The Influence of Parental Educational Involvement in Early Childhood on 4th Grade Students' Mathematics Achievement

Abstract:

Research Findings: This study employed data from the TIMSS 2015 survey to investigate whether parental educational involvement behaviour in early childhood and parental attitudes towards mathematics and science can enhance children's mathematics achievement in the 4th grade via influencing children's learning interests. Samples from Singapore (N=6237) and Hong Kong (N=3316), which share similar cultural backgrounds, and students demonstrating outstanding mathematical performance in TIMSS were selected to examine whether a hypothesized model fit the TIMSS data. The overall model fit was found good. As hypothesized, after controlling for gender, immigration status, and family learning resources variables, both parental involvement in learning activities and parental attitudes towards mathematics and science had positive significant effects on children's mathematics achievement in the 4th grade. However, a variation was also discovered in terms of the influences of parental attitudes in the two samples. The significance of the findings is then discussed.

Practice or Policy: The current findings shed light on the importance of parents' attitudes on education and their involvement in their children's mathematics activities during early childhood. Family education should be given greater attention given that it is necessary for educating family members so that they can provide full support to children. The importance of family education should be communicated thoroughly to the public, and the government should provide more support for parents to involve more in early learning activities at home.

Key Words: Parental education involvement; Early childhood; Parental attitude; Academic achievement; TIMSS 2015

1. Introduction

Early childhood care and education provides important foundation for children's life-long development, health, and well-being (UNESCO, 2015). Education 2030 proposed that "By 2030, ensure that all girls and boys have access to quality early childhood development, care, and pre-primary education so that they are ready for primary education" (UNESCO, 2015, p. 38). Early childhood education has also received more and more attention in China in recent years (Cheng, 2009; Y.W. Li, Y. F. Li, Liu, & Lv, 2013; Li & Lv, 2013). In 2015, Chinese Ministry of Education published *Guidance on Strengthening Family Education*. It emphasizes the significance of improving family education for children aged 0-6 and points out that parents should enhance the understanding of basic knowledge of parenting and improve the skills in guiding their children at home (Ministry of Education of the People's Republic of China, 2015).

The Ecological and Dynamic Model of Transition Theory also illustrates the impact of the dynamic relationship network formed by the child, home, peer, and neighbourhood on a child's transition to school over time (Rimm-Kaufman & Pianta, 2000). The theory suggests that the interaction between parents and preschool children exerts continuous influence on children's behaviour and academic performance upon attending school later in their lives. Guided by the theory, the importance of childhood education has been addressed by many researchers, and the influences of parents' involvement in early childhood on children's development have been examined in numerous studies. It is widely accepted that parental involvement is a very important source of educational input (Sun, Bradley, & Akers, 2012), as it plays an important role in influencing students' development (Englund, Luckner, Whaley, & Egeland, 2004; Starkey & Klein, 2000). Considerable evidence supports the idea that parental behavioural input in learning and parents' attitudes towards learning could facilitate children's learning and ultimately have positive impacts on their academic achievements (Lee & Shute, 2010; Sha, Schunn, Bathgate, & Beneliyahu, 2016). Previous studies have also shown that increasing student exposure to diverse learning activities during their childhood has been linked to enhanced cognitive and sociability development (Foster, Lambert, Abbottshim, Mccarty, & Franze, 2005; Zhou et al., 2006, 2007), especially to better prepare young children for entry into elementary school (Starkey & Klein, 2000).

The mechanism behind the influence of early parental involvement on students has received much attention (Pomerantz, Moorman, & Litwack, 2007; Sha et al., 2016). In response to increasing interest in this topic, students' motivational beliefs such as interest have been proposed as having important mediating effects on the relationship between parents' involvement and children's learning outcomes (Sha et al., 2016; Szechter & Carey, 2009). Motivational theories are based on cognitive frameworks that focus on thought, feelings, and beliefs (Hidi & Renninger, 2006; Meyer & Turner, 2002). A person's intrinsic enjoyment or interest in doing something is one widely recognized motivational belief (Sha et al., 2016). Guided by the Motivation Theory (Schunk, Pintrich, & Meece, 2008), learning interest was examined in this study as a mechanism through which parents' involvement facilitates children's achievement.

Most extant studies focus on influences by employing cross-sectional data (Fan & Williams, 2010; Fan, Williams, & Wolters, 2011; Lee & Shute, 2010; Sha, Schunn, & Bathgate, 2015). The present study differs from prior work in its focus on the role of parents' early learning involvement during childhood in influencing students' mathematics performance in the 4^{th} grade. This is not a longitudinal study, as it uses information collected based on parents' recall. However, it may provide insights for understanding parents' sustained influences on their children over the long term.

Through examining samples from Hong Kong and Singapore, this study also expands previous research, which primarily focused on samples from Western cultures. As multicultural societies, Hong Kong and Singapore might have benefited from the strengths of both the Eastern and Western cultures, and this may be one of the reasons their students have performed well in international studies of mathematics achievements such as the Trends in International Mathematics and Science Study (TIMSS), ranking amongst the top four for the past 20 years (1995 to 2015). Both Hong Kong and Singapore are located in East Asia and are influenced by the culture of Confucianism (Lin, Tan, & Tsai, 2013), which strongly values education (Wong & Rao, 2015) and family ties, attaching significant importance to the upbringing of children. Unlike other societies in East and Southeast Asia (such as South Korea and Malaysia), Hong Kong and Singapore are also influenced by Western culture (Ip et al., 2016; Li & Rao, 2000), but the degree of cultural influence differs. Specifically, Hong Kong's population is dominated by people of Chinese ethnicity, who still adhere to many traditional Chinese concepts and are less influenced by Western culture, compared to the population in Singapore. On the other hand, Western parents give their children less control than Eastern parents (Ip et al., 2016). Subjected to individualistic values and early expectations of autonomy, Western children emphasize autonomy and independence more than children who are influenced by traditional Confucian culture (Ngai et al., 2018). Given their outstanding mathematical achievements in TIMSS and their unique but non-identical cultural backgrounds, especially the importance the parent and family attach to the education of the child (Leung, 1998), we chose Hong Kong and Singapore to investigate how parental educational involvement in the early childhood influences the mathematics achievement of children when they reach the 4th grade and whether parents' involvements in the two places exerts different influence on children.

In summary, the current study examines the relationships among parental activities, parental attitudes, students' learning interests, and students' mathematics achievement. As our focus is on parental involvement in early childhood, parental activities refer to parental involvement in family activities (such as playing numbers games, building blocks, or construction toys) and extracurricular activities (such as visiting a science and technology museum, aquarium, or botanical garden). After controlling for gender, immigration status, and family learning resources, variables that have been widely found to have an impact on student academic performance (Englund et al., 2004; Jacobs, Davis-Kean, Bleeker, Eccles, & Malanchuk, 2005; Lau & Cheng, 2016; Starkey & Klein, 2000), we aim to answer the following research questions:

(1) Does parental educational involvement in early childhood have a significant positive effect on students' mathematics achievement in the 4th grade?

(2) What is the relationship between parents' activities and their attitudes towards mathematics and science?

(3) Is students' interest a significant mediating variable in the above relationships?

(4) Are there any significant differences in pattern, direction, and relative size of the relationships between Singapore and Hong Kong?

2. Theoretical Background

2.1 Parental Involvement

Parental involvement is considered a very important part of educational input (Sun et al., 2012). It refers to parents' participation in the education of their children in order to improve their academic and social achievements (Vukovic, Roberts, & Wright, 2013). Parental involvement has been defined in various ways. Some researchers explained it from the perspective of behavioural input and identified three different types of behaviours (Fan & Williams, 2010; Fishel & Ramirez, 2005; Grolnick & Slowiaczek, 1994; Vukovic et al., 2013). First, parents' participation in and support for school activities have been studied (Grolnick & Slowiaczek, 1994; Izzo, Weissberg, Kasprow, & Fendrich, 1999; Miedel & Reynolds, 1999; Rafiq, Fatima, Sohail, Saleem, & Khan, 2013; Schuepbach, 2014; Sha et al., 2016; Siegel, Esterly, Callanan, Wright, & Navarro, 2007). For example, parents attend school-related activities or school meetings and help children in arranging learning activities according to their performance in school. Second, communication with children about school-related matters have been studied (Christenson, Rounds, & Gorney, 1992; Keith, Reimers, Fehrmann, Pottebaum, & Aubey, 1986; Walberg, 1986) and discussion with teachers to understand their children's situations at school (Deslandes, Royer, Turcotte, & Bertrand, 1997; Epstein, 1991; Grolnick & Slowiaczek, 1994). Third, parents' supervision and management of family activities and out-of-school activities are considered (Keith et al., 1993; Keith et al., 1986; Marjoribanks, 1983). For example, parents participate in their children's practical activities, taking their children to the library and museum and providing learning materials (such as books) to help their children to learn. Most of these family activities are designed to complement the learning activities in school (Rafiq et al., 2013; Schuepbach, 2014; Sha et al., 2016; Shumow & Miller, 2001; Siegel et al., 2007; Singh et al., 1995; Sui-Chu & Willms, 1996).

In addition to the perspective of behavioural input, parents’ attitudes towards children’s education are also widely recognized as a key component of parental involvement. Attitudes, as an external expression of emotion, reflect people’s values, expectations, and feelings towards things (Freedman, 1997; L. Zhang & X. Zhang, 2003). Jeynes (2010) suggests that parents’ attitudes toward education are very important, since parents will transfer these feelings to children through interactions with them in school and family activities (Grolnick & Slowiaczek, 1994; Sha et al., 2015). According to Grolnick and Slowiaczek, parent’s attitudes about learning consist of two perspectives, including their cognitive judgement about learning, such as their values and expectations (Grolnick & Slowiaczek, 1994), and their emotional or affective perceptions about learning (Grolnick & Slowiaczek, 1994; Jeynes, 2010; Sha et al., 2015; Yan & Lin, 2005). For example, Bloom (1980) points out that parents' expectations of children’s academic achievement should be considered part of parental participation. Vukovic et al. (2013) also emphasize parental expectations and aspirations for their children and their encouragement in learning mathematics.

The construct of parental involvement in the current study is defined by the above definitions and further narrowed down since we will only examine parents' involvement in early childhood. At this stage, children have not yet received any formal mathematics education from school, as such, in the behaviour dimension, we particularly targeted at parents' interaction with children through mathematics related game-playing activities (e.g., telling mathematics stories, playing with building blocks, etc.). These games have been discovered to be helpful in improving children's mathematics competencies (Zhou et al., 2006). Second, we used the construct of parents' attitudes towards mathematics and science as a more general and integrated indicator of their perceptions of students' mathematics and science learning, including parents' cognitive judgement on the value of mathematics and science in their children's daily lives and future development.

2.2 Theoretical framework & hypothesized model for the current study

Bandura's social learning theory emphasizes the interaction among environment, cognition, and behaviour in the process of social learning (Bandura, 1977). It also focuses on the important role of "self" in the learning process (Bandura, 1978). Therefore, the influence of environmental factors on students' behaviour could be mediated by students' self-cognition and self-regulation (Bandura, 1993). Correspondingly, the family environment created by parents through their language, behaviour, and attitudes will have an impact on students' external behaviour directly and indirectly through children's internal cognition. Therefore, the initial hypothesized mechanism of parents' early educational involvement and students' later academic achievement is illustrated in Figure 1.

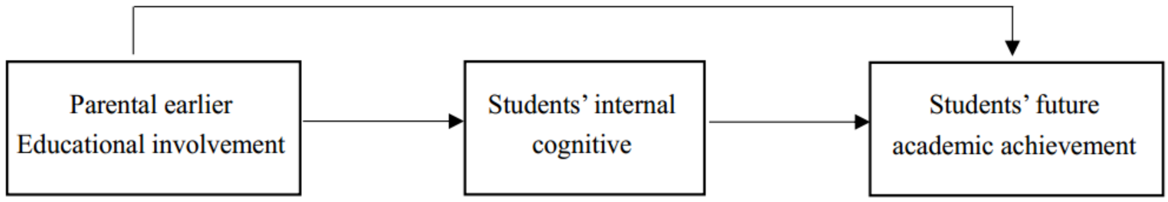

Figure 1: Hypothesized model of the influence of early parental educational involvement on children's later academic achievement.

Based on the above literature review, parental involvement in activities and parental attitudes towards mathematics and science were used as two important indicators of parental educational involvement. Students' interest in learning mathematics, as a very important motivational belief (Hidi & Renninger, 2006; Renninger & Hidi, 2011), was used as the indicator of inner cognition and modelled as a mediating variable. In addition, gender, immigration, and family socioeconomic status may have different effects on students' academic performance (Jacobs et al., 2005; Starkey & Klein, 2000), so these three variables were used as controlled variables in this study. The hypothesis of the theoretical model for this study is shown in Figure 2. In this inquiry model, when parents show positive attitudes towards mathematics and science, they tend to be more involved in their children's learning in early childhood, so that the children become more interested in learning mathematics, thereby enhancing their mathematics achievement.

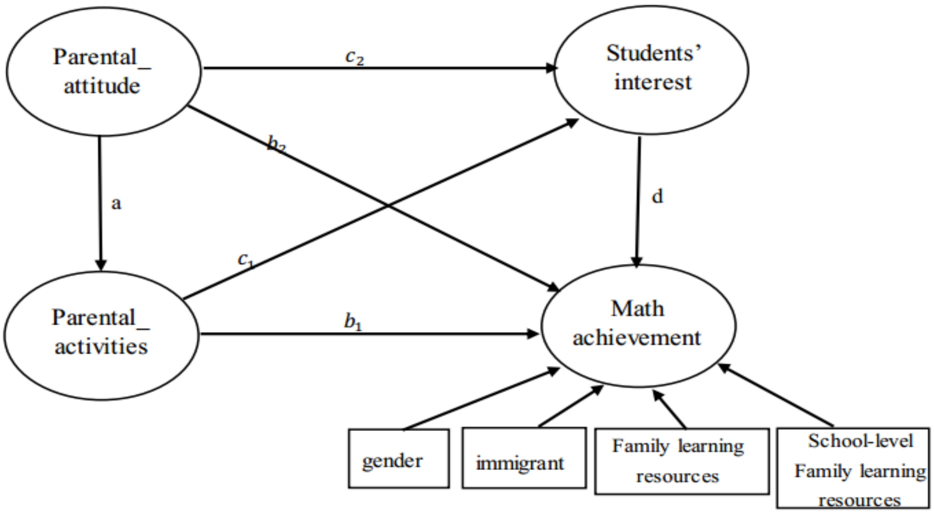

Figure 2: Hypothesized model of the influence of early parental educational involvement on children's later mathematics achievement.

2.3 Influence of parental involvement on students' academic performance

2.3.1 Rationale of the direct path from parental involvement to students' achievement in the hypothesized model

Numerous studies have shown that parental involvement, including their behaviour participants and attitudes, have a positive impact on student achievement (Johnson, 2016; Lee & Shute, 2010; Seginer, 2006). For example, Blevins-knabe, Austin, Musun, Eddy and Jones (2000) and Zhou et al. (2006) find that parental involvement in mathematics-related extracurricular activities, such as counting, playing with building blocks, and talking about the sequence of events in their daily lives, show positive influences on students' mathematics achievements. Holmes (2011) and the National Research Council (2009) point out that students visiting a science and technology museum, aquarium, botanical garden, or planetarium with parents, and both parties carrying out related discussions at home, have a positive effect on students' science achievements. The findings based on the above studies supported the path from parental involvement behaviour to students' achievement in the hypothesized model presented in Figure 2 (path b_1).

The importance of parents' attitudes towards mathematics and science on their children's mathematics and science achievements has also been highlighted in some empirical studies (Gunderson, Ramirez, Levine, & Beilock, 2012; Sun et al., 2012; Szechter & Carey, 2009; Perera, 2014). Perera (2014) examined 2006 PISA data from 15 countries and discovered that parents' attitudes towards science had a significant positive effect on their children's science achievement even after controlling for other important student- and school-level variables such as SES, self-efficacy, and quantity of instruction. These studies provided evidence to support a direct path between parents' attitudes towards mathematics and science and students' mathematics achievement (Path b_2 in Figure 2).

2.3.2 Rationale of the indirect path from parental involvement via interest to students' achievement in the hypothesized model

In addition to investigating the direct relationship between parents' involvement and students' academic performance, an important research question concerning the mechanism behind such a relationship has been raised by many researchers (Pomerantz et al., 2007; Sha et al., 2015). Many researchers have defined interest as a motivational variable (Hidi & Renninger, 2006; Renninger & Hidi, 2011; Sha et al., 2016) that plays a mediating role between parents' behaviours and attitudes and students' external academic performance (Pomerantz et al., 2007; Sha et al., 2016). For instance, Hidi and Renninger (2006) point out that interest refers to "the psychological state of engaging or the predisposition to reengage with particular classes of objects, events, or ideas over time". Many studies have shown that there is a significant positive correlation between parental behaviour participation and students' learning interests (Cannon & Ginsburg, 2008; Crowley, Callanan, Tenenbaum, & Allen, 2001; Jacobs et al., 2005). Moreover, when students are interested in a subject, they are more likely to participate in related activities, learn corresponding knowledge, and succeed (M. Ainley & J. Ainley, 2011; Alexander, Johnson, & Kelley, 2012; Markowitz, 2004; Sha et al., 2016; Simpkins, Daviskean, & Eccles, 2006). In addition, some empirical studies have demonstrated that students' interest in mathematics and science can be a mediator between parental involvement and mathematic as well as scientific achievements. For example, Zhou et al. (2006, 2007) investigated the effects of mathematics related activities on children's mathematics learning with a sample of 85 four-year-old Shanghai children and their parents. They revealed that the frequency and quality of parent-child joint activities at home positively affected their children's development in mathematics, possibly through influencing students' interest in mathematics activities. Sha et al. (2015) explored the relationship between family support and the science achievements of 5^{th} and 6^{th} grade children. They found that children who perceived family support for learning, such as taking them to places where they could learn new things, could influence children's interest, which, in turn, could influence their preferences and engagement in science learning. These studies illustrated the possible indirect path by which parental involvement behaviour influences students' achievement through the mediation of interest in the hypothesis model presented in Figure 2 (path c_{1*}d).

In addition, some researchers suggested that there was a significant positive correlation between parental attitude and students' achievement through influencing students' learning attitudes. For example, Soni and Kumari (2015) revealed a positive relationship between parental attitudes towards mathematics and children's mathematic achievement and pointed out a mediating variable in such a relationship, namely, children's attitudes towards mathematics. They suggested that when children felt that their parents considered mathematics important, they were more likely to think that mathematics was important, and this would in turn generate intrinsic motivations and interests in mathematics (Soni & Kumari, 2015, 2017). In addition, parental attitudes regarding their child's education are helpful in promoting students' intrinsic motivation, which then could improve academic performance (Fan et al., 2011; Georgiou & Tourva, 2007). Jacobs et al. (2005) pointed out that when parents provide positive messages about their values related to science and mathematics, children develop their own interest in those subjects too, thus enhancing their learning engagement. Based on these studies, in the hypothesis model of Figure 2, the path of parental attitudes towards mathematics and science affects students' academic performance through affecting interest was added (path c_{2*}d).

2.3.3 Rationale of the direct path from parental attitudes towards mathematics and science to their involvement behaviour in the hypothesized model

Summarizing existing research, Sun et al. (2012) proposed another mediating variable between parents' attitudes towards learning and children's academic performance: parents' behavioural involvement. As revealed in previous research, the more positive parents' attitudes towards mathematics and science are, the more time they are willing to spend with their children in mathematics- and science-related learning activities (Cannon & Ginsburg, 2008; Szechter & Carey, 2009). Tare, French, Frazier, Diamond, and Evans (2011) observed the dialogue between 16 children who were approximately 10 years old and their parents when visiting museums. The results showed that parents' attitudes towards science could affect the length of time they spent visiting museums and the number of times they explained relevant scientific knowledge to their children. Gunderson et al. (2012) found that parents' attitudes towards mathematics affected children's mathematics performance by influencing the arrangement of extracurricular learning activities for children. Szechter and Carey's research (2009) also found that parents' attitudes towards science and scientists were positively related to the frequency of visits to science museums by parents and children. These studies indicated a possible path between parents' attitudes towards mathematics and science and their involvement in the hypothesis model in Figure 2 (path a).

2.4 Influence of control variables (gender, immigration, family learning resources) on students' academic performance

Family socioeconomic status (SES) has been found to have influential effects on students' academic performance (Foster et al., 2005; Perera, 2014), for example, on mathematics achievement (Starkey & Klein, 2000). Based on Duncan's Socioeconomic Index, as one of the most frequently used measure of socioeconomic status, SES is typically assessed by family income and the level of parental education or occupation (Duncan, 1961; Foster et al., 2005). Family income usually is indicated by reporting on household finances, such as housing situation, book holdings, and electronics ownership (Currie, Elton, Todd, & Platt, 1997). Researchers argued that low SES families might provide fewer mathematics-related activities before students entering school (Hickman, Greenwood, & Miller, 1995), while high SES families with better educated parents are more willing to spend time in their children's learning (Fantuzzo, Tighe, & Childs, 2000). Thus, the influence of SES, which named as *family learning resources* in TIMSS reports, was controlled as a confounding variable in this study.

The second controlled variable was gender. The effects of gender differences on academic achievement have also been widely acknowledged (Georgiou & Tourva, 2007; Jacobs et al., 2005; Tenenbaum & Leaper, 2003). It is generally acknowledged that boys' mathematics scores are higher than girls' (Jacobs et al., 2005; Tiedemann, 2000). Moreover, parents' gender stereotypes might lead to different levels of educational involvement between boys and girls, influence their children's perceptions of their own mathematical ability, and lead to differences in mathematical performance (Gunderson et al., 2012).

The third variable of concern was immigration. Pong and Tsang (2010) found that mainland Chinese immigrant students in Hong Kong's junior secondary schools attained higher achievement gains than native students in most subjects. Moreover, there might be significant differences in academic achievement among local students, first-generation immigrants, and second-generation immigrants (Kong & Zhu, 2019; Mitchell, 2005). Therefore, students' immigration level was considered as a control variable.

3. Methods

3.1 Data Source

TIMSS was first conducted by the International Association for the Evaluation of Educational Achievement (IEA) in 1995. It is a widely recognized, large-scale assessment that is valued internationally. Every four years, a round of assessment is carried out to investigate students' mastery of mathematics and science in grades 4 and 8. The data from the TIMSS 2015 survey was utilized in the current study. In addition to the student survey, parents were also asked to fill out a family questionnaire in which they were asked to recall their parenting behaviours and attitudes during the students' childhood.

The sample sizes in Singapore and Hong Kong for TIMSS 2015 were 6517 and 3600, respectively. Prior to the final analysis, data screening was conducted to identify the outliers and cases with a high percentage of missing values (>10%). After screening, the final sample sizes in Singapore and Hong Kong were 6237 and 3316, respectively. Students' demographic information, including gender, immigration status, family learning resources, and school-level family learning resources (see explanation in section 3.2.3 below), were included in the model as control variables, since they are generally accepted as most closely related to achievements (Ip et al. 2016; C. O. Okpala, A. O. Okpala, & Smith, 2001; Starkey & Klein, 2000). Basic demographic information about the samples is shown in Table 1.

Table 1: Demographic information for **Singapore** and **Hong Kong** in TIMSS 2015.

		Gender		**Immigration Status**		
	Category	Male	Female	1st generation immigrants	2nd generation immigrants	Indigenous
Singapore	**Number**	3158	3079	885	565	4787

	Percentage (%)	50.6	49.4	14.2	9.1	76.8
Hong Kong	**Number**	1806	1510	149	768	2399
	Percentage (%)	54.5	45.5	4.5	23.2	72.3

3.2 Measures

3.2.1 Predictive variables

Parental activities: This indicator included mathematics-related games between parents and their children at home (for example, “Play games involving shapes”; “Play with number toys”; “Count different things”). The frequency of playing these various mathematical activities at home during childhood was reported by students’ parents and measured using seven items. For each activity, three choices were designed to indicate the participation frequency: “1” was “never or almost never”, “2” was “sometimes”, and “3” was “often” (Mullis, Martin, Foy, & Arora, 2016). Cronbach’s alpha reliability coefficients of Parental Activities Scale for Singapore and Hong Kong were 0.85 and 0.83, respectively. According to the confirmatory factor analysis, the factor loadings of the Singapore samples ranged from 0.510 to 0.769, and those of the Hong Kong samples ranged from 0.429 to 0.738, which indicated high construct validity. The item parameters and model information were shown in Appendix 1.

Parental attitudes towards mathematics and science: This construct included parents’ cognitive judgement about the importance of mathematics and science, including parents' recognition of their potential influences on children's future development (for example, “My child needs mathematics to get ahead in the world”) and parents’ recognition of the value of mathematics and science (for example, “Mathematics is applicable to real life”). It was measured with eight Likert-scaled items. Parents were asked to indicate their level of agreement using a four-point Likert scale from “1” (disagree a lot) to “4” (agree a lot) (Mullis et al., 2016). Cronbach’s alpha reliability coefficients of Singapore and Hong Kong on the scale of parents' attitudes towards mathematics and science were 0.86 and 0.83, respectively. According to the confirmatory factor analysis, all of the factor loadings of the Singapore sample ranged from 0.594 to 0.683, and those of the Hong Kong sample ranged from 0.545 to 0.667, which indicated high construct validity. The item parameters and model information were shown in Appendix 2.

Learning interest in mathematics. The key variable that serves as the mediating variable in the hypothesized model is students' learning interests in mathematics, which measures the level of students' affective feeling for mathematics. In TIMSS 2015, nine items (for example, "I enjoy learning mathematics", "I like any schoolwork that involves numbers") with a four-point Likert scale were used (1=disagree a lot, 4=agree a lot) (Mullis et al., 2016). Cronbach's alpha reliability coefficients for Singapore and Hong Kong for the scale of learning interest in mathematics indicated high reliability, with coefficients of 0.93 and 0.94, respectively. According to the principal component analysis, all of the component loadings of the Singapore sample ranged from 0.72 to 0.89 and those of the Hong Kong sample ranged from 0.65 to 0.91, indicating high construct validity (Martin, Mullis, & Hooper, 2016) .

3.2.2 Outcome variable

Mathematics achievement in the 4th grade. In total, 171 items distributed in 14 booklets were used to assess students' mathematics proficiency. Each item was designed to measure students' proficiency on two different dimensions: content and cognition. The content dimension referred to the subject knowledge to be assessed, which had three domains: number, geometric shapes and measures, and data display. The percentages of items for the three content domains were 50%, 35%, and 15%. The cognition dimension aimed to measure students' thinking processes, which also had three domains: knowing, applying, and reasoning. The percentages of items for the three cognition domains were 40%, 40%, and 20% (Mullis & Martin, 2013, p.11-27). The Item Response Theory (IRT) model was used to calculate the mathematics achievement scores of students, using 500 points as the mean and 100 points as the standard deviation (Martin et al., 2016).

3.2.3 Control variables

Gender. According to the students' answers, 1 indicates girl and 2 indicates boy.

Immigrant was created based on parents' responses to their own and their child's birthplaces. It can be divided into three categories: 1 indicates indigenous people, indicating that at least one parent is a native; 2 indicates second-generation immigrants, meaning that both parents are immigrants, but the child was born in the local area; 3 signals first generation immigrants, meaning that neither parents nor children were born locally.

Family learning resources reflected the level of material support that parents provided as learning resources. This variable consists of 5 items: number of books in the home (from the parent questionnaire), number of books in the home (student questionnaire), amount of home study support, highest level of education of either parent, and the highest level of occupation of either parent. Based on students' responses to the 2nd and 3rd questions and parents' responses to the other questions, an index called Home Resources for Learning was created and reported in the TIMSS report in order to measure the socioeconomic status of parents (Mullis & Martin, 2013, p.61-83; Mullis et al., 2016). Cronbach's alpha reliability coefficients for Singapore and Hong Kong were 0.68 and 0.76, respectively. All of the component loadings from the principal components analysis for Singapore ranged from 0.33 to 0.78, and those for Hong Kong ranged from 0.29 to 0.82, indicating acceptable reliability and validity (Martin et al., 2016).

School-level family learning resources. It should be pointed out that TIMSS data were structured hierarchically with students nested within schools, resulting in a two-level hierarchy of measurement. Specifically, all the students in one school would be considered to be influenced by similar family backgrounds. Therefore, the level of family learning resources was also aggregated at the school level, which could serve as a school-level control variable. Intra Class Coefficient (ICC) measures the percentage of between-school variation among the total variation. As shown in Table 2, all the ICCs were above 20%, which justified the need to consider the school-level control variable (Muñoz & Chang, 2007).

Table 2: The ICC of students' mathematics achievement

	Singapore	**Hong Kong**
Residual (student)	5622.928***	2947.131***
Residual (school)	1658.431***	1314.828***
ICC (school)	22.78%	30.85%

*** means p<0.001.

3.3 Data Analyses

Structure equation modelling (SEM) was selected as an analysis tool for its ability to deal with complex relationships among different variables and control for the measurement error. Given the nested data structure, a two-level SEM was used to examine whether the hypothesized model fits the data, with the student variables at the first level and school attributes at the second level. First, separate SEM for Singapore and Hong Kong were established to explore the relationships among the variables. In each model, direct paths shown as a, b_1, b_2, c_1, c_2, and d, as well as two chained mediating paths, c_1*d and c_2*d, were tested (see Figure 2). Second, to identify the effect size of the mediating effects, the Sobel method in Mplus was used, and the coverage of the indirect effects over the total effects was calculated. Third, the corresponding paths for each of the two samples were also compared to investigate the variations across Hong Kong and Singapore. To compare whether the impact of this path is significant between Hong Kong and Singapore, we compared the two models by adding restrictions between paths one by one while holding the two measurement models identical.

The overall model fit was evaluated based on the following indices: the root mean square error of approximation (RMSEA) should be below 0.08; the tucker-lewis index (TLI) and comparative fit index (CFI) were suggested to be greater than 0.90 (Schermelleh-Engel, Moosbrugger, & Müller, 2003); all the loading values of the items on the latent factors should be over 0.4. As for the outcome variables, IEA reported 5 plausible values. To explain the measurement errors for these plausible values, we put the five plausible values into the model as result variables separately and analyzed the mean values of the results obtained five times.

4. Results and analysis

Descriptive statistics for the variables and correlations among the variables in Singapore and Hong Kong were shown in Table 3 and Table 4. All variables were found to have positive and significant relationships with each other for both samples, which allowed for further analysis.

Table 3: Descriptive statistics and correlation analysis of variables in **Singapore** (n=6237).

	M	**SD**	**1**	**2**	**3**
1. Parental_attitude	10.73	1.89	1		
2. Parental_activities	9.93	2.11	0.159***	1	
3. Children's interest	9.63	1.76	0.086***	0.064***	1
4. Family learning resources	10.72	1.59	0.106***	0.270***	0.058***

Table 4: Descriptive statistics and correlation analysis of variables in **Hong Kong** (n=3316).

	M	**SD**	**1**	**2**	**3**
1. Parental_attitude	9.65	1.88	1		
2. Parental_activities	9.38	1.83	0.129***	1	
3. Children's interest	9.52	1.87	0.048***	0.082***	1
4. Family learning resources	10.26	1.85	0.096***	0.261***	0.011***

4.1 The mediating model

Since two dimensions of parental involvement were examined, this study further explored the relationship between parental attitudes and parental learning activities involvement, as well as the direct impact of these two dimensions on students' mathematics achievement. In each model, five paths were tested:

1. The direct path connecting parental_activities and their children's mathematics achievement (b_1 in Figure 2);

2. The direct path connecting parental_attitude and their children's mathematics achievement (b_2 in Figure 2);

3. The direct path connecting parental_attitude and parental_activities (a in Figure 2);

4. The chained mediating path from parental_activities to children's interest and then to children's mathematics achievement (c_1*d in Figure 2);

5. The chained mediating path from parental_attitude to children's interest and then to children's mathematics achievement (c_2*d in Figure 2).

The multi mediating model fit indices for Singapore were χ^2/df=10.398, RMSEA=0.039, CFI=0.953, TLI=0.947. The multi mediating model fit indices for Hong Kong were χ^2/df=6.262, RMSEA=0.040, CFI=0.949, TLI=0.943. All factor loadings were above 0.4. Since the chi-squared statistic is very often significant in large samples (Wheaton, Muthen, Alwin, & Summers, 1977), some researchers have proposed that the chi-squared statistic is not a good fitting index when the sample size is large, and other statistics should be considered to examine the goodness of fit (Wen, Hau, & Herbert, 2004). In the present study, although the values of χ^2/df in both the Hong Kong and Singapore samples exceeded 5, other model fitting indices such as CFI, TLI, RMSEA, and factor loadings showed good fit (Hooper, Coughlan, & Mullen, 2008).

Since the path between parental attitudes towards mathematics and science and students' learning interests was found to be different in the two samples, we tested the structure equivalence of two models. By holding the measurement model consistent, the model with all six paths constrained to be equal was compared to one with all paths set free (Null model).

These two models were significantly different from each other ($\Delta\chi^2$=13.052, Δdf=6, p<0.05). So we freed the path between parental attitudes towards mathematics and science and students' learning interests among two models and discovered that the new model and the null were not significantly different ($\Delta\chi^2$=10.828, Δdf=5, p>0.05). Therefore, this is the only path found to be different between the two samples.

Table 5: Result of Model equivalence tests

	Delta χ^2	Delta df	CFI	TLI	RMSEA
Model with 5 paths restricted Vs. Null model	10.828	5	0.924	0.921	0.046
Model with 6 paths restricted Vs. Null model	13.052	6	0.924	0.921	0.046

Note: Delta $\chi2$=10.828， Delta df=5， cutoff score: 11.07
Delta χ^2=13.052， Delta df=6， cutoff score: 12.59

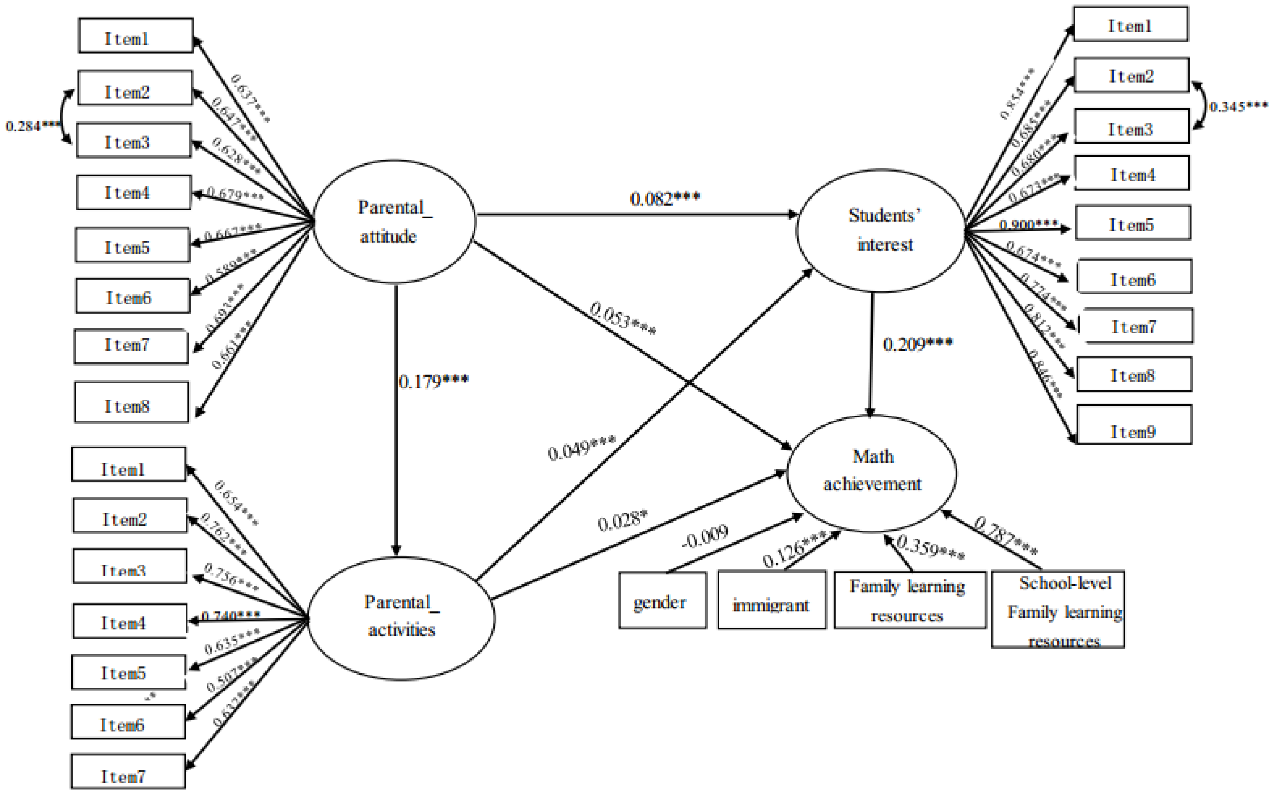

Figure 3: The model of the relationships among parental_activities, parental_attitude, students' interests, and students' mathematics achievement in **Singapore**. χ^2/df=9.622, RMSEA= 0.037, CFI=0.953, TLI= 0.947.

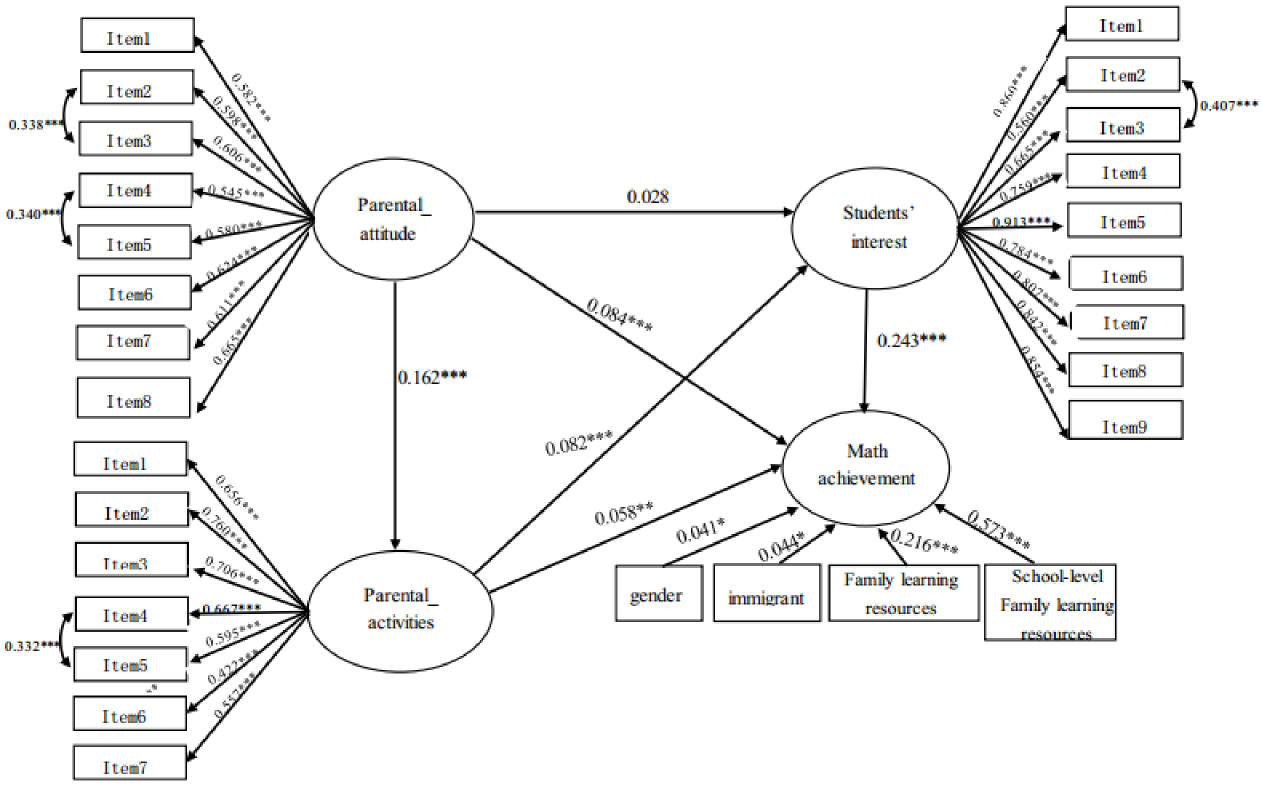

Figure 4: The model of the relationships among parental_activities, parental_ attitude, students' interests, and students' mathematics achievement in **Hong Kong**. χ^2/df=6.213, RMSEA= 0.040, CFI=0.949, TLI= 0.943.

4.1.1 The direct influence of parental involvement on students' 4th grade mathematics achievement (the paths 1&2&3)

As shown in Figures 3 and 4, similar patterns of inter-relationships among the variables could be observed in both Hong Kong and Singapore. As hypothesized, when controlling for gender, immigrant status, and family learning resources, the path directly connecting parents' involvement in early mathematics learning activities and students' mathematics achievement was significantly positive, indicating that the mathematics games in childhood contribute to students' later mathematics achievements in the 4th grade. Additionally, as predicted, the direct path between parents' attitudes and student achievement was found to be positive and significant in both samples. It can be inferred that if parents value mathematics highly, then their children tend to show better performance in mathematics. In addition, the results also show that parents' attitudes were significantly and positively related to their involvement in mathematics-related learning activities, indicating that if parents regard mathematics as an important subject for their children, then the parents tend to spend more time on mathematics learning activities with their children.

4.1.2 The mediating roles of learning interest (the paths 4&5)

In addition to the above direct associations, the mediating role of learning interest was explored for both samples in the SEM models. Consistent findings were also revealed for both samples, except for the relationship between parental attitude and students' learning interests. In the model for Singapore, both parents' involvement in early mathematics learning activities (β=0.049, $p<0.001$) and parents' attitudes (β=0.082, $p<0.001$) had significant positive predictive effects on children's interests in mathematics. However, for Hong Kong, only parents' involvement in early mathematics learning activities showed significant positive influences on students' learning interests (β=0.082, $p<0.001$). Although the path connecting parental attitudes and interest for Hong Kong was also positive, it was not statistically significant (β=0.028, p=0.147). It could be concluded that, if parents from the Singapore sample recognized the importance of learning mathematics, they could successfully communicate this to their children. Thus, their children are more likely to show greater interest in learning mathematics. However, such a relationship was not observed for the Hong Kong parents.

As a result, the chained mediating effect between both dimensions of parental education involvement and student achievement in the 4^{th} grade via connections through interest was found to be significant for the Singapore sample. On the contrary , only one chained effect (from parental involvement in learning activities to student achievement) was observed to be significant in the Hong Kong sample (effect size=0.009, $p<0.05$) given that the path connecting parents' attitudes and students' learning interests was not significant (effect size=0.007, p=0.143). In addition, the indirect effect of parental attitudes towards mathematics and science on children's mathematics performance by influencing parental involvement in early mathematics learning activities and then improving students' interests was significant in both Singapore (β=0.002, $p<0.01$) and Hong Kong (β=0.003, $p<0.001$). The models for Singapore and Hong Kong are shown in Figures 3 and 4, respectively, and the coverage of the indirect effects over the total effects is presented in Tables 6 and 7, respectively.

Table 6: The mediating chain analysis of the relationship between parental attitudes and students' mathematics achievement in **Singapore**.

	Effect size	**P**	**Coverage**
Indirect effect	0.024	<0.001	31.17%
$c_2 * d$	*0.017*	*<0.001*	*22.08%*
$a * b_1$	*0.005*	*0.054*	*6.49%*
$a * c_1 * d$	*0.002*	*0.001*	*2.60%*
Direct effect	0.053	<0.001	68.83%
Total effect	0.077		100%

Table 7: The mediating chain analysis of the relationship between parental attitudes and students' mathematics achievement in **Hong Kong.**

	Effect size	**p**	**Coverage**
Indirect effect	0.019	0.001	18.45%
$c_2 * d$	*0.007*	*0.143*	*6.80%*
$a * b_1$	*0.009*	*0.006*	*8.74%*
$a * c_1 * d$	*0.003*	*<0.001*	*2.91%*
Direct effect	0.084	<0.001	81.55%
Total effect	0.103		100%

4.2 Gender differences of parental involvement between Singapore and Hong Kong

The gender differences in terms of parental involvement in learning activities and their attitudes for Hong Kong and Singapore were also examined. The TIMSS & PIRLS

International Study Center used IRT partial credit scaling to place the questionnaire data from student responses on a scale with a mean of 10 and a standard deviation of 2 across all TIMSS countries (Martin et al., 2016). We compared the IRT synthetic scores of the variables officially reported by IEA (the International Association for the Evaluation of Educational Achievement). As shown in Table 8, in Hong Kong, the parents of boys were involved in their children's early mathematical activities significantly more frequently than the parents of girls (parents of girls $M=9.22$, parents of boys $M=9.51$, $t=-4.63$, $p<0.001$). Parents of boys also showed more positive attitudes than parents of girls (parents of girls $M=9.57$, parents of boys $M=9.71$, $t=-2.26$, $p<0.05$). However, in Singapore, neither of these differences was found.

Table 8: Independent sample t-test for Parental_activities and Parental_attitude in **Singapore** and **Hong Kong.**

		Female students		**Male students**		**Independent sample test**			**95% Confidence Interval**	
		M	SD	M	SD	T	p	Cohen's	lower	Upper
Parental_ activities	SGP	10.72	1.86	10.74	1.92	-.490	0.624	-0.011	-0.117	0.070
	HK	**9.22**	**1.86**	**9.51**	**1.79**	**-4.63**	**<0.001**	**-0.159**	**-0.411**	**-0.182**
Parental_ attitude	SGP	9.92	2.12	9.95	2.10	-.527	0.598	-0.014	-0.133	0.077
	HK	**9.57**	**1.89**	**9.71**	**1.85**	**-2.26**	**0.024**	**-0.075**	**-0.285**	**-0.011**

5. Discussion

This study examined the associations between parents' education involvement in children's early childhood and students' mathematics achievement in the 4^{th} grade as well as the psychological mechanism behind this relationship using TIMSS 2015 data from Hong Kong and Singapore. As hypothesized, the current research reveals that parents' involvement in early childhood could positively influence children's achievement in the 4^{th} grade by impacting on their learning interests. Several important highlights of the findings are discussed below.

5.1 The effect of early parental education involvement on children's later mathematics achievement

The most important and interesting finding worthy of addressing is the sustained influence of parents' education involvement in early childhood, both emotionally and behaviourally, on students' mathematics achievement when they progressed to the 4^{th} grade. Mathematics-related learning activities, such as singing digital songs, playing graphic games, and playing with building blocks, could help children develop their mathematical thinking capabilities. In addition, these simple activities may successfully arouse children's interests in learning mathematics, thus positively predicting mathematics performance in the 4^{th} grade. Such a conclusion about the effects of mathematics activities is aligned with findings from some cross-sectional studies (Starkey & Klein, 2000; Zhou et al., 2006). The results in terms of the relationship between parents' attitudes towards mathematics and their children's mathematics achievement are also consistent with the findings in previous studies (Der-Karabetian, 2004; Soni & Kumari, 2015). In addition, the mediating role of interest (Cannon & Ginsburg, 2008; Jacobs et al., 2005) revealed in previous cross-sectional studies was verified in this study from a quasi-longitudinal perspective. Similar conclusions have also been found in past research. Sha et al. (2016) found that 5^{th} and 6^{th} grade students' perceived parental support affected their scientific engagement and achievements six months later through influencing their interests and self-efficacy in science.

As advocated by the National Association for the Education of Young Children and National Council of Teachers of Mathematics (2002), "high-quality, challenging, and accessible mathematics education for 3-6-year-old children is a vital foundation for future mathematics learning". According to the learning theory of constructivism (Fosnot, 1996), learners construct their own understanding about the world and acquire learning by making connections between prior experiences and new surroundings (Driscoll, 2000; Vrasidas, 2000). Following this philosophy, it is not difficult to understand that in playing mathematics-related games with parents, children are able to experience mathematics in real life, connect mathematics knowledge with their previous experiences, and construct meaning through their own learning. As a result, these interactive activities provide a solid foundation for children's formal mathematics learning in school as well as their logical and conceptual growth. Additionally, constructivism emphasizes learners' initiative in the learning process (Shuell, 1988; Stage & Muller, 1998). Therefore, by providing interesting mathematics activities and expressing positive attitudes towards mathematics and science, parents can stimulate their children's interest, which is also beneficial to their active construction of mathematics learning.

5.2 The effect of parental attitudes towards mathematics and science on children's later mathematics achievement

This study also highlights the importance of parental attitudes towards mathematics and science. According to existing studies, parental attitudes towards mathematics can affect their children's mathematics achievement in two ways (Sun et al., 2012). One is through influencing parental involvement behaviour, and the other is by influencing children's attitudes. The first path is observed for both the Singapore and Hong Kong samples in this study. Specifically, parents' attitudes towards mathematics were found to significantly and positively affect their behaviour in participation in mathematics-related activities with their children. This finding is consistent with the theory of self-worth orientation, meaning that an individual's value of something has a directional effect on behaviour (Jacobs et al., 2005; Tare et al., 2011). Parents' attitudes towards mathematics and science can reflect their judgement about the value of mathematics, which may then affect their behaviour in providing mathematics activities for their children in daily life. If parents have a positive attitude towards mathematics and science, then they are naturally willing to carry out more mathematics-related activities with their children.

The second path is confirmed in this study, as well. As explained by Bandura's observational learning theory (Bandura, 1978), parents are the closest relatives of their children, and the majority of children's early accepted views about the world come from their parents. The children observe their parents' attitudes, imitate their parents' words and behaviours, and subconsciously receive parental influences. In terms of the findings in our study, if parents show more positive attitudes towards learning mathematics and recognize its importance, then their children would be better guided by their parents and are more likely to value mathematics highly. As a result, they tend to develop greater interest in learning mathematics and perform better in that subject. However, although this path was found to be positive for both samples, the relation was significant only for the Singapore sample. One possible explanation is that Singapore put forward "family values" in 1993, which is a unique social culture of Singapore (Huo, 2008). It attaches importance to the communication between parents and children and emphasizes that the family passes on values to the next generation in an imperceptible way (Tan, 2017). When parents have high values on mathematics and science, they will focus on cultivating their children's inner perception, such as high motivation and interest. Consequentially, Singaporean parents' positive attitudes towards mathematics and science are conducive to promoting students' interest in learning and thus learning as a whole. Parents in Hong Kong value mathematics and science because it can help their children gain access to higher education (Teng & Cheng, 2017), and they focus more on the instrumental value of mathematics in solving practical problems in life.

In addition, through comparing the IRT scores of parents' attitudes towards mathematics and science in Singapore and Hong Kong, it is found that Singapore scored significantly higher than Hong Kong (Singapore's score M=10.73, Hong Kong's score M=9.65, t=26.85, p<0.001). One possible explanation for this difference may be the different socioeconomic structures in Singapore and Hong Kong. Since the 1970s, Hong Kong's manufacturing sector has declined, and its tertiary sector has increased. In 2015, the tertiary sector became the most important contributing industry to Hong Kong’s economy, accounting for more than 92% of Hong Kong’s GDP (To & Lee, 2017). However, as an independent country, Singapore relies on the development of different types of industries (Kong, 2007). After entering the 21^{st} century and in order to enhance its overall competitiveness, Singapore attaches great importance to innovation and technological development (Koh, 2006). As a result, it is not difficult to understand the importance that Singapore parents attach to mathematics, science, and technology.

5.3 Gender differences in parental education involvement between Hong Kong and Singapore

Analysis of gender differences shows that in Hong Kong, parents of male students paid more attention to mathematics than parents of female students, and male students were involved more in early mathematics learning activities. However, in Singapore, no gender differences were identified. As Gunderson et al. (2012) pointed out, parental gender stereotypes can make girls’ self-concept and mathematics achievement lower than those of boys. Stereotypes in parental expectations for boys and girls may hinder the realization of children’s potential in mathematics and thus negatively influence their achievements. Through analysis of mathematics achievements in Hong Kong and Singapore, it was found that the mathematics achievements of boys in Hong Kong were significantly higher than those of girls (girls’ achievement M=610.60, boys’ achievement M=619.90, t=-4.48, p<0.001), while there was no significant difference between boys and girls in Singapore (girls’ achievement M=616.06, boys’ achievement M=613.16, t=1.39, p=0.164). Our results suggest that, especially for the Hong Kong sample, the parents of girls should increase early participation in their daughters' mathematics activities and strengthen their understanding of the importance of mathematics in order to minimize negative influences and enhance positive influences on their children's mathematics development.

6. Conclusion

For a number of reasons, we believe that the present study expands the perspectives of previous research and could offer significant empirical evidence for understanding the role of parents in early childhood education. The findings also provide practical suggestions for educators and parents. First, in previous studies, both parents' educational involvement and students' academic performance were collected at the same time. The key strength of this study lies in shedding light on the sustained influence of parents' earlier learning involvement on their children's future development. Although the information was based on parents' recall, it might provide useful implications for further exploration of longitudinal trends. Second, this study adds to a handful of studies examining the mechanism underlying the effects of parents' involvement on learning interests, based on motivation theory (Schunk et al., 2008). The substantial positive influences of this mediating variable suggest that parents' involvement and attitudes will contribute to children's mathematics performance both directly and indirectly. Third, this study explored two important dimensions of parental education involvement: involvement in learning activities and attitudes. In previous studies, these two dimensions were usually combined as a synthesized concept (e.g., Fan, 2001; Vukovic et al., 2013). In our study, they served as separate predictors. Moreover, based on self-worth orientation theory (Jin, 2005), according to which an individual's self-worth has a directional effect on behaviour, parents' attitude was modelled to influence their behaviours. The findings were consistent with those of Georgiou and Tourva (2007), who discovered that parents' understanding of their orientation role affects their participation in children's learning activities. Specifically, when parents believed they had an impact on their children's educational development, they would be more likely to participate in their children's education activities.

Despite the strengths of the study discussed above, there are limitations in this study which warrant cautions. Given the data are based on "recall", they could not be regarded as "longitudinal" evidence. It is also important to note that findings based on such data might not provide implications inferring causality. Second, this study is only focused on mathematics. As parental involvement in their children's childhood could cover a variety of subjects, such as reading, second language learning, arts, etc., to arrive at a comprehensive picture of the influence of parental educational involvement in early childhood on children's achievement, a study involving more subjects is needed. In follow-up studies, we hope to explore the applicability of this model to other subjects. The third limitation is related with the usage of secondary dataset TIMSS. Although the secondary dataset has been considered one of the most important data sources for providing new and valuable evidence in education (Gorard, 2012), some variables were not generated based on the constructs' comprehensive definitions. Finally, since the focus of this study is on the impact of parental educational involvement in early childhood, the potential influence of school education on students' mathematical capacity over the years was not taken into consideration. In order to arrive at a more comprehensive picture on factors that affect children's achievement, it is suggested that subsequent research could examine the influences from both the school and the family past and present, on children's academic performance.

Appendixes

Appendix 1 The item parameters and model information for the TIMSS 2015 Parental behavior and Parental attitude towards mathematics and science

Items	Delta	Tau_1	Tau_2	Infit	Item Loadings		Model Fit	
					Hong Kong	Singapore	Hong Kong	Singapore
Item 1	0.48348	-1.02734	1.02734	1.01	0.633	0.644	χ^2: 471.631	χ^2: 779.024
Item 2	0.39214	-1.07179	1.07179	0.89	0.738	0.756	df:14 χ^2/df: 33.69	df:14 χ^2/df: 55.64
Item 3	-0.60000	-1.25574	1.25574	0.90	0.693	0.742	TLI:0.902	TLI:0.929
Item 4	-0.28391	-1.03163	1.03163	0.95	0.728	0.769	CFI:0.935	CFI:0.952
Item 5	-0.32170	-0.85306	0.85306	1.02	0.666	0.678	RMSEA: 0.099	RMSEA: 0.094
Item 6	0.30628	-1.16501	1.16501	1.08	0.429	0.510		
Item 7	-0.08545	-1.21120	1.21120	1.02	0.543	0.619		

Note: the loadings might be different from those reported in TIMSS technical report due to the modeling differences.

Appendix 2 The item parameters and model information for the TIMSS 2015 Parental attitude towards mathematics and science

Items	Delta	Tau_1	Tau_2	Infit	Item Loadings		Model Fit	
					Hong Kong	Singapore	Hong Kong	Singapore
Item 1	-0.13348	-1.30430	1.30430	1.06	0.578	0.633	χ^2: 370.384	χ^2: 998.716
Item 2	0.46466	-1.45183	1.45183	1.02	0.596	0.683	df:18 χ^2/df: 20.58	df:20 χ^2/df: 49.94
Item 3	-0.14365	-1.51755	1.51755	0.98	0.608	0.670	TLI:0.929	TLI:0.919
Item 4	0.26093	-1.15860	1.15860	0.98	0.545	0.670	CFI:0.954	CFI:0.942
Item 5	0.49246	-1.14023	1.14023	1.07	0.578	0.666	RMSEA: 0.077	RMSEA: 0.089
Item 6	-0.23279	-1.41401	1.41401	1.07	0.626	0.594		
Item 7	-0.42471	-1.32106	1.32106	0.97	0.614	0.673		
Item 8	-0.28342	-1.41733	1.41733	1.02	0.667	0.655		

Note: the loadings might be different from those reported in TIMSS technical report due to the modeling differences.

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