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Investigating the associations of early numeracy activities and skills with mathematics dispositions, engagement, and achievement among fourth graders in the United Arab Emirates

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Abstract

The present study aimed to examine the relations of early numeracy activities and skills to mathematics dispositions, engagement, and achievement among 26,859 fourth graders in the United Arab Emirates who took part in the sixth cycle of the Trends in International Mathematics and Science Study (TIMSS) in 2015. The study also explored the mediating effects of mathematics dispositions and engagement on the relations between early numeracy activities and skills and mathematics achievement among these fourth graders. Results of path analyses, after controlling for participants' demographic and socioeconomic characteristics, indicated that early numeracy activities and skills were significantly and positively related to mathematics dispositions, engagement, and achievement. Further, results of mediational analyses suggested that confidence in mathematics had a significant mediating effect on the relations between early numeracy activities and skills and mathematics achievement. The findings of the study highlight the crucial role that early numeracy activities and skills play in enhancing fourth graders' mathematics dispositions, engagement, and achievement in the United Arab Emirates.

Keywords: Early numeracy activities and skills, Mathematics achievement, Mathematics engagement, Mathematics dispositions, TIMSS

Introduction

Compared with the mathematics performance of school children hailing from several countries across the globe, school children in the United Arab Emirates (UAE) have been displaying significantly lower performance on standardized mathematics assessments. For example, the UAE has been taking part in two major international standardized mathematics assessments, such as the Program for International Student Assessment (PISA; 15-year-old students) and the Trends in International Mathematics and Science Study (TIMSS; fourth and eighth graders), for a while. Students from schools across the

country performed considerably lower on the PISA and TIMSS mathematics assessments than did their peers in several other PISA and TIMSS participating countries (Mullis et al., 2016; Organization for Economic Cooperation & Development [OECD], 2016). The 15-year-old students in the Emirate of Abu Dhabi scored 412 points on the PISA 2015 mathematics assessment, compared to an average of 490 points in OECD-member countries (OECD, 2016). Furthermore, the 15-year-olds belonging to the Emirate of Dubai also scored significantly lower on the PISA 2015 mathematics assessment than did their counterparts from other countries across the world (467 points; OECD, 2016). In addition, fourth and eighth graders in the Emirate of Abu Dhabi who took part in the TIMSS 2015 mathematics assessments also scored significantly lower than the TIMSS mathematics scale average, 500 (419 and 442 points, respectively; Martin et al., 2016; Mullis et al., 2016). Furthermore, the number of low-performers in PISA mathematics (i.e., students who are performing below the proficiency baseline Level 2 in mathematics) has increased alarmingly in the country, at about twice the OECD average (48.7%; OECD, 2017). Brochu et al. (2017) posit that,

> *Mathematics and science are two learning domains universal to all school children across the world. Developing strong skills in mathematics and science can enhance the lives of individuals, helping them adopt healthy habits, make wise financial choices, and apply problem-solving skills effectively in their daily life. Mathematics and science knowledge is not only important at the individual level; it is also fundamental to our collective well-being as a society. Having a population that is well educated in mathematics and science is essential to improving the medical, housing, and transportation sectors, and to maintaining the health of our country's economy while promoting growth, managing environmental issues, and protecting Earth for future generations. (p. 10)*

Given the crucial role that mathematics plays in the lives of individuals, it is crucially important to examine the factors linked to their mathematics achievement. One of the proximal factors related to children's mathematics achievement is home numeracy environment, i.e., the different types of formal and informal numeracy activities available to children at home (see del Río et al., 2017; Napoli & Purpura, 2018; Niklas & Schneider, 2014; Thompson et al., 2017). Nevertheless, the degree and nature of parental involvement in their children's education may vary across cultures (see Antony-Newman, 2019; Frewen et al., 2015; Lee & Bowen, 2006; Suizzo et al., 2014). Antony-Newman (2019) in his meta-synthesis of 40 qualitative and quantitative studies on parental involvement among immigrant parents in North America, Europe, Asia, and Australia documented that immigrant parents tended to perceive parental involvement differently compared to their native-born counterparts. For example, he noted that in Canada, parents originating from Asia, Latin America and the Middle East focused on home-based involvement in children's early years (Antony-Newman, 2019). In addition, there is growing evidence to suggest that home numeracy environment may also vary across cultures (see Cankaya & LeFevre, 2016; Skwarchuk et al., 2016). Cankaya and LeFevre (2016) attributed such differences to the variability across cultures in a multitude of experiential factors, such as "the quality of home learning environment, parents' academic expectations and attitudes towards numeracy, children's early involvement in numeracy-related activities,

the frequency of home numeracy experiences, and the amount of numeracy talk during numeracy activities" (p. 90). Given the highly multicultural nature of the UAE and the previously observed variations in home numeracy practices across cultures, it is critical to investigate whether or not home numeracy environment is associated with children's mathematics dispositions (i.e., positive attitudes toward mathematics), mathematics engagement (i.e., children's views on engaging teaching in mathematics lessons), and mathematics achievement across in the UAE context.

Early childhood education in the UAE

The UAE is a country experiencing rapid development of public services to meet the needs of its citizens. However, development in the area Early Childhood Education (ECE) has been reported to be slower than in other areas of public service reform (Dillon, 2019). Although the age range attributed to ECE is internationally recognized as from birth to compulsory school age (Copple & Bredekamp, 2009), there are currently distinct differences in ECE provision in the UAE for children in the birth to four-years-old range and the four to six-years old range (at which point formal schooling is mandatory).

In terms of the birth to four age range, children stay at home with parents or domestic workers or attend institutions referred to as nurseries or Early Childhood Education Centres (ECECs). All such institutions are subject to a regulatory framework but there is no official curriculum in place, as such there are estimated to be at least 13 different curricula in use in the UAE (Bennett Report, 2009). However, it should be noted that the majority of children attending such nurseries are at the time of the Bennet Report (2009) were Expatriate families and it was estimated that less than 5% of Emirati children were attending ECECs in this age range. In a recent report by PricewaterhouseCoopers estimated overall participation rates of 0–2-year-olds as 7% for the Emirate of Abu Dhabi and 10% for the Emirate of Dubai (the OECD average is 33%; PwC, 2019). However, considerable growth is expected in this sector as the UAE continues to emphasize the importance of ELC and the importance of females in the national workforce. This low participation in ECECs by families in the UAE (consisting of Emiratis and expatriates) is likely compounded by the relatively inexpensive support available from female domestic workers and, as such, the majority of children are raised at home until at least kindergarten level (Dillon, 2019). These domestic workers are often considerably less expensive than ECECs and are relatively easy to employ and dismiss as needed. However, these workers tend to be transient, not fluent in the language of the household (and instruction) and do not have qualifications relating to childcare (Al Sumaiti, 2012). Thus, it seems likely that, if these workers are a primary source of home numeracy activities during this early childhood phase, they are unlikely to effectively improve the home numeracy environment.

The situation for many children in the four to six age range is markedly different with a 90% participation rate in formal education (kindergarten) in the Emirate of Dubai, as reported in 2009 (Bennett Report, 2009). Children can attend kindergarten in either the public (mainly consisting of Emirati nationals) or the private sector (available to Emiratis and expatriates alike; Dillon, 2019). Public kindergartens currently follow the Emirati School Model curriculum and private kindergartens also offer a wide range of

international curricula. For example, in the Dubai Emirate there is provision for 17 different kindergarten curricula (Knowledge & Human Development Authority, 2018) and these kindergarten classes are included in the national school inspection program. However, other than inspection reports that are for the whole school under inspection (K-12), there is little publicly available documentation regarding the effectiveness of kindergarten provision (Dillon, 2019).

As such, no study to date, to the best of our knowledge, has examined the relations of early childhood, home numeracy environment to children's mathematics dispositions, mathematics engagement, and mathematics achievement elementary schools in the UAE. Therefore, the purpose of the present study was two-fold:

1. To investigate the associations of early numeracy activities and skills with mathematics dispositions, engagement, and achievement for Grade 4 students in the UAE; and
2. To examine the mediating effects of mathematics dispositions and engagement on the relations between early numeracy activities and skills and mathematics achievement for these students.

Literature review

According to the home numeracy model (Skwarchuk et al., 2014), early numeracy activities can be categorized into formal and informal numeracy activities. Formal numeracy activities are defined as "shared experiences in which parents directly and intentionally teach their children about numbers, quantity, or arithmetic to enhance numeracy knowledge" (Skwarchuk et al., 2014 p. 65). On the contrary, informal numeracy activities are "those shared activities for which teaching about numbers, quantity, or arithmetic is not the purpose of the activity but may occur incidentally" (Skwarchuk et al., 2014 p. 65). Examples of informal numeracy activities include spatial processing, carpentry, and playing number board games (Skwarchuk et al., 2014). Prior studies have documented the relations of both formal and informal early home numeracy activities with a wide array of academic outcomes, such as mathematics achievement and mathematics dispositions. In this study early numeracy activities are encompassed in the home numeracy model but are conceptualized as parents interacting with their children through the use of numeracy-based activities outside the formal national curriculum for early childhood education. This can be referred to as informal learning and includes such activities as playing games with number toys, shapes or building blocks, writing numbers, counting, talking about time and playing board games (Chiu, 2018; Martin et al., 2016; Zhu & Chiu, 2019) in ways that are not linked to a formal curriculum or program of study. The rationale for this is that such activities are also commonly used in formal educational settings and, as such, the type of activity is not the key distinction only the purpose of the activity (either to meet the standards of a formal study plan or to teach a child about numeracy in an informal, unplanned manner).

Early numeracy activities and skills and mathematics achievement

Kleemans et al. (2012) demonstrated that early home numeracy activities, after accounting for student and family demographic characteristics, were positively and significantly

associated with early numeracy skills among 89 kindergarten children from four primary schools in the Netherlands. Similarly, LeFevre et al. (2009) found that early informal numeracy activities were positively and significantly related to mathematical skills among 146 kindergarten, Grade 1, and Grade 2 children in Canada. Yet another study conducted by LeFevre et al. (2010) also provided empirical support for the home numeracy model. LeFevre et al. (2010) documented that early numeracy activities, primarily involving activities related to direct experiences with numbers or mathematical content, were significantly positively linked to numeracy skills among 100 Greek and 104 Canadian five-year-old children. The most recent studies have also corroborated the home numeracy model's predictions. For example, Dunst et al. (2017) reported in their meta-analysis of 13 samples comprising over 5000 children aged between 36 and 84 months that early numeracy activities were significant positive predictors of children's mathematics performance. However, Missall et al. (2015) found that early numeracy activities were not significantly associated with mathematics performance among 72 children aged between 37 and 69 months in the United States.

A growing corpus of research has also investigated the relations of early numeracy skills with later mathematics achievement. For instance, Nguyen et al. (2016) found that early numeracy skills were the strongest predictors of later mathematics achievement among 781 fifth-grade students in the United States. The authors also reported that advanced counting competencies were more strongly associated with later mathematics achievement than basic counting competencies. Recently, Rittle-Johnson et al. (2017) reported that early numeracy skills, such as non-symbolic quantity, counting, and patterning knowledge, were significant and positive predictors of fifth-grade mathematics achievement among 517 children who had been participating in a longitudinal study from 4 years old onwards in the United States. Some studies also report longer-term cognitive benefits of early numeracy knowledge. Watts et al. (2014) found that early numeracy skills were positively and highly significantly associated with mathematics achievement through age 15 among 1364 children who had been taking part in a longitudinal study from 54 months old onwards in the United States. Another study reported a positive relationship between a child's number system knowledge in kindergarten and their functional numeracy six years later (Geary et al., 2013). These studies illustrate the importance of early numeracy for cognitive outcomes even beyond the age group examined in the current study.

Mathematics dispositions

Much of the work relating to affective factors in mathematics education stems from a study by McLeod (1992) that refers to three domains: emotions, attitudes and beliefs. These words exist on a spectrum consisting of the interplay between different levels of cognitive and affective involvement, changing level of intensity of reaction, and varying levels of response stability. As such, a belief such as "mathematics is difficult" is developed through a process of reasoning, is relatively low in intensity, and remains largely stable. The reverse is true for emotions. Attitudes (referred to as dispositions in this study) assume a middle ground and are of moderate stability and intensity (McLeod, 1992).

Although the construct of interest (and in this study, mathematics interest) is multifaceted the dispositional element of interest in academic subjects is related to the associations between personal value systems regarding the subject, and positive experiences in studying (for example) mathematics (Marsh et al., 2005). Although there are situational fluctuations in mathematics interest, as a disposition, mathematics interest remains stable over time, with changes only observed over longer periods (Frenzel et al., 2010). Another key characteristic of interest is its domain specificity. As a result, there is no generalized form of the interest construct (Frenzel et al., 2010) and, consequently a student may have a strong interest in mathematics but not in other subject areas.

The dispositions of self-concept and self-efficacy have both been conceptualized in terms of confidence (Pajares & Miller, 1994; Reyes, 1984). Self-concept refers to a domain specific perception of competence with respect to say, learning mathematics. Self-efficacy is related to specific concepts (namely, it is item specific) and therefore differs from self-concept at the construct level. If follows then, that self-efficacy in learning mathematics is a form of confidence that is a pre-requisite for domain level confidence in mathematics (self-concept). As such, confidence in learning mathematics is an important dispositional affect, especially in terms of explaining phenomena such as academic success in mathematics (Clarkson et al., 2017).

The concept of engagement in learning mathematics is, again, multidimensional but has a significant attitudinal element (Brown, 2009; Fredricks et al., 2004). This affective engagement measure can be described by the degree that a student likes or enjoys learning mathematics (Martin et al., 2015) and can be influenced by repeated emotional reactions to the mathematics learning context (such as a student's relationships with their teachers and peers). Engagement is also influenced by behavioral and cognitive factors such as active participation in mathematics lessons, and the investment of effort in learning mathematics, respectively (Martin et al., 2015).

Early numeracy activities and skills and mathematics dispositions

A very small body of research has documented the associations of early numeracy activities with children's dispositions toward mathematics. For instance, Cheung and McBride (2017) examined the role of one of the early numeracy activities—number board game playing—in promoting 120 kindergarten children's numeracy skills and mathematics interest in China. The findings of the study indicated that number board game playing improved kindergarten children's numeracy skills as well as mathematics interest. In yet another study, Cheung et al. (2018) also found that early numeracy activities were significantly and positively linked to interest in numeracy among 673 Filipino children aged between 33 and 71 months in the Philippines. However, early numeracy activities were not significantly related to these children's numeracy competence. Only demographic characteristics, such as gender, age, and socioeconomic status (SES), were significantly linked to children's numeracy competence.

Some recent studies with larger, representative sample sizes, using data drawn from the TIMSS 2015 survey, have analyzed the relationships between early numeracy activities and 4th Grade mathematics achievement (Chiu, 2018; Cui et al., 2021; Hwang, 2020; Zhu & Chiu, 2019). Using a structural equation modelling (SEM) approach, Chiu (2018) demonstrated that when using parental values and gender as

preconditions and controlling for socioeconomic status (SES), early numeracy activities were positively related to Taiwanese Grade 4 students' mathematics achievement, confidence and interest. Similarly, in a multilevel path analysis study based on the TIMSS 2015 data for Grade 4 students in Hong Kong, a direct, positive link to mathematics achievement was observed for the frequency of early numeracy activities Zhu and Chiu (2019). Similar results were reported for Grade 4 Korean students where early numeracy activities positively predicted mathematics achievement when taking into account the mediating effects of early numeracy competency and numeracy self-efficacy (Hwang, 2020), and for Grade 4 students in Singapore when accounting for gender, immigration status and family learning resources (Cui et al., 2021).

No study to date has examined the associations of early numeracy skills with later dispositions toward mathematics, such as interest in mathematics and confidence in mathematics in the UAE. Moreover, to the best of our knowledge, no study to date has investigated the relations of early numeracy activities and early numeracy skills to later mathematics engagement in this context. Because the current focus of the home numeracy model is solely on the relations between early numeracy activities, early numeracy skills, and mathematics achievement (see Skwarchuk et al., 2014), further research incorporating other proximal factors associated with mathematics achievement, such as mathematics dispositions and mathematics engagement, is warranted. Prior research has demonstrated the significant positive associations of interest in mathematics and confidence in mathematics with mathematics achievement among school children (e.g., Stankov, 2013; Stankov & Lee, 2017; Stankov et al., 2012; Ufer et al., 2017). Extending the home numeracy model by including these critical non-cognitive correlates of mathematics achievement for Grade 4 students in the UAE may help us better understand how home numeracy environment contributes to children's achievement in mathematics. Hence, the present study focused on addressing the following research questions:

1. Are early numeracy activities and skills related to fourth graders' mathematics achievement in the UAE?
2. Are early numeracy activities and skills related to fourth graders' dispositions toward mathematics (i.e., interest in mathematics and confidence in mathematics) in the UAE?
3. Are early numeracy activities and skills related to fourth graders' mathematics engagement in the UAE?
4. To what extent do dispositions toward mathematics and mathematics engagement mediate the relationships between early numeracy activities and skills and mathematics achievement among fourth graders in the UAE?

Based on prior literature, we hypothesized that early numeracy activities and skills would positively predict mathematics achievement, dispositions, and engagement. We also hypothesized that dispositions toward mathematics and mathematics engagement would positively mediate the relationships between numeracy activities and skills and mathematics achievement.

Method

Participants

The study drew data from the Trends in International Mathematics and Science Study (TIMSS) 2015 international database (https://timssandpirls.bc.edu/timss2015/international-database). TIMSS, held every four years, measures the mathematics and science achievement of fourth grade and eighth-grade students in participating countries. In 2015, a total of 47 countries and 6 benchmarking entities participated in TIMSS fourth-grade assessments. The UAE was one of the TIMSS 2015 participating countries, and 33,631 fourth-grade students (48% girls) from 889 schools in the UAE took part in the TIMSS 2015 fourth-grade assessments. Cases with missing data were excluded from the present study, resulting in a final sample of 26,859 fourth-grade students (50% girls) from 853 schools, with a mean age of 9.79 years ($SD = 0.61$).

Measures

Mathematics achievement

The TIMSS 2015 mathematics achievement scale measured fourth-grade students' mathematics achievement. The TIMSS 2015 fourth-grade mathematics assessment included 179 items, comprising both multiple-choice and constructed response type items (TIMSS & PIRLS International Study Center, 2017). The TIMSS 2015 fourth-grade sample mathematics items can be found here, https://timssandpirls.bc.edu/timss2015/downloads/T15_FW_AppB.pdf. Item response theory (IRT) scaling procedures were used to construct the TIMSS 2015 mathematics achievement scale (Foy & Yin, 2016). The following TIMSS 2015 context questionnaire scales were also constructed using IRT scaling techniques (see Martin et al., 2016).

Early numeracy activities before beginning primary school

This scale was based on parents' frequency of doing the following seven activities with their children before they began primary school: say counting rhymes or sign counting songs, play with number toys, count different things, play games involving shapes, play with building blocks or construction toys, play board or card games, and write numbers (Martin et al., 2016). All these items were rated on a three-point Likert-type scale, ranging from 1 (never or almost never) to 3 (often). The internal consistency reliability of the scale was 0.86 (Cronbach's α).

Could do early numeracy tasks when beginning primary school

This scale was based on parents' responses to how well their children could do the following five tasks when they began primary school: count by himself/herself, recognize written numbers, write numbers, do simple addition, and do simple subtraction (Martin et al., 2016). The first three items were rated on a four-point Likert-type scale, ranging from 1 (not at all) to 4 (up to 100 or higher). The last two items were dichotomous items (1 = yes, 0 = no). The internal consistency reliability of the scale was 0.88.

Students like learning mathematics

This scale was based on students' degree of agreement with the following nine items: "I enjoy learning mathematics"; "I wish I did not have to study mathematics"; "Mathematics is boring"; "I learn many interesting things in mathematics"; "I like mathematics"; "I like any schoolwork that involves numbers"; "I like to solve mathematics problems"; "I look forward to mathematics lessons"; and "Mathematics is one of my favorite subjects" (Martin et al., 2016). All items were rated on a four-point Likert-type scale, ranging from 1 (disagree a lot) to 4 (agree a lot). The negatively worded items were reverse scored. The internal consistency reliability of the scale was 0.89.

Students confident in mathematics

This scale was based on students' degree of agreement with the following nine items: "I usually do well in mathematics"; "Mathematics is harder for me than for many of my classmates"; "I am just not good at mathematics"; "I learn things quickly in mathematics"; "Mathematics makes me nervous"; and "I am good at working out difficult mathematics problems"; "My teacher tell me I am good at mathematics"; "Mathematics is harder for me than any other subject"; and "Mathematics makes me confused"(Martin et al., 2016). These nine items were rated on a four-point Likert-type scale, ranging from 1 (disagree a lot) to 4 (agree a lot). All negatively worded items were reverse scored. The internal consistency reliability of this scale was 0.80.

Students' views on engaging teaching in mathematics lessons

This scale was based on students' degree of agreement with the following 10 items: "I know what my teacher expects me to do"; "My teacher is easy to understand"; "I am interested in what my teacher says"; "My teacher gives me interesting things to do"; "My teacher has clear answers to my questions"; "My teacher is good at explaining mathematics"; "My teacher lets me show what I have learned"; "My teacher does a variety of things to help us learn"; "My teacher tells me how to do better when I make a mistake"; and "My teacher listens to what I have to say" (Martin et al., 2016). All items were rated on a four-point Likert-type scale, ranging from 1 (disagree a lot) to 4 (agree a lot). The internal consistency reliability of this scale was 0.88.

Control variables/measures

Because participants in the study had varying socioeconomic and demographic characteristics, the following variables and measures were controlled for in the analysis: gender (1 = female, 0 = male), immigration status (1 = non-immigrant, 0 = immigrant), language of test spoken at home (rated on a four-point Likert-type scale, ranging from 1 = I never speak language of test at home to 4 = I always speak language of test at home), home resources for learning (a scale constructed using students' and parents' responses to the following: number of books in the home, number of home study supports, number of children's books in the home, highest level of education of parents, and highest level of occupation of parents; see Martin et al., 2016), and parental attitude toward mathematics and science (8 items, e.g., "My child needs mathematics to get ahead in the world";

Martin et al., 2016). All eight items on the parental attitude toward mathematics and science scale were rated on a four-point Likert-type scale, ranging from 1 (disagree a lot) to 4 (agree a lot). The internal consistency reliability of the scale was 0.85.

Data analysis

The four research questions in the study were answered using path analysis as the analytic strategy (see Loehlin & Beaujean, 2017). Path analyses were performed employing the statistical software, *M*plus 7.4 (Muthén & Muthén, 1998–2015). Because the participants in the TIMSS 2015 data were nested within the schools, the *M*plus command type = complex was used to estimate the correct standard error parameters (see Muthén & Muthén, 1998–2015). Mediational analyses were conducted using the *M*plus option, *model indirect* (see Muthén & Muthén, 1998–2015). Bootstrapped bias-corrected 95% confidence intervals were obtained for the indirect effects (see Preacher & Hayes, 2008). The complete syntax used to examine the direct and mediation effects in the study is given in Appendix A. The description of all variables and measures is given in Appendix B. The hypothesized model in the study is shown in Fig. 1. The following goodness-of-fit indices were employed to examine the fit of the hypothesized model in the study (see Hu & Bentler, 1999; Schreiber et al., 2006): comparative fit index (CFI $\geq$ 0.95), Tucker-Lewis

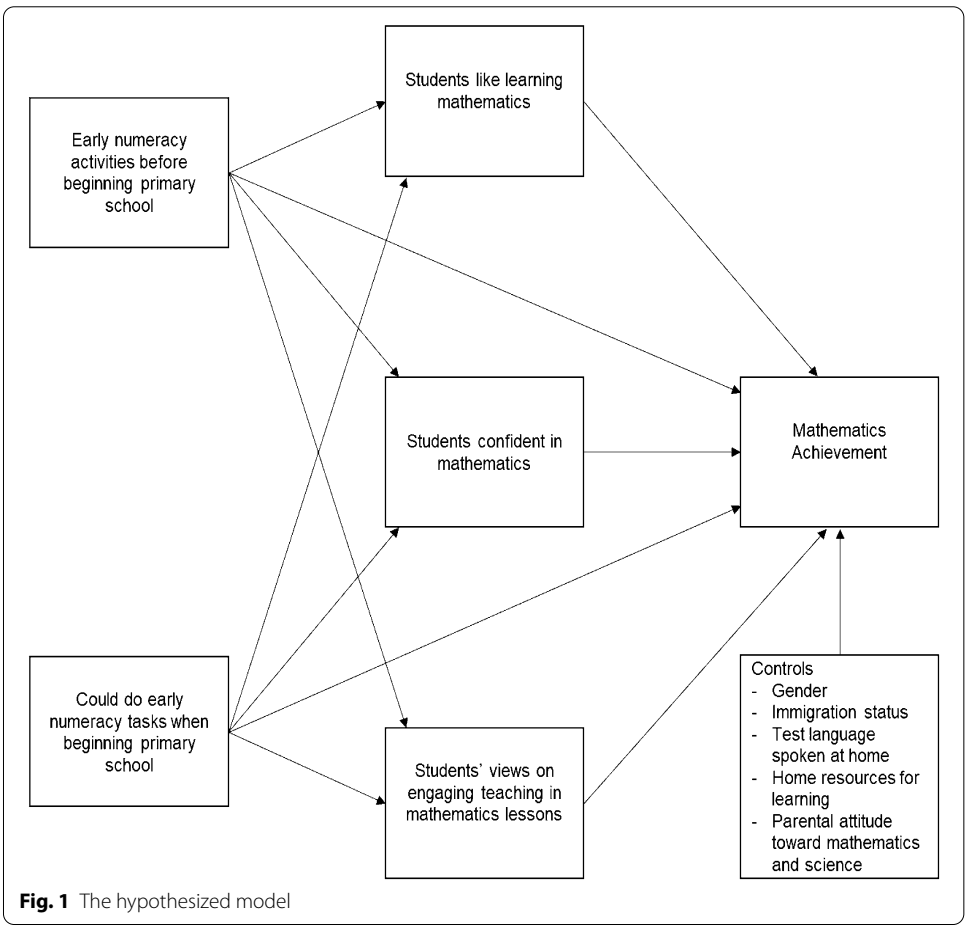

Fig. 1 The hypothesized model

index (TLI ≥ 0.95), standardized root mean square residual (SRMR ≤ 0.08), and root mean square error of approximation (RMSEA ≤ 0.06).

Results

Descriptive statistics for all variables and measures in the study are given in Table 1. Bivariate correlations among all variables and measures in the study are given in Table 2. Prior to performing path analyses, the data were screened for potential univariate and multivariate outliers. No potential univariate and multivariate outliers were detected.

Path analyses (see Fig. 2) revealed that all goodness-of-fit indices were within the acceptable limits, suggesting that the hypothesized model in the study fitted the data well: CFI = 1.000, TLI = 1.000, RMSEA = 0.007 (90% CI = 0.005, 0.008), and SRMR = 0.002.

RQ#1: Are early numeracy activities and skills related to fourth graders' mathematics achievement in the UAE?

The results of path analyses suggested early numeracy activities were statistically significantly positively associated with mathematics achievement among fourth-grade students in the UAE, $\beta = 0.05$, $SE = 0.01$, $p < 0.001$. Moreover, early numeracy skills were also statistically significantly positively associated with mathematics achievement among fourth-grade students in the UAE, $\beta = 0.08$, $SE = 0.01$, $p < 0.001$.

RQ#2: Are early numeracy activities and skills related to fourth graders' dispositions toward mathematics (i.e., interest in mathematics and confidence in mathematics) in the UAE?

Early numeracy activities were statistically significantly positively related to interest in mathematics (i.e., students like learning mathematics: $\beta = 0.03$, $SE = 0.01$, $p < 0.001$) and confidence in mathematics ($\beta = 0.07$, $SE = 0.01$, $p < 0.001$) among fourth-grade students in the UAE. Likewise, early numeracy skills were also statistically significantly positively associated with interest in mathematics ($\beta = 0.09$, $SE = 0.01$, $p < 0.001$) and confidence in mathematics ($\beta = 0.11$, $SE = 0.01$, $p < 0.001$) among fourth-grade students in the UAE.

Table 1 Descriptive statistics

	M	SD	Skewness	Kurtosis
Gender	0.48	0.50	0.067	− 1.996
Immigration status	0.60	0.49	− 0.390	− 1.848
Language of test spoken at home	2.94	1.02	− 0.237	− 1.422
Home resources for learning	10.11	1.53	0.111	1.140
Parental attitude toward math and science	10.37	1.91	− 0.270	− 0.816
Students like learning math	10.32	1.74	− 0.225	− 0.379
Students confident in math	10.00	1.80	0.883	0.503
Students engaged in math lessons	10.12	2.07	− 0.230	− 0.600
Early numeracy activities	10.19	2.04	− 0.003	− 0.048
Could do early numeracy tasks	10.42	1.96	− 0.270	− 0.816
Math achievement	464.58	108.00	− 0.019	− 0.463

Table 2 Correlations among the study variables

	1	2	3	4	5	6	7	8	9	10	11
1. Gender	–										
2. Immigration status	0.02**	–									
3. Language of test spoken at home	0.01*	0.16**	–								
4. Home resources for learning	− 0.01	− 0.21**	− 0.10**	–							
5. Parental attitude toward math and science	− 0.02**	− 0.16**	− 0.11**	0.16**	–						
6. Students engaged in math lessons	0.06**	− 0.07**	− 0.00	0.07**	0.09**	–					
7. Students like learning math	0.04**	− 0.06**	0.04**	0.02**	0.09**	0.55**	–				
8. Students confident in math	0.01	− 0.09**	0.02**	0.12**	0.10**	0.40**	0.55**	–			
9. Early numeracy activities	0.02**	− 0.06**	0.06**	0.22**	0.17**	0.17**	0.07**	0.12**	–		
10. Could do early numeracy tasks	0.01	− 0.07**	− 0.03**	0.04**	0.08**	0.08**	0.10**	0.12**	0.12**	–	
11. Math achievement	0.03**	− 0.35**	− 0.12**	0.47**	0.20**	0.20**	0.19**	0.34**	0.20**	0.15**	–

For a correlation, effect size is indicated by the absolute value; those under 0.10 are trivial and values between 0.10 and 0.30 are small (Cohen, 1992)

*$p < 0.05$. **$p < 0.01$

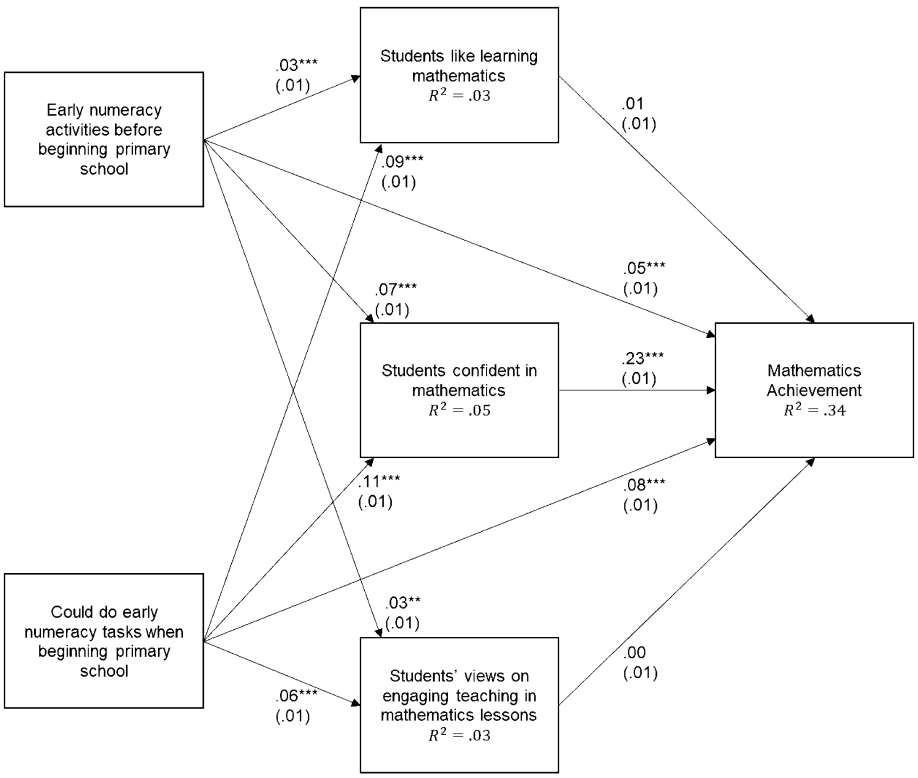

Fig. 2 Results of path analyses. Standard errors are in parentheses. The control variables were included in the analysis. For the sake of clarity, they are not included in the figure. $^{**}p < 0.01$. $^{***}p < 0.001$

RQ#3: Are early numeracy activities and skills related to fourth graders' mathematics engagement in the UAE?

Early numeracy activities were statistically significantly positively related to mathematics engagement among fourth-grade students in the UAE, $\beta = 0.03$, $SE = 0.01$, $p < 0.01$. Similarly, early numeracy skills were also statistically significantly positively linked to mathematics engagement among fourth-grade students in the UAE, $\beta = 0.06$, $SE = 0.01$, $p < 0.001$.

RQ#4: To what extent do dispositions toward mathematics and mathematics engagement mediate the relationships between early numeracy activities and skills and mathematics achievement among fourth graders in the UAE?

The results of mediational analyses suggested that confidence in mathematics significantly mediated the associations between early numeracy activities and mathematics achievement among fourth-grade students in the UAE, $\beta = 0.02$, $SE = 0.00$, $p < 0.001$, bias-corrected 95% CI (0.01, 0.02). Moreover, confidence in mathematics also significantly mediated the relationships between early numeracy skills and mathematics achievement among fourth-grade students in the UAE, $\beta = 0.03$, $SE = 0.00$, $p < 0.001$, bias-corrected 95% CI (0.02, 0.03). Nonetheless, interest in mathematics and engagement in mathematics did not significantly mediate the

relationships between early numeracy activities and skills and mathematics achievement among fourth-grade students in the UAE.

Discussion

The present study, employing path analysis, aimed to investigate the relations of early numeracy activities and skills to mathematics dispositions, engagement, and achievement among fourth-grade students in the UAE who took part in the latest cycle of the TIMSS mathematics assessment. The study also examined the mediational roles of mathematics dispositions and engagement in the association between early numeracy activities and skills and mathematics achievement among these fourth-grade students.

The findings of the study, consistent with the findings of previous studies (e.g., del Río et al., 2017; Dunst et al., 2017; Kleemans et al., 2012; LeFevre et al., 2010; Missall et al., 2015; Napoli & Purpura, 2018) indicated that early numeracy activities and early numeracy skills were significantly positively associated with mathematics achievement for fourth grade students in the UAE. In other words, students who were more frequently engaged in early numeracy activities tended to perform significantly better on the TIMSS 2015 mathematics assessment than did their peers who were less frequently engaged in early numeracy activities. Similarly, students who possessed higher levels of early numeracy skills tended to perform significantly better on the TIMSS 2015 mathematics assessment than did their counterparts who possessed lower levels of early numeracy skills. These findings suggest a clear positive link between early home numeracy support and children's numeracy knowledge and skills. Parents who provide support for their young children's numeracy knowledge and skills may continue to provide such support as their children grow older. Moreover, parents who are confident in their own numeracy knowledge and skills, value the importance of own numeracy knowledge and skills, and find mathematics interesting are more likely to provide frequent support for their children's early numeracy activities at home (Zippert & Rittle-Johnson, 2020). Thus, the quality and frequency of early numeracy activities at home may help foster children's numeracy development.

The results of the study, congruent with the findings of prior studies (e.g., Cheung & McBride, 2017; Cheung et al., 2018), also suggested that early numeracy activities and early numeracy skills were significantly positively related to interest in mathematics among fourth-grade students in the UAE. Put another way, students who were more frequently engaged in early numeracy activities tended to report higher levels of interest in mathematics than did their peers who were less frequently engaged in early numeracy activities. Furthermore, students who possessed higher levels of early numeracy skills tended to report higher levels of interest in mathematics than did their counterparts who possessed lower levels of early numeracy skills. Moreover, early numeracy activities and early numeracy skills were significantly positively linked to confidence in mathematics among fourth-grade students in the UAE. Students who were more frequently engaged in early numeracy activities tended to report higher levels of confidence in mathematics than did their peers who were less frequently engaged in early numeracy activities. Further, students who possessed higher levels of early numeracy skills tended to report higher levels of confidence in mathematics than did their counterparts who possessed lower levels

of early numeracy skills. Parents' beliefs about their young children's mathematical abilities and interests may also influence the quality and frequency of early home numeracy activities (Zippert & Rittle-Johnson, 2020). Parents of young children with keen interests and high abilities in mathematics are more likely to provide frequent early home numeracy experiences (Zippert & Rittle-Johnson, 2020). Such a deliberate, systematic, and sustained attempt may not only enhance children's interest and confidence in mathematics but also improve their mathematical abilities.

The results of mediational analyses revealed that confidence in mathematics significantly mediated the relationships between early numeracy activities and skills and mathematics achievement among fourth-grade students in the UAE. In other words, the frequency of early numeracy activities influences students' levels of confidence in mathematics, which, in turn, predicts students' achievement in mathematics. Likewise, early numeracy skills influence students' levels of confidence in mathematics, which, in turn, predict their achievement in mathematics. As previously discussed, the construct of confidence in mathematics learning is considered to be a dispositional bridge from mathematics self-efficacy (a student's confidence in their abilities to perform specific mathematics-related tasks; Hackett & Betz, 1989) to mathematics self-concept (a student's confidence in their overall mathematics abilities; Reyes, 1984). Previous studies have consistently shown that, as hypothesized by the performance model in social cognitive career theory (SCCT; Lent & Brown, 2019), mathematics self-efficacy (and to some extent self-concept) directly (and indirectly) predicts positive academic performance in mathematics (see, Recber et al., 2018; Van der Beek et al., 2017). In light of this, the direct and mediated effects of mathematical confidence observed in this study offer further support for its important affective relationship with mathematical cognitive performance.

Our analysis indicated insignificant mediating effects between early numeracy experiences and mathematics achievement for both interest and engagement. This suggests that there is no mechanism by which early numeracy activities and tasks lead to an increased association with achievement through an increase in interest and engagement in mathematics when accounting for the effects of confidence. In terms of interest, the SCCT interest model suggests that self-efficacy and outcome expectations (reported to be associated with self-concept; Rodriguez, 2009) directly predict interests. However, according to the integrated SCCT model presented by Lent and Brown (2019) interests do not directly predict performance but rather influence performance though choice goals and then choice actions. The effect of student confidence on interest was not specified in our model and any possible significant associations between interest and achievement are likely accounted for by the direct positive relationship between confidence and academic performance. We also posit a similar explanation for the non-significant mediation effect of engagement between early childhood learning experiences and mathematics achievement. Again, referring to the SCCT model, the affective factor of engagement in mathematics (emotional reactions to the learning environment) is encompassed by the construct "learning experiences" (Lent & Brown, 2019). The abbreviated SCCT performance model does not include learning experiences, as these are used to predict self-efficacy (confidence) that, in turn, directly and indirectly predicts performance.

No direct effect between engagement (derived from vicarious learning) and academic performance is suggested.

Implications for policy and practice

The findings of the study have important implications for educational policy and practice. Given the crucial roles that early numeracy activities and early numeracy skills play in improving students' mathematics dispositions, engagement, and achievement, both parents and teachers have crucial roles to play in promoting young children's numeracy development. Furthermore, the likely longer-term benefits of early numeracy activities beyond Grade 4 for cognitive outcomes add even greater weight to these findings as mathematics grades at the end of formal schooling influence a range of adult outcomes (Watts et al., 2014). However, all parents may not possess the requisite skills to effectively engage their young children in meaningful, evidence-based numeracy activities or practices. As a result, kindergarten teachers may need to empower parents to enable them to contribute to their young children's numeracy development. As there is a substantial gap in the coverage and content of numeracy activities that parents provide to their children (see Drešar & Lipovec, 2017), home-school partnerships should be fostered and supported. Prior studies have demonstrated the effectiveness of home-school partnerships in encouraging parents to support their children's mathematics learning (e.g., Sheldon & Epstein, 2005). Hence, educational interventions aimed at improving the home numeracy environment may need to be developed and implemented. Previous research has documented the efficacy of such interventions. For example, Niklas et al. (2016) showed that educational interventions targeted at enhancing home numeracy environment significantly improved preschool children's numerical abilities. Moreover, Vukovic et al. (2013) found that parents' support of their children's numeracy development positively influenced children's mathematics performance by reducing their mathematics anxiety. Thus, parents should be provided with culturally appropriate training instigated by experts in early childhood education such as kindergarten teachers, resources that are easy to use (for non-experts) and effective for developing early numeracy, and ongoing, pro-active support to help them create a positive home numeracy environment, which, in turn, may foster children's early numeracy development (see Vukovic et al., 2013). Tools employed within empirical studies of home numeracy could be used in the UAE context. These include handouts for parents containing ideas for informal mathematics learning opportunities such as counting the number of steps in a staircase, comparing prices in shops, playing board games that involve manipulating numbers on a dice, measuring ingredients whilst cooking, carrying out "connect the dots" activities, using calendars and dates, telling the time, and reading number storybooks (LeFevre et al., 2009; Niklas et al., 2016).

Limitations of the study and directions for future research

The findings of the present study should be interpreted taking into consideration the three major limitations of the study. First, the current study primarily employed self-reported measures to examine the relationships among variables of interest. Although self-reported measures are not inherently weak, using a combination of both subjective and objective measures may further strengthen the validity and reliability of the

study. Second, because the nature and extent of parental involvement in their children's education may vary widely from one culture to another, the findings of the study may have very limited cross-cultural generalizability. Future research may need to take into account cultural factors related to home numeracy environment. Finally, the present study was correlational in nature. Hence, no causal conclusions could be drawn from the study. Future studies may employ longitudinal or experimental research designs.

Conclusion

Notwithstanding these limitations, the findings of the present study, in the context of the UAE, provided empirical support for the significant roles that early numeracy activities and early numeracy skills play in young children's mathematics dispositions, engagement, and achievement. Further, the study also revealed the mediational role of confidence in mathematics in the association between early numeracy activities and skills and mathematics achievement. Well thought-out educational interventions targeting parental capacity building for engaging their children in evidence-based early numeracy activities may, to a certain extent, help improve the mathematics performance of young children in the UAE.

Appendix A: *M*plus Syntax

```
Data: File is implist.dat;
Type = Imputation;
  Variable: Names are IDSTUD IDCNTRY IDSCHOOL ITSEX ITLANG ASBG03 ASBG07 ASDAGE TOTWGT ASMMAT01 ASBGSLM ASBGEML ASBGSCM ASBGHRL ASBHENA ASBHENT ASBHAMS;
  Usevariables are ITSEX ASBG03 ASBG07 ASMMAT01 ASBGSLM ASBGEML ASBGSCM ASBGHRL ASBHENA ASBHENT ASBHAMS;
Weight = TOTWGT;
Cluster = IDSCHOOL;
Missing are all (-9999);
Analysis:
Type = Complex;
Bootstrap = 1000;
REPSE = Bootstrap;
Model:
  ASMMAT01 ON ITSEX ASBG03 ASBG07 ASBGSLM ASBGEML ASBGSCM ASBGHRL
  ASBHENA ASBHENT ASBHAMS;
  ASBGEML ON ITSEX ASBG03 ASBG07 ASBGHRL ASBHENA ASBHENT ASBHAMS;
  ASBGSLM ON ITSEX ASBG03 ASBG07 ASBGHRL ASBHENA ASBHENT ASBHAMS;
  ASBGSCM ON ITSEX ASBG03 ASBG07 ASBGHRL ASBHENA ASBHENT ASBHAMS;
  Model indirect:
ASMMAT01 IND ASBGSLM ASBHENA;
ASMMAT01 IND ASBGSLM ASBHENT;
ASMMAT01 IND ASBGEML ASBHENA;
```

ASMMAT01 IND ASBGEML ASBHENT;
ASMMAT01 IND ASBGSCM ASBHENA;
ASMMAT01 IND ASBGSCM ASBHENT;
Output:
STDYX SAMPSTAT CINTERVAL (BCBOOTSTRAP);

Appendix B: List of variables/measures

IDSTUD	Student ID
IDCNTRY	Country ID—Numeric Code
IDSCHOOL	School ID
ITSEX	Sex of Students
ASBG03	GEN\OFTEN SPEAK < LANGUAGE OF TEST > AT HOME
ASBG07	GEN\WERE YOU BORN IN < COUNTRY >
TOTWGT	TOTAL STUDENT WEIGHT
ASMMAT01	1ST PLAUSIBLE VALUE MATHEMATICS
ASMMAT02	2ND PLAUSIBLE VALUE MATHEMATICS
ASMMAT03	3RD PLAUSIBLE VALUE MATHEMATICS
ASMMAT04	4TH PLAUSIBLE VALUE MATHEMATICS
ASMMAT05	5TH PLAUSIBLE VALUE MATHEMATICS
ASBGSLM	Students Like Learning Mathematics/SCL
ASBGEML	Engaging Teaching in Math Lessons/SCL
ASBGSCM	Students Confident in Mathematics/SCL
ASBGHRL	Home Resources for Learning/SCL
ASBHENA	Early Numeracy Activities Before School/SCL
ASBHENT	Early Numeracy Tasks/SCL
ASBHAMS	Parental Attitude Towards Math and Science/SCL

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Authors' contributions
MMAH, SA, and DC contributed to developing the research design and writing the manuscript. Statistical analysis was conducted by MMAH and SA. All authors read and approved the final manuscript.

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Availability of data and materials
The data sets used in this study are accessible online via the provided link within the manuscript.

Declarations

Competing interests
The authors declare that they have no competing interests.

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