Solve math problems in small groups or with a partner	.65
Work on math problems that reflect real-life situations	.74
Music and movements	
Use music to understand math concepts	.73
Use creative movement or creative drama to understand math concepts	.83
Arts or life materials	
Art materials	.59
Musical instruments	.49
Costumes for creative dramatics/theater	.58
Cooking or food-related items	.59
Technology	
VCR resources	.65
TV resources	.58
Reading or singing	
Read books to your child	.57
Tell stories to your child	.61
Sing songs with your child	.39
Physical play	
Help child to do arts and crafts	.50
Play games or do puzzles with child	.57
Build something or play with construction toys with child	.53
Play a sport or exercise together	.46
Pre math skills	
Sorts, classifies, and compares math materials according to various rules and attributes	.62
Orders a group of objects	.69
Shows an understanding of the relationship between quantities	.74
Solves problems involving numbers using concrete objects	.69
Demonstrates an understanding of graphing activities	.60
Uses instruments accurately for measuring	.60
Post math skills	
Sorts, classifies, and compares math materials according to various rules and attributes	.85
Orders a group of objects	.86
Shows an understanding of the relationship between quantities	.84
Solves problems involving numbers using concrete objects	.80
Demonstrates an understanding of graphing activities	.78
Uses instruments accurately for measuring	.56

Home Activities, Classroom Practices, and Children's Math Performance

As seen in Figure 2, home reading or singing was positively associated with children's directly assessed pre-math score (β = 0.13, p < 0.001); however, an association was not found with children's pre-math skills, as reported by teachers (β = 0.01, p = 0.76). Home physical play was not significantly associated with children's pre-math score (β = -0.04, p = 0.08) or pre-math skills (β = 0.03, p = 0.24). These findings suggest that the more children engaged in reading and singing songs at home, the more likely they were to show greater math performance in directly assessed math tests.

After controlling for the effects of children's pre-math skills and math scores, the frequency and duration of the kindergarten math teaching in class had a significantly positive association with the post math skills (β = 0.03, p < 0.01) and post achievement scores (β = 0.02, p < 0.05). Regarding children's math activities in the classroom, manipulative activities in class were negatively associated with children's post-math skills (β = -0.06, p < 0.001) and post- achievement scores (β = -0.03, p < 0.01); solving math problems was positively associated with children's post-math skills (β = 0.12, p < 0.001) and post-achievement scores (β = 0.05, p < 0.001). Music and movements activities were positively associated with children's post-math skills (β = 0.03, p < 0.05), but were not significantly associated with their post-achievement scores (β = 0.00, p = 0.85). Among the classroom math activities, solving problems showed the strongest positive association with children's post-math performance, including teachers' report of children's math skills and directly assessed math test scores.

For in-class materials and resources, children's use of arts- or life-related materials was found to be positively associated with their post-math skills (β = 0.04, p < 0.01) and post-achievement scores (β = 0.03, p < 0.01). Class materials involving a VCR or TV was negatively associated with children's post-math skills (β = -0.06, p < 0.001), and not significantly associated with their post-achievement scores (β = -0.02, p = 0.07). Taken together, this model explained 4.7% of the variance in children's pre-math skills, 19% of the variance in their pre math achievement scores, 28% of the variance in children's math skills at the end of their kindergarten year, and 67% of the variance in children's math achievement scores at the end of their kindergarten year.

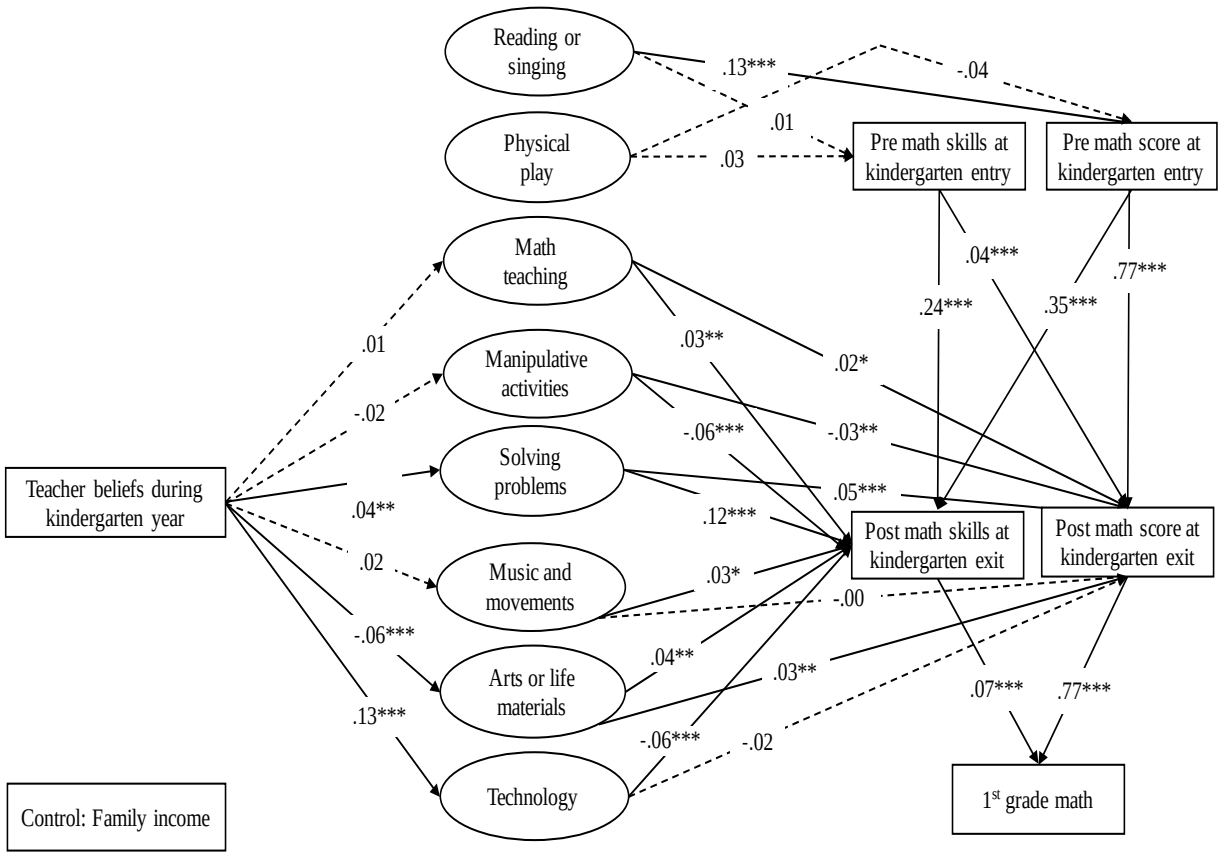

Figure 2. Results of the hypothesized model

Additionally**,** a closer examination into the role of children's pre knowledge in their later math skills and achievement reveals that children's pre math skills and scores significantly predicted their subsequent math skills and achievement scores in the last year of kindergarten and in 1st grade. Specifically, children's pre math skills upon kindergarten entry were positively associated with children's post math skills at the end of the kindergarten year (β = 0.24, p < 0.001) and children's pre math achievement scores upon kindergarten entry were positively associated with their post math achievement scores at the end of the kindergarten year (β = 0.77, p < 0.001). In addition, children's post math skills (β = 0.07, p < 0.001) and post achievement scores (β = 0.77, p < 0.001) at the end of kindergarten were significantly associated with their 1st grade math achievement scores (Figure 2). This model explained 59% of the variance in children's first grade math achievement scores.

Discussion

This study investigated whether teachers' beliefs regarding what is important for children to be ready for kindergarten math relate to their instructional approaches in kindergarten classrooms, and whether children's early experiences at home and math experiences in the classroom are related with their math performance in kindergarten and first grade.

Relationships between Teacher Beliefs and Math Education

One of the major findings from this investigation is that teacher beliefs regarding what is important for children to know to gain math skills were not related to the majority of the teaching practices we investigated, with the exception of problem solving activities and use of technology resources. Children in classrooms with teachers who have strong beliefs regarding math readiness skills were more likely to participate in math problem-solving activities, and more likely to use technology resources (Leu, 2008). The construct that we have used included problem-solving practices that focused on learning geometry, measuring, counting, and math-related games. As an example of actual problem solving practices for kindergarteners that can be used by teachers, some authors wrote that problem solving practices could consist of basic math problems involving addition and subtraction. Hence, children can be provided with a math problem similar to "Rebecca had three pockets. She puts two coins in each one. How many coins does she have in all?" A child then may draw three pockets, place two counters in each, and then count to find that there are six coins total" (Turner & Celedon-Pattichis, 2011, p. 150). Problem solving activities, as illustrated in this example, include practices that ask "what you do when you don't know what to do" (Davis & Keller, 2009, p. 17).

However, the frequency and duration of time that kindergarten teachers engaged in math teaching was not related with teacher beliefs. That is, teacher beliefs were not related to how long they provided math-related activities or how frequently they employed math instruction. The results also suggested that teachers' math beliefs were not related to their actual use of manipulatives, music, or movements when teaching math. Although the use of rhymes, chants, stories, and songs for kindergarten children is evident when teaching numbers and number operations (Ferretti & Bub, 2017; McClain & Cobb, 1999), such practices were not necessarily connected with what teachers believed regarding children's math readiness. This result supports the reports that teacher beliefs are mostly not related with their practices (Francis, 2015; Graham et al., 1997; Mohamed & Al-Qaryouti, 2016; Raymond, 1997; Skott, 2001). Regarding this result, we suspect that it may be difficult for kindergarten teachers to implement a math curriculum based on their individual beliefs, given the circumstances provided by their instructional teams or the classroom environment (Francis, 2015). The actualization of teaching beliefs may have more to do with classroom environment and other constraints than teachers' beliefs alone, supporting the findings of this study. As cognitive constructivism provides us a lens (Echevarria & Graves, 2007; Eggen & Kauchak, 2010) to understand the role of teacher beliefs in teaching practices, perhaps individual teachers have differing beliefs in their teaching environment that may differentially affect how they implement certain practices, and that may or may not be related with their specific beliefs (Hegde & Cassidy, 2009).

Relationships between Early Experiences and Math Performance

Another major finding from this investigation is that all the teaching practices under investigation have significant relationships, either positively or negatively, with children's math performance to varying degrees. Teacher's problem solving activities in kindergarten classrooms appear to be the most critical element that we need to consider in children's math learning. Children who were involved in more problem-solving activities

during kindergarten had stronger math skills and math achievement scores at the end of kindergarten. As Davis and Keller (2009) suggested, children need to be involved in problem-solving activities to engage with concepts that they are unfamiliar with. Our findings support the notion that children who were more involved in problem solving showed greater improvements in math skills. This finding also supports the previous study that indicated that teachers' use of more concrete-spatial approaches results in children's higher achievement scores (Jung, 2014).

Additionally, what was important in teacher's teaching and children's learning was that, for classrooms in which children were frequently exposed for long periods of time to math practices during kindergarten, and when they were frequently involved in music and movement, and arts or life related materials, children tended to show stronger math skills and math achievement scores by the end of kindergarten. Teacher beliefs on math readiness were minimally related to problem solving activities, but problem solving activities were strongly related with children's improved math skills and achievement scores. While teacher beliefs were related with teacher's technology use practices, showing broadcast programs using technology resources to children practice were not helpful in children's math learning. In the classrooms where teaches used more technology in teaching math, students actually showed lower levels of math performance.

In regards to home related factors, when children frequently read or sang at home they tended to show greater math skills and stronger math achievement scores at the beginning of the kindergarten year. This result supports the previous research that indicated the need to pay more attention to shared family activities among family members, as they are important elements in children's learning and academics (Cannon & Ginsburg, 2008; Duncan et al., 2007; Ferretti & Bub, 2017; Jung, 2014). More engaged parents who provide more home learning experiences and activities are likely to also do many things that ready a child for school. Among the many activities that families can be involved in, the result of this study highlights the relative importance of reading and singing with family members over physical activities, which serves as a more positive learning experience for children's math skills improvement. The findings of this study are consistent with previous findings that literacy and numeracy proficiency are related (Lopez, Gallimore, & Garnier, 2007; Vukovic & Lesaux, 2013), and that activities such as reading and singing help children grow mathematically. Physical activities were not helpful in specifically helping children's math performance.

Children's entry math skills are significantly and strongly related with their exiting math skills, and children's end of the kindergarten year math performance is strongly and positively related with their 1st year math performance. This indicates that early childhood math experiences at home and kindergarten are critically important in children's continued math performance, and home and teaching practices that are related to reading and singing activities, and problem solving activities at school may perhaps be the two most important practices worth exploring and focusing on at home and in kindergarten. Additionally, children require more math teaching practices time and use of arts and real life materials in kindergarten classrooms.
Notably, the current study revealed that children whose teachers provide more math teaching and involve them in problem-solving activities during their kindergarten year tend to have stronger math skills and math achievement scores at the end of kindergarten.

However, physical activities at home, the use of manipulatives, and the technology resources provided less positive or nonsignificant experiences for children with regard to their math skills development. The negative or nonsignificant association of physical activities at home, the use of manipulatives and technology resources with children's math skills development runs counter to past studies (Fuson & Briars, 1990; Jung, 2014). Although other reasons may explain these mixed findings in the literature, we suggest one possible reason that may explain this intriguing finding within this sample and research design. When children's problem-solving activities are considered simultaneously with the use of manipulatives or technology resources, we suspect that the efficacy of problem-solving practices may be much more robust than those of all other methods. In our study, we investigated multiple contributing factors in combination and found that problem-solving methods appeared to be the most effective way of teaching kindergarteners' math skills. However, past studies have not considered the role of problem-solving activities used simultaneously with physical objects, including math manipulatives (Fuson & Briars, 1990; Jung, 2014). Therefore, the use of manipulatives and the technology resources may be effective when they were used individually, but when problem-solving practices are used as one of the contributing factors, simultaneously with those other teaching practices, the benefits of problem-solving activities appear to outweigh the benefits of manipulatives or technology resources. This aspect warrants further exploration.

We interpret the findings of the present study cautiously for several reasons. In rapidly changing environments, children's math learning in kindergarten or their home teaching by parents may also experience changes with

regard to what teachers believe is important to teach or how parents teach math at home. Additionally, given that the dataset we utilized was already in existence, we examined the variables as they had already been measured. Although these variables were important, their use limits the nature of the concepts that could be explored. Another limitation of this study was its reliance on teacher and parental self-reports for many of the constructs of interest. Furthermore, math-related experiences may affect one subject area more than they do another (Evans & Shaw, 2008). Children who spend time in different types of educational and home settings during early childhood may experience vastly different outcomes. Although we controlled for the variable of family income in this study, other variables could have differed among the children, including their race/ethnicity, relations with their parents, and the types of guidance they received from their teachers, parents, and peers. Future research should consider the role of the children's background characteristics and the variations in the quality of their experiences.

Conclusion/Recommendations

Despite these limitations, the current study contributes to the literature regarding kindergarten teachers' beliefs, the roles of the classroom, and home environments when targeting early math skills as important content knowledge in kindergarten. By conceptualizing children's math experiences using cognitive constructivism (Echevarria & Graves, 2007; Eggen & Kauchak, 2010) and an ecological perspective (Hayslip, 2014; Pelech & Pelech, 2013), based on our findings, we suggest that four elements are important for children's math learning. These elements are reading and singing activities at home, the frequency and duration of math teaching, problem-solving activities in kindergarten classrooms, and arts or life-related materials in kindergarten classrooms. The more kindergarten children engaged in reading and singing activities, in math learning practices, in problem-solving activities, and with arts or life-related materials, the greater their math thinking skills and achievement scores. Although there were variations in the relative contributions of these elements to children's achievements and gains in math skills and scores, the current study demonstrated that these elements should be highlighted in kindergarten children's math instruction and learning. Children's math achievement is highly correlated with their subsequent math achievement in the early years. The relation between pre math skills and later math skills is significant and the correlation between pre math achievement scores and later math scores at the end of kindergarten is robust. Children's early childhood math experiences at home and school are crucially important in their future and continued math performance. Therefore, these activities are encouraged in children's math learning environment to support and optimize children's math skills improvement.

We conclude this investigation with our previous question regarding whether teacher beliefs matter or not in kindergarten math learning. This was the unresolved issue which this study sought to address. The results of this study support the argument that what matters more is the type of instruction that is arranged and implemented, not teacher's beliefs. Additionally, the more math instruction the better, so this data supports the case for professional development focused on better teaching. However, it was also important to note that teachers who have strong beliefs regarding math readiness skills tended to provide more math problem solving activities and children in such classrooms tended to have stronger math skills and math achievement scores by the end of kindergarten.

Our findings have important implications regarding crucial questions for improving teaching and learning. In developing professional development for teachers increased focus on teacher's instructional practices, rather than concern about the assumption that teacher's beliefs about children's learning, is critically important. What appears to be more critical in kindergarten children's math learning is math practice with problem solving activities, and more home activities that involve reading and singing activities. A better understanding of the relation between teachers' beliefs and math instructional practices in the kindergarten classroom environment will broaden the field's knowledge of how these factors can improve the teaching of math and affect the learning and achievement of young children.

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