

Effects of Early Numeracy Activities on Mathematics Achievement and Affect: Parental Value and Child Gender Conditions and Socioeconomic Status Mediation

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ABSTRACT

Past studies have examined the models for the effects of early numeracy activities on children's later mathematics achievement, with parental values as a precondition and socioeconomic status (SES) as an interaction measure with numeracy activities. This study proposed models of (1) the multiple effects of early numeracy activities, conditioned by parental value, on mathematics achievement and affect (e.g. confidence and interest) and (2) the multiple effects to be mediated by SES and early numeracy activities conditioned by parental value and child gender. The proposed models were examined using structural equation modeling with data from Taiwanese parental reports and child grade-4 tests and reports ($N = 4,291$; 49% girls) of TIMSS 2015. Three major results go beyond those previous research findings and may provide recommendations for educational practices. (1) Early numeracy activities have effects on mathematics confidence and interest in addition to achievement. (2) SES mediates the effects of early numeracy activities on achievement and confidence but not on interest. The mediating effect of SES suggests that high-quality educational provision should be provided during early numeracy activities. (3) Parents provide fewer numeracy activities for girls, which suggests that parents should provide more early numeracy activities to girls.

Keywords: early numeracy, gender, mathematics achievement, parenting, interest

INTRODUCTION

Early numeracy activities may be more than simply serious mathematics games played between parents and children because they may contribute to multiple outcomes affecting children later in life. Parental and children's characteristics may also play roles in early numeracy activities, which in turn may affect children's achievement (Anders et al., 2012). A sufficient, comprehensive path model to organize vital variables may deepen the understanding of the precedent, mediating, and consequent variables in relation to early numeracy activities and provide suggestions for parenting and educational practices.

Past research has posited a likely path model from parents' perceived values toward mathematics (i.e. 'parental mathematics values' in this study) as a pre-condition, to early numeracy activities as a process, which in turn leads to children's achievement as an outcome (Skwarchuk, Sowinski, & LeFevre, 2014). The path model, however, is not fully confirmed. For example, Missall, Hojnosi, Caskie, and Repasky's (2015) study of families in the United States finds that early numeracy activities can be attributed to parental mathematics values but do not relate to children's mathematics achievement. As such, there is a need to first validate this relatively well-developed model especially for a sample from a different culture.

The next steps are to incorporate vital variables into the path model, which may facilitate the design of early numeracy activities. A variable that needs to be added to the path model is family socioeconomic status (SES). Past studies have found that SES interacts with early numeracy activities and children's achievements (Letourneau, Duffett-Leger, Levac, Watson, & Young-Morris, 2013; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson,

Contribution of this paper to the literature

- Early numeracy activities have effects on mathematics achievement, confidence, and interest.
- SES mediates the effects of early numeracy activities on achievement and confidence.
- Parents provide fewer numeracy activities for girls.

Table 1. Fit Index Values for the Examined Models

Models	Fit indexes	χ^2	df	p	RMSEA	CFI	TLI
CFA (Table 2)		3027.881	260	< .0005	.055	.953	.945
SEM Model A (Figure 1)		370.258	33	< .0005	.049	.987	.982
SEM Model C (Figure 1)		511.798	50	< .0005	.046	.983	.978
SEM Model D (Figure 2)		3424.769	223	< .0005	.058	.953	.947
SEM Model E (Figure 2)		3931.155	288	< .0005	.054	.948	.942

Note. χ^2 = chi-square (or minimum function test) statistic; CFA = confirmatory factor analysis; SEM = structural equation modeling; df = degrees of freedom; RMSEA = root mean square error of approximation; CFI = comparative fit index; TLI = Tucker–Lewis index

2010). SES, however, has never been formally incorporated into the path model for early numeracy activities. Two further variables that may need to be considered are children’s mathematics affect and gender. Past mathematics education literature has documented mathematics affect as an important learning outcome in addition to achievement (Chiu & Whitebread, 2011). Parents’ gender stereotypes may reduce their mathematics educational provisions to girls (Gunderson, Ramirez, Levine & Beilock, 2012). The two variables (affect and gender), however, are missing in past research on early numeracy activities.

The purpose of this study therefore is to examine various path models for early numeracy activities. The examination will start from the relatively well-researched path model (from parental mathematics values, early numeracy activities, to child mathematics achievement) and gradually incorporate three vital variables (SES, mathematics affect, and child gender). This will deepen our understanding of how early numeracy activities interact with several important variables well documented in the literature and provide additional suggestions for educational practices and policy making.

The above introduction addresses the educational significance and summarizes the theoretical background of this study. The following review of the literature will present in detail the rationales for proposing the several path models and the conceptual meanings of the terms used in this study (The operational meanings of the terms are presented in the measures section and Table 2).

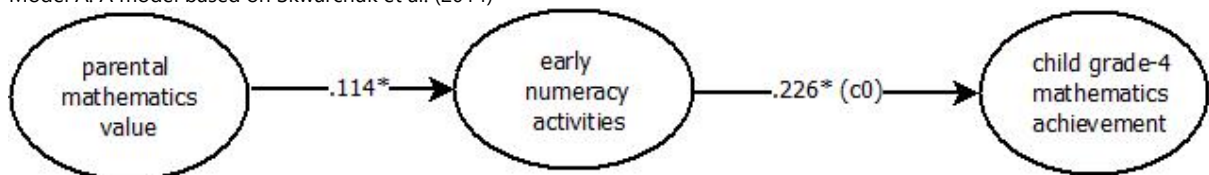
Causal Paths from Parental Values to Early Numeracy Activities to Child Achievements

Defining early numeracy activities. Parents or early caregivers can be their children’s first mathematics teachers through early numeracy activities if parents perceive mathematics as being important (i.e. ‘parental mathematics values’ in this study). Parents may interact with their children through formal, advanced numeracy activities (e.g. helping children to learn simple sums and talking about time with calendars) and informal, basic ones (e.g. playing board games and singing counting songs; Skwarchuk et al., 2014). The basic early numeracy activities can naturally occur in most families because most parents can implement these activities, even those with few formal educational experiences and across various cultural heritages. Thus, basic early numeracy activities will be the focus of this study.

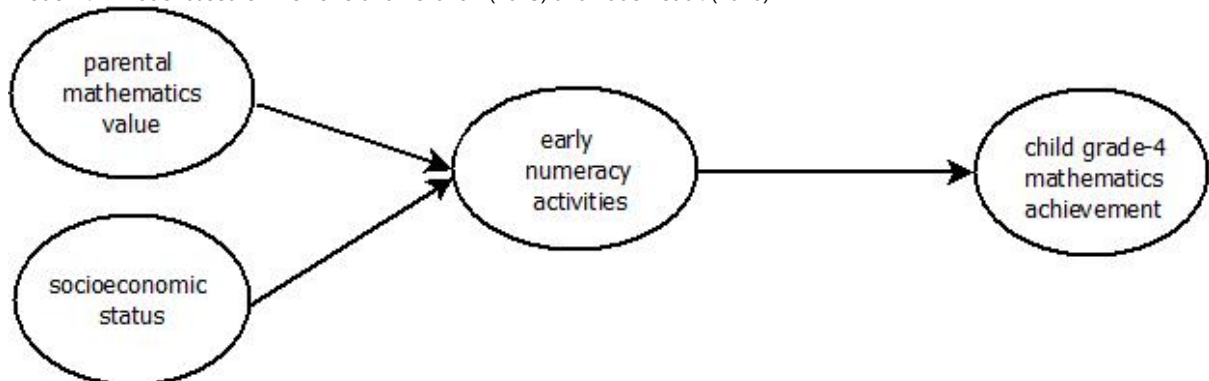
Rationales. A recent meta-analysis finds that informal, basic numeracy activities are better predictors of children’s mathematics achievements than formal numeracy activities (Dunst, Hamby, Wilkie, & Dunst, 2017). Skwarchuk et al.’s (2014) model, however, indicates that parental numeracy attitudes, informal numeracy tools, and formal numeracy activities have effects on children’s mathematics knowledge or skills; on the other hand, the effects of basic numeracy activities on learning outcomes are not significant, which may be because informal numeracy tools are included in their model. Further, Missall et al. (2015) only find that parental mathematics values are related to their provision of early numeracy activities to children, which in turn are not related to child mathematics achievement.

The previous literature appears to suggest but not fully confirm the path model from parental mathematics values, basic early numeracy activities, to mathematics achievement, as indicated by Model A (Figure 1) and Hypothesis 1. Examining the model using a sample of students from a different culture can validate and generalize the speculation suggested by the previous studies and build understanding of how early numeracy activities can serve as part of a process with the pre-condition of children’s learning contexts and the effect on children’s learning outcomes.

Model A. A model based on Skwarchuk et al. (2014)



Model B. A model based on DeFlorio and Beliakoff (2015) and Zadeh et al. (2010)



Model C. A model based on DeFlorio and Beliakoff (2015)

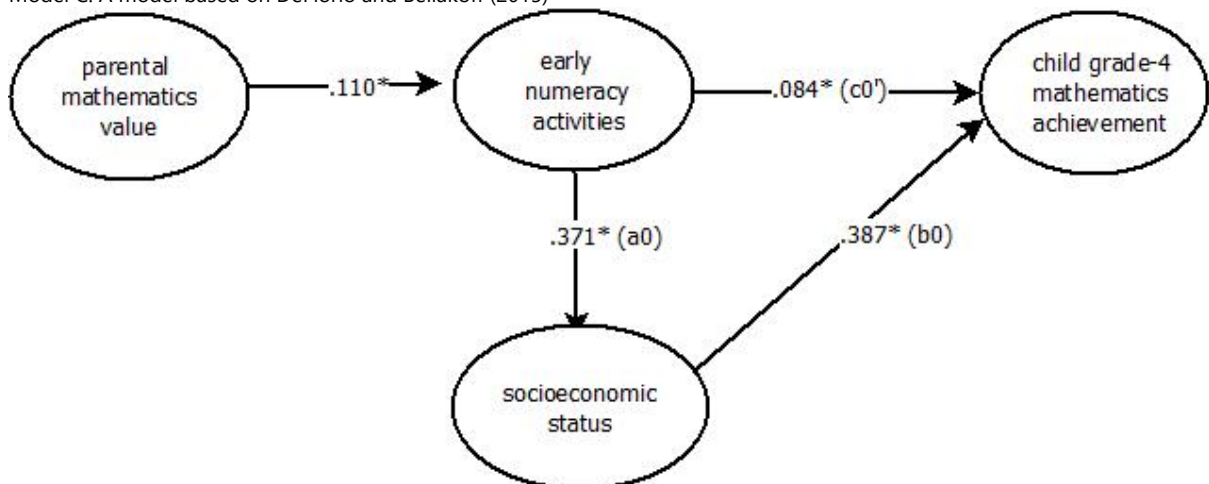


Figure 1. Three proposed models for early numeracy activities based on previous studies. Model B is not supported, failing to generate any solutions and thus the path coefficients are not provided. The notations, a, b, c and c' come from Baron and Kenny (1986). * $p < .050$

Causal or Mediating Effects of SES on Early Numeracy Activities

Defining SES. SES describes the material and cultural capital of a person or a family in obtaining, possessing or using resources (Chiu, 2016). The indicators of SES vary across studies but mainly include the material capital of SES such as family income, possessions, and ability to pay for private schooling, and the cultural capital of SES such as parental education and occupation levels (DeFlorio & Beliakoff, 2015; Letourneau et al., 2013; Organization for Economic Co-operation and Development [OECD], 2014a). This study will focus on the cultural capital of SES in order to emphasize the educational role of SES in early numeracy activities.

Rationales for the causal effect of SES. DeFlorio and Beliakoff (2015) indicate that SES plays an interactive role in early numeracy activities. The interaction effects are examined using the statistical method of mean differences between students from different levels of SES, measured as family ability to pay for private schooling, which is shown to be related to parental education levels. Zadeh, Farnia, and Ungerleider's (2010) study indicates that mothers' education (as a measure of SES) can both directly predict and be mediated by home enriching environments to indirectly predict children's grade-1 mathematics achievement. This means that SES may have a causal effect on early numeracy activities, which in turn predict children mathematics achievement, as will be examined by Model B (Hypothesis 2) in this study.

Rationales for the mediating effect of SES. An interaction effect, however, may not imply a causal theory, effect, or design (Wu & Zumbo, 2008). Another likely interaction effect is that SES plays a role in mediating the effect of early numeracy activities on children's learning outcomes. The mediating role of SES can be posited if there are interactions between SES, early numeracy activities, and learning outcomes (Baron & Kenny, 1986).

Research has indicated that SES has relationships with parent-child interaction quality (Bradley, Corwyn, McAdoo, & García, 2001), additional resources, and supportive neighborhoods directing children to achievement (Dietrichson, Bøg, Filges, & Klint Jørgensen, 2017). Parents' knowledge (e.g. number talk) plays a role in the interaction between parents and children when they engage in early numeracy activities (Levine et al., 2010).

Further, SES has significant but small effects on children's affective and cognitive development (Letourneau et al., 2013). Children with high mathematics achievement tend to have more frequent and higher quality child-parent interactions and more engaging behaviors in numeracy or literacy activities than those with low mathematics achievement (Zhou et al., 2006). Relatively few studies suggest that parental education does not link to children's performance in mathematics skill tests (Murray & Harrison, 2011).

Given the literature and the first focus of this study (Model A), it could be further hypothesized that SES plays a mediating effect on the relationship from early numeracy activities to child learning outcomes (e.g. mathematics achievement and affects). Model C (Hypothesis 3) attempts to examine this. If SES plays a role mediating the effect of numeracy activities on child mathematics learning outcomes, then SES needs to be reconceptualized as 'parental knowledge capital,' which can be utilized to promote, reduce, or intervene in the effects of numeracy activities on learning outcomes.

Multiple Effects of Early Numeracy Activities on Achievement and Affect

Defining mathematics affect. Mathematics curricula and mathematics education focus on both cognitive outcomes (mainly mathematics achievement and skills) and affective learning outcomes (e.g. mathematics confidence and interest; Chiu & Whitebread, 2011). Both cognitive and affective dispositions (e.g. beliefs about self and mathematical learning, heuristic methods, mathematics knowledge, meta-knowledge, and self-regulatory skills) are essential for competent mathematics learners (De Corte, 2004). Furthermore, parental involvement in their children's learning activities relates to children's academic interest, confidence, and engagement (Fan & Williams, 2010). Mothers' involvement in their children's mathematics homework predicts their children's later mathematics confidence (Denner, Laursen, Dickson, & Hartl, 2016).

The above research generally suggests that mathematics-related activities are likely to play roles in both mathematics achievement and affect. There is, however, little agreement on what constitutes mathematics affect or the major components of mathematics affect. Theories on both mathematics education and educational psychology indicate that confidence (or self-concept and self-efficacy) and interest (or enjoyment and being cheerful) are two major components of mathematics affect or motivation for children to engage in mathematics or general learning activities (Gomez-Chacon, 2000; Pintrich, 2003). Further, the relationships between mathematics confidence, interest, achievement, and activities are well documented in mathematics education and educational psychology literature (Chiu, 2012; Riconscente, 2014). This study therefore will focus on the two affective variables in mathematics: confidence and interest.

Rationales. Past research only focuses on the effect of early numeracy activities on cognitive outcomes, mainly mathematics achievement or skills (Dunst et al., 2017; Skwarchuk et al., 2014). There appears to be no research to date addressing the issue of the effect of early numeracy activities on affective outcomes. Children may perceive early numeracy activities as both a learning experience and a playful one (Cohrssen, Tayler, & Cloney, 2015), which in turn may impact their mathematics achievement and affect.

Early numeracy activities can be a playful experience for children and parents, but they can also have a meaningful influence on the young learners (Cohrssen et al., 2015). The early numeracy activities link to children's development of both cognitive and social-emotional skills (Van Voorhis, Maier, Epstein, & Lloyd, 2013). Mathematics related games such as chess, block building, and online games have been shown to have positive relationships with children's mathematics achievement (Kolovou, van den Heuvel-Panhuizen, & Köller, 2013) with a larger effect for unhappy children in chess play (Rosholm, Mikkelsen, & Gumede, 2017) and for block-building tasks combined with storytelling (Casey et al., 2008). Child playfulness comprises factors such as physical spontaneity, social spontaneity, cognitive spontaneity, manifestation of joy, and sense of humor (Bundy, Nelson, Metzger, & Bingaman, 2001). Playfulness is positively related to happiness, including the sense of having a pleasurable, meaningful, and engaged life (Proyer, 2014).

To summarize the above literature, early numeracy activities can be both educational and playful experiences for children. Engaging in early numeracy activities potentially plays a role not only in mathematics achievement, a well-researched learning outcome (e.g. Dunst et al., 2017; Skwarchuk et al., 2014), but also in mathematics affect (mainly confidence and interest), a rarely-researched learning outcome. Hypothesis 4 (Model D) of this study

therefore will focus on the effect of early numeracy activities on both mathematics achievement and the two major affective variables (i.e. mathematics confidence and interest).

Child Gender as a Missing Predictor of Early Numeracy Activities

Gender differences in mathematics achievement. Gender differences in mathematics achievement are highly researched even for young children (Anders et al., 2012). Most small-scale studies have found that gender differences in mathematics achievement are small, favoring girls through middle school but favoring boys starting from high school across countries (Reilly, Neumann, & Andrews, 2015). Large-scale studies reveal a different picture that gender differences in mathematics achievements vary across countries. However, there are generally more boys than girls as top achievers (OECD, 2014b, p. 72), and boys are better at advanced mathematics tasks than girls (Mullis, Martin, Foy, & Hooper, 2016a).

For example, in Taiwan, the longitudinal trend of gender differences in mathematics achievements reveals variations across years and initial evidence warning that boys may be outperforming girls. Gender differences in grade-4 mathematics achievements are not significant from 2003 to 2011 but began favoring boys in 2015 although the gender differences in grade-8 mathematics varied and were not significant from 1999 to 2015, as revealed in a report using the data from the Trends in International Mathematics and Science Study (TIMSS; Mullis et al., 2016b). In the PISA 2012 study, Taiwanese 15-year-old boys also outperformed girls in mathematics (OECD, 2014b, p. 73).

The phenomenon of gender differences that are small but slightly favor boys, especially in advanced mathematics participation in Taiwan and some other countries, suggests a need to examine reasons arising from the very early years of children's mathematics learning experiences. Past research rarely addresses how children's gender may play a role in parents' provision of early numeracy activities. This study appears to be the first in the literature to consider this missing variable in the path model for early numeracy activities and may contribute to both knowledge and educational practices.

Rationales. Parents' gender-biased perspectives of mathematics as a males' domain may limit their provision of early numeracy activities to girls (Gunderson, Ramirez, Levine & Beilock, 2012). Research has indicated that mothers with gender stereotypes tend to reduce their involvement in their daughters' mathematics homework in late primary school (Denner et al., 2016). Further, mothers' gender stereotypes relate to their daughters' lower mathematics confidence and to their son's higher mathematics confidence, and mothers' rating of their children's mathematics ability is a stronger predictor of children's mathematics confidence than teachers' (Jacobs & Eccles, 1992). There are also consistent findings that girls have lower mathematics and science confidence and interest than boys even though girls have similar mathematics and science achievements to boys worldwide (OECD, 2007, 2014b).

Given the aforementioned literature, it is reasonable to hypothesize that children's gender affects parents' provision of early numeracy activities to their children and girls have fewer opportunities to experience early numeracy activities than boys do (Hypothesis 5, Model E). Adding gender as a pre-condition may deepen our understanding of whether parents will preclude girls' participation in numeracy activities starting from early years.

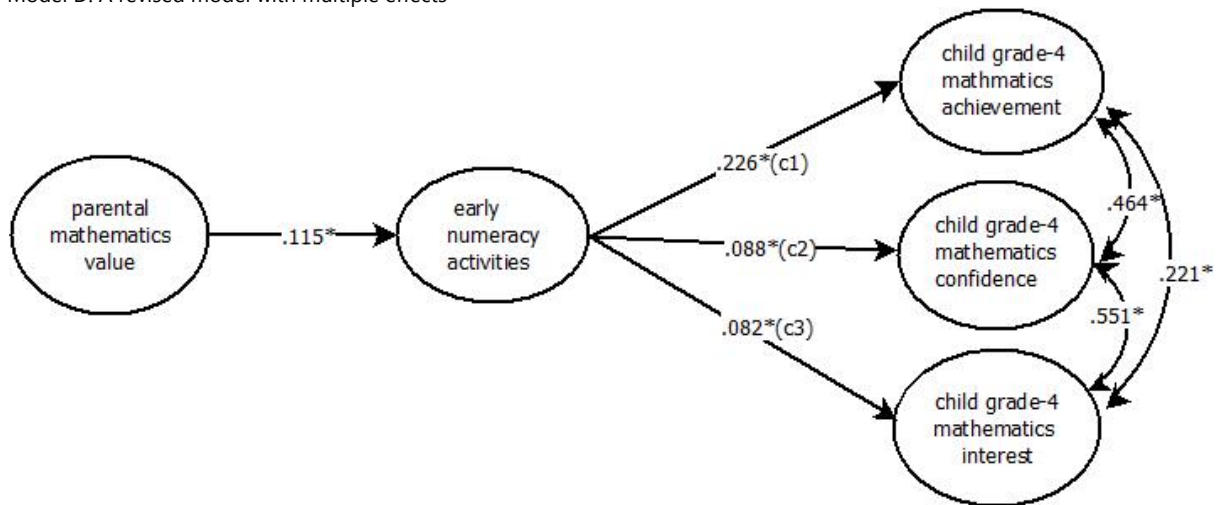
The Current Study and Hypotheses

Past studies on path, causal, or interaction models for early numeracy activities have investigated detailed activities in relation to parental factors (e.g. parental mathematical value) and cognitive learning outcomes (i.e. mathematics achievement; DeFlorio & Beliakoff, 2015; Skwarchuk et al., 2014). The aforementioned review of the literature further suggests that early numeracy activities may play a role not only in mathematics achievement but also in mathematics affects such as confidence and interest at a later stage of learning. The missing variable, gender, may need to be added, and the confusing role of SES needs to be clarified. Further, the relationships between precedent, mediating, and consequent variables in the path model may be elaborated by using structural equation modeling (SEM) instead of regression analysis when there is a large sample size. This study, therefore, examines the following five hypotheses or models:

Models based on past studies

1. Early numeracy activities, conditioned by parental mathematical value, have an effect on children's later mathematics achievement (Model A, developed based on Skwarchuk et al. (2014), in [Figure 1](#)).
2. Early numeracy activities, conditioned by parental mathematical value and SES, have an effect on children's later mathematics achievement (Model B, based on DeFlorio and Beliakoff (2015), in [Figure 1](#)).
3. Early numeracy activities, conditioned by parental mathematical value and mediated by SES, have an effect on children's later mathematics achievement (Model C, based on DeFlorio and Beliakoff (2015), in [Figure 1](#)).

Model D. A revised model with multiple effects



Model E. A revised model with multiple effects, a mediator, and two conditions

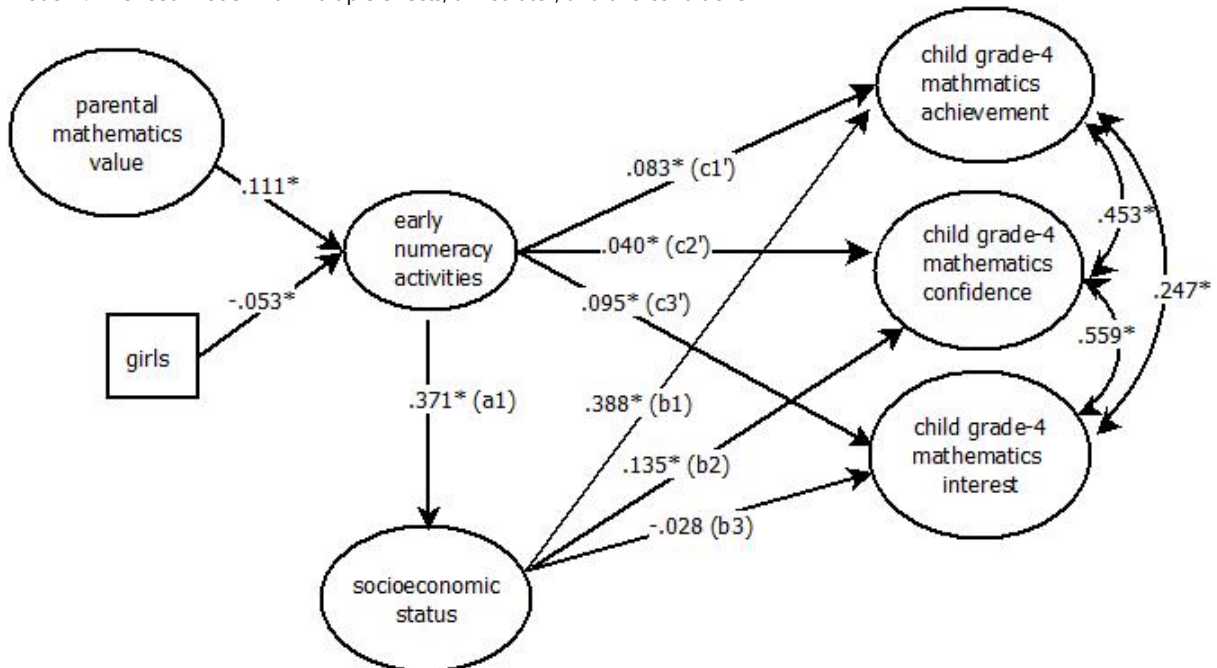


Figure 2. Two revised structural equation models for the effects of early numeracy activities. The notations of a, b, c, and c' come from Baron and Kenny (1986). * $p < .050$

Revised models

4. Early numeracy activities, conditioned by parental mathematical value, have effects on children’s later mathematics achievement, confidence, and interest (Model D in [Figure 2](#)).
5. Early numeracy activities, conditioned by parental mathematical value and child gender and mediated by SES, have effects on children’s later mathematics achievement, confidence, and interest (Model E in [Figure 2](#)).

METHOD

Data Source and Sample

This study used data from the TIMSS of 2015, compiled by the International Association for the Evaluation of Educational Achievement (2017). The five hypotheses were examined using the sample from Taiwan as a case

study, which contained data from 4,291 grade-4 students (2,088 girls; 2,203 boys) and their parents. The dataset provided measures needed for examining the hypotheses in this study.

The Taiwan sample was especially suitable for the purpose of this study in terms of its specific context of educational equity. Among the high-achieving countries in the PISA 2012 study, Taiwan is one of the two countries that have the highest relationships between SES and mathematics achievements; the other country is New Zealand. (OECE, 2013, pp. 36-37). There is also a trend that boys outperform girls in mathematics achievement, as revealed in the previous literature review based on TIMSS and PISA studies (Mullis et al., 2016b; OECD, 2014b).

Measures

This study used seven measures. Three measures were from parental reports: (1) frequency of early numeracy activities (4 items); (2) SES, including educational and professional levels (2 items); and (3) perceptions of mathematics value (3 items). Four measures were from the student dataset: (4) results of tests on knowing, applying, and reasoning mathematics (3 items); (5) perceptions of mathematics confidence (4 items); (6) perceptions of mathematics interest (9 items); and (7) gender (1 = *female*; 2 = *male*; TIMSS name = ITSEX; reversely coded to let girls had a higher value in order to facilitate the interpretation of the result, Model E in **Figure 2**). The items of the measures were reversely coded if needed to let higher numbers represent higher degrees in the meanings of the measures (**Table 2**).

Measures 1–6 contained more than one item and were confirmed as suitable factors fitting the data using confirmatory factor analysis (CFA), as revealed from the fit index results in **Table 1** (RMSEA = .055, CFI = .953, TLI = .945, which will be explained in the Data Analysis section). **Table 2** presents the detailed item contents and measurement characteristics of Measures 1–6. The Cronbach's alphas were from .700 to .966 (> .700), revealing that the measures were unidimensional and had acceptable internal consistency reliabilities (Cortina, 1993). The absolute sizes of factor loadings for their respective factors (measures) were from .656 to .968, showing generally high correlations (> .700) between the items and their factors (Hair, Black, Babin, & Anderson, 2010). In addition, the absolute sizes of the correlations between the latent variables were generally small (r = less than .0005 to .581; variance-covariance matrix in **Table 2**). The two results (high factor loadings and low between-factor correlations) revealed that the six measures (factors) had desirable construct validities and were different constructs from each other.

Table 2. Contents and Measurement Characteristics for the Latent Variables

Latent variable	Item contents	TIMSS variable name	Scale ¹	CFA: Factor loading ²					CFA: Variance ²	
				Num	SES	Pval	Mach	Mcon		Mint
Early numeracy activities (Num; Cronbach's alpha = .833)										
	number toys	ASBH02K	1 = Often to 3 = Never or almost never	<u>.727</u>					.472	
	count things	ASBH02L		<u>.704</u>					.504	
	shape games	ASBH02M		<u>.781</u>					.390	
	building blocks	ASBH02N		<u>.744</u>					.446	
Socioeconomic status (SES; .700)										
	parents' highest education level	ASDHEDUP	1 = University or higher to 5 = Some primary, lower secondary or no school	.816					.333	
	parents' highest occupation level	ASDHOCPP	1 = Professional to 6 = Never worked for pay	.656					.570	
Parental mathematics values (Pval; .721)										
	Most occupations need skills in mathematics, science or technology	ASBH16A	1 = Agree a lot to 4 = Disagree a lot			.684			.532	
	My child needs mathematics to get ahead	ASBH16D					.660			.565
	Mathematics applicable to life	ASBH16G					.698			.513
Grade 4 mathematics achievement (Mach; .966)										
	knowing	ASMKNO01	scores from itme response theory				.944		.108	
	applying	ASMAPP01					.968			.063
	reasoning	ASMREA01					.939			.118
Grade 4 mathematics confidence (Mcon; .836)										
	harder for me than for others	ASBM03B	1 = Agree a lot to 4 = Disagree a lot					.660	.565	
	just not good in mathematics	ASBM03C						.673	.547	
	mathematics harder for me	ASBM03H						.847	.283	
	mathematics makes me confused	ASBM03I						.828	.314	
Grade 4 mathematics interest (Mint; .947)										
	enjoy learning mathematics	ASBM01A	1 = Agree a lot to 4 = Disagree a lot					.891	.206	
	wish have not to study mathematics (reverse)	ASBM01B							-.701	.509
	mathematics is boring (reverse)	ASBM01C							-.705	.502
	learn interesting things	ASBM01D							.757	.428
	like mathematics	ASBM01E							.923	.148
	Like schoolwork involving numbers	ASBM01F							.818	.331
	like mathematics problems	ASBM01G							.845	.286
	look forward to mathematics lessons	ASBM01H							.865	.252
	mathematics favorite subject	ASBM01I							.857	.265
variance-covariance matrix ²										
	Num			1.000						
	SES			.357	1.000					
	Pval			.101	-.062	1.000				
	Mach			.189	.387	.055	1.000			
	Mcon			.077	.137	.084	.477	1.000		
	Mint			.074	-.000	.085	.242	.581	1.000	

Note. ¹All the scales are reversely coded if needed to let higher numbers represent higher degrees in the meanings of the latent variables. ²All parameter estimates are completely standardized solutions. The estimate underlined is not significant at $p < .05$. CFA = confirmatory factor analysis

Data Analysis

The hypotheses (i.e. Models A–E in **Figures 1–2**) were examined using structural equation modeling (SEM) using R software Version 3.1.3 (R Core Team, <http://www.R-project.org/>) and its lavaan package (Rosseel, 2012). In lavaan, missing data were handled using full information maximum likelihood. The posited models were regarded as fitting the data properly if the models met the following criteria: a root mean square error of approximation (RMSEA) value smaller than .080, a comparative fit index (CFI) or a Tucker–Lewis index (TLI) value larger than .900, and a non-significant chi-square (χ^2) (Hair et al., 2010). Chi-square on its own, however, may not be a suitable criterion because a large sample size tends to generate a significant result but may not be a sign of not being a good fit (Bollen & Long, 1993).

Table 3. Selected Effects based on Models C and E

Outcomes	Effects	SES ~ Num (a)	Outcome ~ SES (b)	Mediating effect from Num via SES (a*b)	Outcome ~ Num (c')	Total effect (a*b+c')
Model C (Figure 1): mathematics achievement		.371	.387	.144	.084	.228
Model E (Figure 2):						
Mathematics achievement		.371	.388	.144	.083	.227
Mathematics confidence		.371	.135	.050	.040	.090
Mathematics interest		.371	<u>-.028</u>	<u>-.010</u>	.095	.085

Note. The underlined effect statistics are not significant at $p = .050$. '~' = regressed on; SES = socioeconomic status; Num = Early numeracy activities. The values of a, b and c' come from Model C (Figure 1) and Model E (Figure 2)

RESULTS

Path Model from Parents' Value to Numeracy Activities to Children's Achievement (Model A)

The first hypothesis (Model A in Figure 1), stating that 'early numeracy activities, conditioned by parental mathematical value, have an effect on children's later mathematics achievement' and developed based on Skwarchuk et al. (2014), was examined using SEM. The SEM analysis results revealed that Model A properly fitted the empirical data, as revealed by the fit index values, with RMSEA (= .049) smaller than .080 and both CFI (= .987) and TLI (= .982) larger than .900 (χ^2 to be ignored due to the large sample size in this study; Table 1). As hypothesized, parents' values of mathematics for the world and for their children positively predicted their provision of early numeracy activities to their children (.114), which in turn positively predicted children's mathematics achievement at grade 4 (.226; Figure 1).

SES as a Cause (Model B)

The second hypothesis was 'early numeracy activities, conditioned by parental mathematical value and SES, have an effect on children's later mathematics achievement' (Model B in Figure 1). The hypothesis, with SES as a cause, was developed on the basis of DeFlorio and Beliakoff's (2015) research finding that there were interaction effects between SES and early numeracy activities. However, SEM analysis failed to generate any solutions (including no fit index and no regression coefficients produced), which was a sign that Model B completely failed to fit the empirical data.

SES as a Mediator (Model C)

Hypothesis 3 (Model C in Figure 1) added SES as a mediator to Model A. Thus, SES in Model C was re-conceptualized as 'parental knowledge capital', which mediated the effect of early numeracy activities on children's later mathematics achievement. Like Hypothesis 2, Hypothesis 3 was developed on the basis of DeFlorio and Beliakoff's (2015) study, which indicated interaction effects between SES and early numeracy activities.

The SEM results revealed that Model C fitted the empirical data properly, as revealed by the fit index values (RMSEA = .046, CFI = .983, TLI = .978; Table 1). SES partially mediated the effect of early numeracy activities on achievement because the direct effect of numeracy activities on achievement decreased from .226 (c0 in Model A) to .084 (c0' in Model C), with both effects being significant. It should be noted that, if SES could reduce the significant effect of numeracy activities on achievement in Model A (c0) to a zero effect in Model C (c0'), then SES would be viewed as fully mediating the effect of numeracy activities on achievement (Baron & Kenny, 1986; Preacher & Hayes, 2004).

The SEM analysis could calculate and examine the significance of mediating and total effects (Table 3). The results revealed that the mediating effect of SES was significant, with its total effect on achievement (.228) mostly coming from SES mediation (.144) and slightly from the direct effect of early numeracy activities (.084).

Revised Model: Multiple Effects on Mathematics Achievement and Affect (Model D)

Hypothesis 4 (Model D in Figure 2) posited that early numeracy activities, conditioned by parental mathematics values, had effects on not only mathematics achievement (Sowinski & LeFevre, 2014) (cf. Model A in Figure 1) but also mathematics affect (i.e. confidence and interest). Both achievements and affects are important outcomes from learning mathematics (Chiu & Whitebread, 2011). The results of the SEM analysis revealed that Model D fitted the data properly, as revealed by the fit index values (RMSEA = .058, CFI = .953, TLI = .947; Table 1). In addition, early

numeracy activities, conditioned by parental value (.115), significantly predicted not only mathematics achievement (.226) but also confidence (.088) and interest (.082), as shown by Model D in [Figure 2](#).

Adding Gender as a Condition to the Revised Model (Model E)

Hypothesis 5 was developed on the basis of past research findings that, for girls, their gender can threaten the availability of opportunities to learn mathematics from parents (e.g. Denner et al., 2016). The SEM analysis results revealed that girls had fewer opportunities to experience early numeracy activities provided by parents (regression coefficient = $-.053$, $p < .05$; 1 = female, 2 = male; Model E in [Figure 1](#)). Similar to Model D, Model E with the additional predictor, gender, also fits the data well (RMSEA = .054, CFI = .948, TLI = .942; [Table 1](#)).

DISCUSSION

Influential Paths from Parental Values to Numeracy Activities to Mathematics Achievement (Model A)

This study supports the path model from parental mathematics values, basic numeracy activities, to mathematics achievement for Taiwanese students (Model A). This finding confirms Skwarchuk et al.'s (2014) speculation and replicates their research findings that parental mathematics values play a role in children mathematics achievements. However, in Skwarchuk et al.'s study, basic numeracy activities fail to have effects on child mathematics knowledge or skills, and only formal numeracy activities and informal numeracy tools do. As such, this study contributes to knowledge by demonstrating that informal, basic numeracy activities can play a role in the path model similar to formal, advanced numeracy activities.

One may argue that one of the reasons for this result may be that Skwarchuk et al.'s study places basic and formal numeracy activities and informal numeracy tools together in their model, whereas this study only uses basic numeracy activities. However, the result is consistent with research findings that child-parent interactions relate to children's mathematics achievements even with few parental strategies (Letourneau et al., 2013; Zhou et al., 2006) and that basic numeracy activities predict children's mathematics achievement better than formal numeracy activities do (Dunst et al., 2017).

The result suggests that parental values affect parents' provision of early numeracy activities, which in turn lead to increased children's later mathematics achievement in grade 4, even with few formal numeracy teaching activities. Educators and policymakers can encourage parents to provide their children basic numeracy activities or games (even without formal mathematics teaching), which still benefit children's later mathematics achievement.

Taiwanese parents normally value academic achievements and frequent formal teaching (Huntsinger, Jose, & Larson, 1998; Shih & Yi, 2014). This finding suggests that Taiwanese parents can reduce their anxiety about formally teaching their children by themselves, in school, or in after-school classes. Informal, basic, and playful mathematics-related activities or games (e.g. counting things, playing shape games, and playing with building blocks) can also play roles in their children's future mathematics achievement. Educators and policymakers need to encourage parents to initiate basic, playful numeracy activities even if they do not engage in formal or advanced teaching in their daily lives. This encouragement can include raising parental mathematics values and emphasizing the long-term effects of early numeracy activities on their children's mathematics achievement.

Mediating Role of SES (Models B and C)

DeFlorio and Beliakoff (2015) find that SES (indicated by family ability to pay for private schooling) positively interacts with early numeracy activities and mathematics achievements. This study finds that SES (indicated by educational and professional levels) plays a role mediating the effect of early numeracy activities on mathematics achievements (Model C), not a role conditioning early numeracy activities (Model B). This result is partially consistent with Levine et al.'s (2010) finding that parents' number talks predict children's mathematics achievement even when controlling for SES.

Past studies on SES in relation to early numeracy activities and mathematics achievement tend to only focus on its moderating or conditioning role (DeFlorio & Beliakoff, 2015; Letourneau et al., 2013). The mediating role of SES is only partially implied. For example, children's mathematics achievements in primary school can be predicted by children's early numeracy activities at home (LeFevre et al., 2009) and supportive home environment, which can reduce SES mathematics achievement gaps (Galindo & Sonnenschein, 2015). The present study's finding contributes to the knowledge that SES (if measured as parental educational and professional levels) can mediate the effects of early numeracy activities on mathematics achievement at grade 4. This finding has several implications for parenting and educational practices.

The mediating role of SES may mean that parents transfer their knowledge capital to children's executive functions such as in-depth self-talk, self-regulatory strategies, and numeracy skills, which then lead to later mathematics achievement (Lee & McDonough, 2015; LeFevre, Polyzoi, Skwarchuk, Fast & Sowinski, 2010). Future research can deepen the understanding of the knowledge transfer process by adding further parental and child mediating variables into the models. Identifying more mediating variables between early numeracy activities and mathematics achievement can help in the design of effective teaching and parenting programs.

Early childhood education is viewed as one of the most effective measures to break the cycle of poverty worldwide (Connell, 1994; Leseman & Slot, 2014). Parents in Taiwan play a much more important role in influencing children's achievements than those in Western countries do (D'Ailly, 2003). The present findings appear to support the worldwide belief that early childhood education breaks the cycle of poverty and the cultural effort that parents play important roles in children's achievement because SES plays a mediating role, not a conditioning one, for the parents and children from Taiwan in this study.

On the other hand, the findings may serve as a warning that there is social reproduction involved in high-SES families creating high-achieving children, but this is through the cultural capital of SES (as a mediator, not a condition). Early childhood education has been shown to be a notable predictor for low-SES children's later achievements (including mathematics achievement), even when controlling for child gender and parental disability (Apps, Mendolia, & Walker, 2013).

Educational policymakers need to provide free, high-quality early childhood education for children from low-SES families (Bauchmüller, Gørtz, & Rasmussen, 2014). Another measure would be to increase low-SES parents' parenting knowledge and skills, which may be incorporated into early childhood education programs, in order to teach both children and parents concurrently. The parenting education program can also start from the maternal pregnancy period in order to increase future caregivers' abilities to provide mental stimulation and responsive caregiving that promotes children's cognitive and social-emotional development (Leseman, 2002).

Effects of Early Numeracy Activities on Cognition and Affect (Models D and E)

This study confirms that early numeracy activities have effects not only on mathematics achievement but also on mathematics affects (i.e. confidence and interest) with (Model D) or without (Model E) adding gender as a condition. Although the effects of early numeracy activities on mathematics achievement have been widely researched (DeFlorio & Beliakoff, 2015; Skwarchuk et al., 2014), their effects on mathematics affects have received little attention in past research. Early numeracy activities are meaningful for children not only because they are playful but also because they are educational. Mathematics curricula and mathematics teaching emphasize both cognitive and affective outcomes, as revealed in the national mathematics curricula of Taiwan and most countries (Chiu & Whitebread, 2011; Cohrssen et al., 2015).

Including affective outcomes (e.g. confidence and interest) into the model has increased the understanding of the effects of early numeracy activities. The same coefficient leads from early numeracy activities to mathematics achievement (.266) in Models A and E, but early numeracy activities in Model E have additional significant effects on affects (confidence and interest). This result suggests that mathematics affects are a missing outcome in past research and worth incorporating into future models for examining the effects of early numeracy activities.

SES mediates the effects of early numeracy activities on mathematics achievement and confidence but not on interests (Model E; [Table 3](#)). The result reveals that early numeracy activities only have direct effects on children's later mathematics interest, which emerges regardless of SES or parental knowledge capital. This result provides valuable suggestions for educational practices. In particular, even without high SES or parental knowledge capital, children can still benefit from early numeracy activities in their later mathematics interest development. Confidence and interest are two major reasons for students to choose advanced science courses and careers (Chiu, 2017; Venville, Rennie, Hanbury, & Longnecker, 2013; Uitto, 2014). In this sense, early numeracy activities are a worthwhile investment, and the results of this study suggest that they be advocated by educators and policymakers and implemented by parents.

Taiwanese students generally have high mathematics and science achievements, but the variances in the achievement scores are large compared with other countries in large-scale international studies (Mullis, Martin, Foy, & Arora, 2012, p. 42; OECD, 2014b, pp. 19 and 72). This means that, even though Taiwan's mean scores are high compared with most countries in the world, there are large differences or gaps between low and high achievers in test results. On the other hand, the mathematics motivations of students in Taiwan (and some East Asian countries such as Singapore and Japan) are more highly related to mathematics achievements than those in some Western countries (e.g. England and Australia) (Zhu & Leung, 2011). Research also indicates that mathematics achievement can lead to mathematics affect and vice versa (Chiu, 2012). Although cultural factors or educational designs may play roles in the issue, this finding offers a measure (i.e. playful, informal, or basic numeracy activities

that can increase both mathematics achievement and affect) to reduce the gap between low and high achievers in Taiwan.

Effects of Child Gender on Early Numeracy Activities (Model E)

This study finds that girls are given fewer opportunities to experience early numeracy activities with their parents than boys (Model E). This result suggests that parents in Taiwan may still have a misconception that girls are not good at, interested in, or suited to doing mathematics. In other words, Taiwanese parents, like parents in Western cultures (Denner et al., 2016; Jacobs & Eccles, 1992), have a gender stereotype that mathematics is a male domain.

This stereotype may reflect the phenomenon that there are large gender gaps favoring males in advanced mathematics in the final year of secondary education (Mullis et al., 2016a) and more top-achieving boys than girls at 15 years old (OECD, 2014b). This phenomenon continues into higher education. More male students than female students studied science and engineering in Taiwan and OECD countries in 2006 (Ministry of Education in Taiwan, 2009). This trend has continued even until the most recent 2016 statistical report provided by Ministry of Education in Taiwan (2018), with only 27.47% females studying science and 13.78% females studying engineering, compared with 52.84% females studying education and 50.55% females studying the humanities and arts. The phenomenon that males are better at advanced mathematics than girls or that more boys than girls are top mathematics achievers across cultures suggests in-depth research is needed to identify reasons and narrow this gender gap using a wide range of student, school, and cultural variables.

Educators and policymakers need to raise parents' awareness about the detrimental impacts of limiting early numeracy activities for girls and encourage parents to provide girls early numeracy activities. Teaching programs to decrease the gender stereotype of mathematics and science as male domains are still needed in Taiwan (Chiu, 2011). One way to encourage parents may be to emphasize the contribution that early numeracy activities can make in their children's later mathematics achievement, confidence, and interest, as Models D and E (Figure 2) show.

Limitations of this Study and Suggestions for Future Research

This study has two limitations relating to the methodology. Firstly, this study used survey data to examine path models, which imply a cause-and-effect relationship. However, only experiments can address the relationships between causes and effects. Secondly, this study only uses data from a specific culture. For example, perhaps the mediating role of SES is only salient for parents in Taiwan, most of whom have the habit of teaching their children through early numeracy activities, and knowledgeable parents provide higher quality teaching during early numeracy activities than less knowledgeable parents do. Future research can use data from other cultures to validate the mediating role of SES.

Two limitation relates to the conception of the model formulated in this study. Firstly, this study uses the numeracy activity as a whole (latent concept), which comprises several numeracy activities (i.e. number toys, counting things, shape games, and building blocks). Future research can further investigate whether certain numeracy activities are more effective in predicting children's later learning outcomes than some other numeracy activities (e.g. one-to-one counting and labeling set sizes; Casey et al., 2018). Secondly, SES is indicated in this study by parental educational and professional levels. However, the methods that SES is transferred to children's learning outcomes are still under-researched. Past research has indicated that parents may value and attempt to apply early numeracy activities for their children but lack early mathematics knowledge and place less emphasis on mathematics than on languages (Cannon & Ginsburg, 2008). Future research needs to achieve a clearer understanding about the process of how SES (or parental knowledge capital) is transferred from parents to their children. Educators can develop measures to teach parents about how to support their children's learning during early numeracy activities, which can both benefit educational practices and increase understanding of the knowledge transfer process.

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