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個體發展的有效教育提供：多元數據分析取向

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中文摘要：過去的研究已經檢驗了早期數學活動對兒童後期數學成就影響的模型，以父母價值觀為前提，社會經濟地位（SES）作為計算活動的相互作用衡量標準。本研究提出了以下模型：（1）早期數學活動，以父母價值為條件，對數學成就和情意（例如信心和興趣）會產生多重效應；（2）上述多重效應，也可透過SES和早期數學活動調節，並以父母價值和子女性別為先決條件。本研究使用結構方程模型檢驗所提出的模型，資料來源為來自臺灣父母報告和四年級兒童的測試和報告（N = 4,291；49%女孩）的TIMSS 2015數據。三個主要結果超越了之前的研究結果，提供教育實務建議如下：（1）早期的數學活動除了成就之外，還會對數學的信心和興趣產生影響。（2）SES調節早期計算活動對成就和信心有影響，但不影響興趣。SES的中介效應表明，應該在早期的數學活動中提供高品質的教育。（3）父母為女孩提供較少的數學活動，這表明父母應該為女孩提供更多的早期數學活動。

中文關鍵詞：早期算術，性別，數學成就，育兒，興趣

英文摘要：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.

英文關鍵詞：early numeracy, gender, mathematics achievement, parenting, interest

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Effects of Early Numeracy Activities on Mathematics Achievement and Affect: Parental

Value and Child Gender Conditions and Socioeconomic Status Mediation

Abstract

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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, Hojnoski, 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, 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.

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:

I. 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)

II. 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)

<Insert Figure 1 and Figure 2 here.>

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.

<Insert Table 1 and Table 2 here.>

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).

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 (c_0 in Model A) to .084 (c_0' 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 (c_0) to a zero effect in Model C (c_0'), 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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Table 1

Fit Index Values for the Examined Models

Models \ Fit indexes	χ^2	<i>df</i>	<i>p</i>	<i>RMSEA</i>	<i>CFI</i>	<i>TLI</i>
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.

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 = <i>Often</i> to 3 = <i>Never or almost never</i>	.727						.472
	count things	ASBH02L		.704						.504
	shape games	ASBH02M		.781						.390
	building blocks	ASBH02N		.744						.446
Socioeconomic status (SES; .700)										
	parents' highest education level	ASDHEDUP	1 = <i>University or higher</i> to 5 = <i>Some primary, lower secondary or no school</i>		.816					.333
	parents' highest occupation level	ASDHOCCP	1 = <i>Professional</i> to 6 = <i>Never worked for pay</i>		.656					.570
Parental mathematics values (Pval; .721)										
	Most occupations need skills in mathematics, science or technology	ASBH16A	1 = <i>Agree a lot</i> to 4 = <i>Disagree a lot</i>			.684				.532

Early Numeracy Activities Effects

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		.660	.565
just not good in mathematics	ASBM03C	1 = Agree a lot to 4 = Disagree a lot	.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		.891	.206
wish have not to study mathematics (reverse)	ASBM01B	1 = Agree a lot to 4 = Disagree a lot	-.701	.509
mathematics is boring (reverse)	ASBM01C		-.705	.502
learn interesting things	ASBM01D		.757	.428
like mathematics	ASBM01E		.923	.148

Early Numeracy Activities Effects

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	<u>-.000</u>	.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.

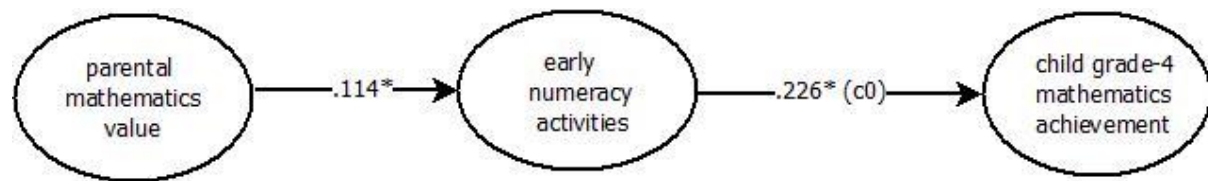
Table 3

Selected Effects based on Models C and E

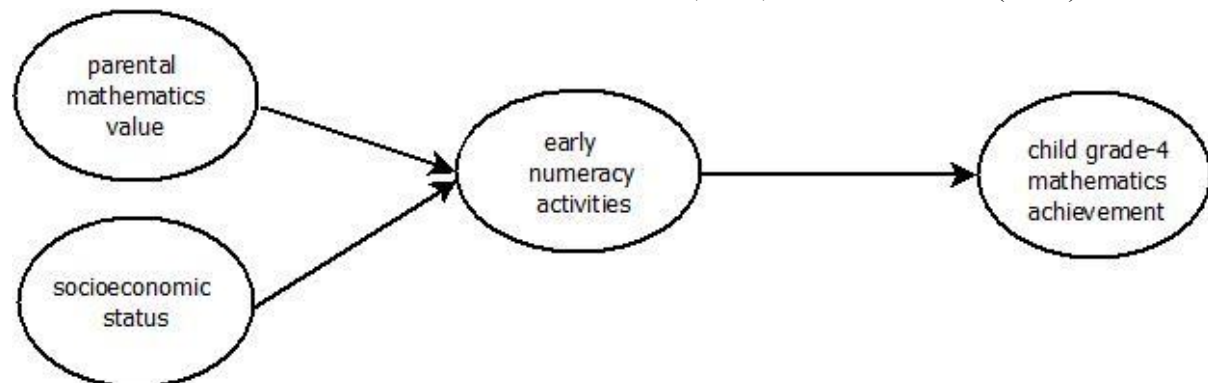
Outcomes	Effects	SES	Outcome	Mediating	Outcome	Total effect
		~ Num (a)	~ SES (b)	effect from Num via SES (a*b)	~ Num (c')	(a*b+c')
Model C (Figure 1): mathematics achievement		.371	.387	.144	.084	.228
Model E (Figure 2):						
Mathematics achievement		.371	.388	.144	.083	.227
Mathematics confidence		.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).

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)

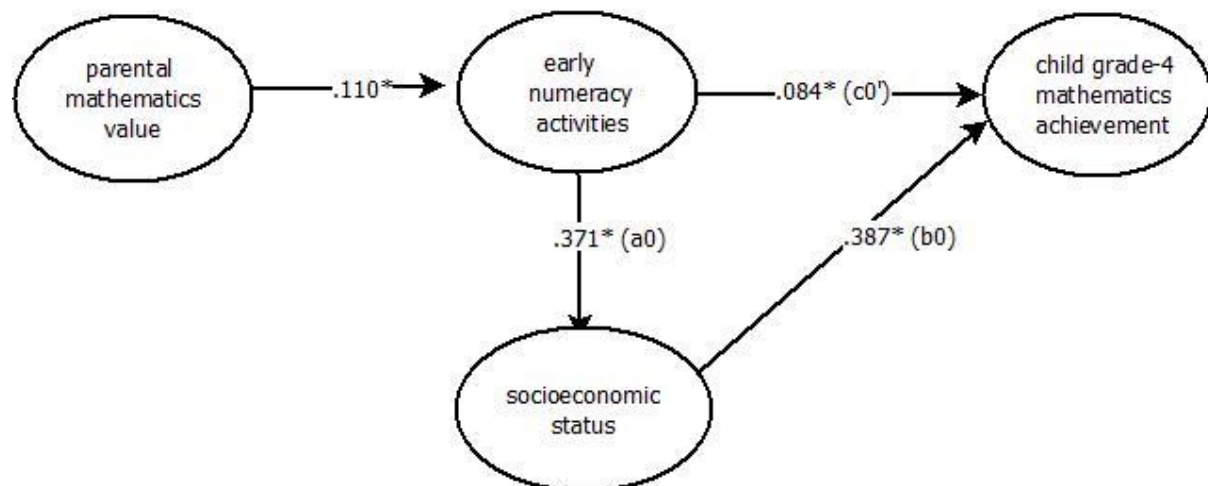
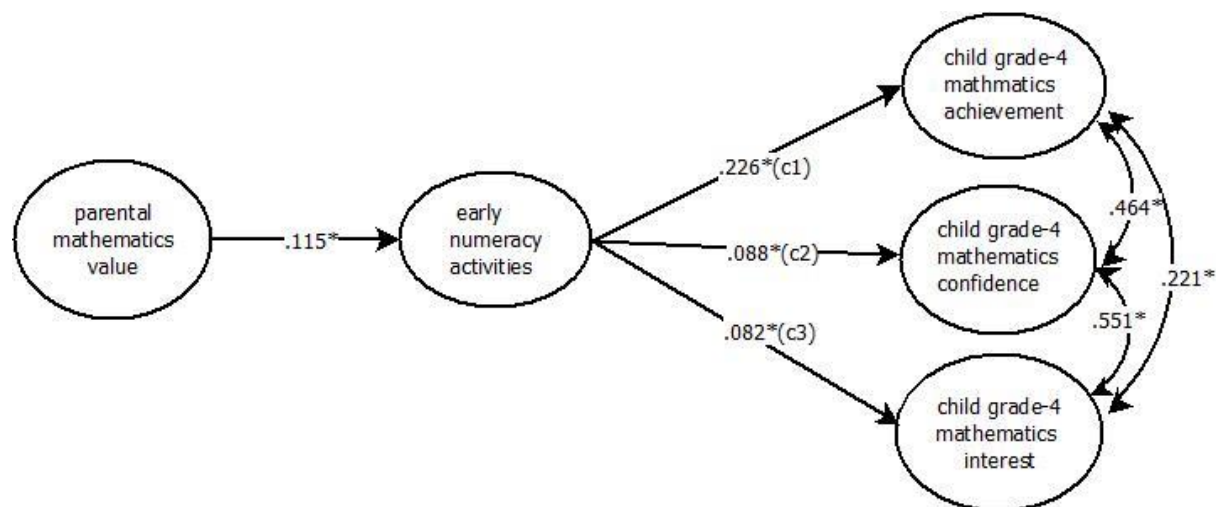


Figure 1. Three proposed models for early numeracy activities based on previous studies. Model B is not supported, failing to generate any solutions and thus the path coefficients are not provided. The notations, a, b, c and c' come from Baron and Kenny (1986). * $p < .050$

Model D. A revised model with multiple effects



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

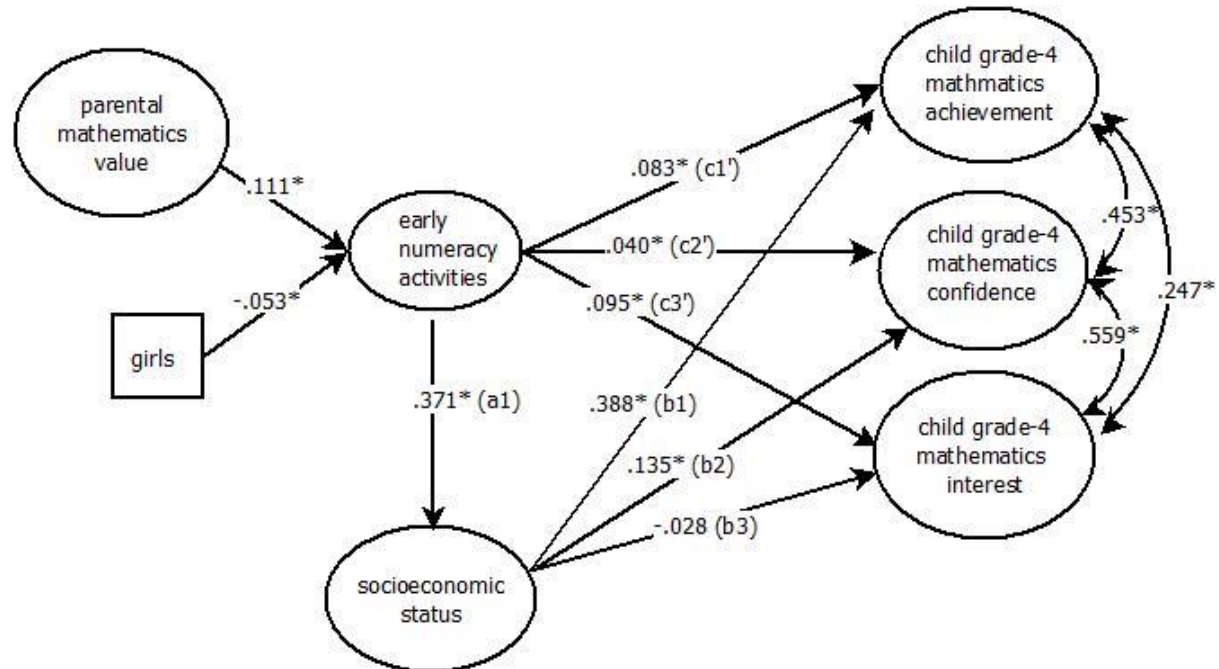


Figure 2. Two revised structural equation models for the effects of early numeracy activities. The notations of a, b, c, and c' come from Baron and Kenny (1986). * $p < .050$

科技部補助專題研究計畫出席國際學術會議心得報告

日期：107 年 2 月 9 日

計畫編號	MOST 106-2410-H-004-131		
計畫名稱	個體發展的有效教育提供：多元數據分析取向		
出國人員姓名	邱美秀	服務機構及職稱	國立政治大學教育學系教授
會議時間	107 年 1 月 12 至 13 日	會議地點	Imperial College London, London, UK
會議名稱	(中文) 2018 年 e 社會，e 學習和 e 科技國際會議 (英文) 2018 International Conference on e-Society, e-Learning and e-Technologies		
發表題目	(中文) 製作開放教育視頻：有效的個人，團隊和教育因素 (英文) Producing Open Educational Videos: Effective Individual, Team and Pedagogical Factors		

一、參加會議經過

1 月 12-13 日：註冊，發表論文，參加 keynote speech、其他學者的論文發表、會議安排的學術與交流活動。

二、與會心得

- 1、此會議為工程領域的學者主辦，並且與另一個學術研討會「2018 International Conference on Information Mangement and Processing」同時舉辦。此次與會的學者多數為大專院校教師，少部分為研究生(或兼具大專老師的身分)，來自全世界(美、非、歐、亞、澳、非洲)與各領域，包括工程各領域、圖書館學、教育，人文等。
- 2、keynote 演講主要重在目前最新的人工智慧、音樂與科技、人臉辨識等議題，演講者分別來自美國、義大利、英國的大學與學術研究機構。第一個演講是介紹性、思性的。第二個演講，有點跨領域。第三個演講實在是高深，談了很多科技方面的難題與解決方案，但因為演講者圖文、動畫併呈，感受到科技的進步。
- 3、與來自各國的學者的交流中發現，科技真的已融入到各領域，各領域都可用他們的方式研究「e」這個主題。即使是文科的學者，例如，英文教學，可用手機、社交媒體、上傳檔案到平台等方式進行多元的 e 教學。圖書館方面，可研究論文發表、論文使用與學者領域間的關係。工程，更可大量的使用 e，來進行機械工程設計。數據分析、工程人員的身心健康平台的建立等。教育方面，包括 e learning、e testing、data platform 建立、數據分析等。E 主題的多元化，這些只是一個部分，還有許多待開發的無限寬廣創意空間。

三、發表論文全文或摘要

Producing Open Educational Videos: Effective Individual, Team and Pedagogical Factors

The aim of this study was to identify effective individual, team and teaching factors that supported students to produce open educational video products on protecting the environment. Students registering for three teacher training courses were invited to produce educational video products and placed the products on YouTube as part of the course requirement. Students provided their weekly journals and a final reflection on the whole

process of producing the products. Qualitative data analysis revealed that the students who engaged in and valued the production tend to value environmental issues and the power of the Internet for educating the public. The quality of the products was determined by team members of diverse technical skills relating to producing and broadcasting videos. The course provided sufficient support for team works and pedagogical designs but lacked technological support. Implications for supporting students to produce digital products are discussed.

Keywords: digital products, effective teaching, learning process, production process

四、建議

1. 這次的會議，相當的國際化。程度好的新一代研究生，在 ppt 的製作精美和發表的態度、談吐上，另人覺得長江後浪推前浪。即使他們的母語非英文，但仍有極佳的英文發表(表演)能力，往日，能用「表演」的方式發表學術英文論著者，大多是以英語為母語的國家(尤其是「美國」)的學生，但這次，看到了非英語為母語國家的一些碩班生，其英文口頭發表學術著作和 ppt 製作的能力甚佳。台灣的新一代研究生，可能要加強。
2. 「e」相關研究，已由工程逐漸開展到在各領域，尤其是社會、文史。至於如何開發，則留待未來學者與各領域人才的投入，有很大的開發潛力。

五、攜回資料名稱及內容

紙本：會議手冊(紙本)，含會議簡介、會議相關資訊、keynote speaker 的簡介與演說主要內容、議程(含時間安排、所有與會者名單、論文名稱等)。

電子檔：議程。

六、其他：發表證明



106年度專題研究計畫成果彙整表

計畫主持人：邱美秀				計畫編號：106-2410-H-004-131-			
計畫名稱：個體發展的有效教育提供：多元數據分析取向							
成果項目				量化	單位	質化 (說明：各成果項目請附佐證資料或細項說明，如期刊名稱、年份、卷期、起訖頁數、證號...等)	
國內	學術性論文	期刊論文		0	篇		
		研討會論文		0			
		專書		0	本		
		專書論文		0	章		
		技術報告		0	篇		
		其他		0	篇		
	智慧財產權及成果	專利權	發明專利	申請中	0	件	
				已獲得	0		
			新型/設計專利		0		
		商標權		0			
		營業秘密		0			
		積體電路電路布局權		0			
		著作權		0			
		品種權		0			
		其他		0			
	技術移轉	件數		0	件		
		收入		0	千元		
國外	學術性論文	期刊論文		1	篇	Chiu, M.-S. (2018). Effects of early numeracy activities on mathematics achievement and affect: Parental value and child gender conditions and socioeconomic status mediation. EURASIA Journal of Mathematics, Science and Technology Education, 14(12), em1634.	
		研討會論文		1		Chiu, M.-S. (2018). Producing open educational videos: Effective individual, team and pedagogical factors. Paper presented at the 2018 International Conference on e-Society, e-Learning and e-Technologies, Imperial College London, London, UK, January 12-13.	
		專書		0	本		
		專書論文		0	章		
		技術報告		0	篇		

		其他			0	篇	
	智慧財產權 及成果	專利權	發明專利	申請中	0	件	
				已獲得	0		
			新型/設計專利		0		
		商標權			0		
		營業秘密			0		
		積體電路電路布局權			0		
		著作權			0		
		品種權			0		
		其他			0		
	技術移轉	件數			0	件	
		收入			0	千元	
參與計畫人力	本國籍	大專生			0	人次	
		碩士生			3		三位學生進行相關學術研究訓練，例如資料分析等。
		博士生			1		一位博班生，學習資料分析、論文發表與寫作。
		博士後研究員			0		
		專任助理			0		
	非本國籍	大專生			0		
		碩士生			0		
		博士生			0		
		博士後研究員			0		
		專任助理			0		
	其他成果 （無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。）						

科技部補助專題研究計畫成果自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現（簡要敘述成果是否具有政策應用參考價值及具影響公共利益之重大發現）或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

☒ 達成目標

☐ 未達成目標（請說明，以100字為限）

☐ 實驗失敗

☐ 因故實驗中斷

☐ 其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形（請於其他欄註明專利及技轉之證號、合約、申請及洽談等詳細資訊）

論文：☒ 已發表 ☐ 未發表之文稿 ☐ 撰寫中 ☐ 無

專利：☐ 已獲得 ☐ 申請中 ☒ 無

技轉：☐ 已技轉 ☐ 洽談中 ☒ 無

其他：（以200字為限）

研究結果已正式發表於一期刊論文、一會議論文。

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性，以500字為限）

學術成就：研究結果已正式發表於一期刊論文、一會議論文。

技術創新：使用進階統計技術分析國際資料庫中的臺灣資料。

社會影響：研究結果顯示：（1）早期的數學活動除了成就之外，還會對數學的信心和興趣產生影響。（2）SES調節早期計算活動對成就和信心有影響，但不影響興趣。SES的中介效應表明，應該在早期的數學活動中提供高品質的教育。（3）父母為女孩提供較少的數學活動，這表明父母應該為女孩提供更多的早期數學活動。

4. 主要發現

本研究具有政策應用參考價值：☒ 否 ☐ 是，建議提供機關

（勾選「是」者，請列舉建議可提供施政參考之業務主管機關）

本研究具影響公共利益之重大發現：☐ 否 ☐ 是

說明：（以150字為限）