European Journal of Psychology of Education
https://doi.org/10.1007/s10212-020-00506-0

Gender differences in effects of father/mother parenting on mathematics achievement growth: a bioecological model of human development

Mei-Shiu Chiu[1]

Received: 1 April 2020 / Revised: 22 July 2020 / Accepted: 14 September 2020
Published online: 29 September 2020
© Instituto Universitário de Ciências Psicológicas, Sociais e da Vida 2020

Abstract
This study aims to investigate gender differences in effective parenting strategies for adolescent mathematics achievement growth, taking into account socioeconomic status (SES), based on a bioecological model. Latent growth curve modeling examines longitudinal data ($n = 4163$) from the Taiwan Education Panel Survey. The analysis reveals that girls' performance fits to a quadratic development model; boys' performance better fits to a linear model. At early adolescence, mothers' monitoring is the only common effective parenting strategy for both genders. At later adolescence, fathers need to monitor boys but to play a peripheral role (e.g., school participation and rescued discussion)for girls; mothers play direct roles (e.g., listening and persuasion) for boys, but a rational or light-minded role (e.g., discussion and letting-conflict-go) for girls. SES matters mostly in early adolescence. The findings generally support the bioecological model in terms of differential model fit and effective parenting strategies between genders.

Keywords Bioecological model · Human development · Gender · Mathematics achievement · Parenting · SES

Theoretical basis

Adolescent mathematics achievement (MAch) or cognitive ability growth may be determined by diverse psychobiosocial factors (Halpern et al. 2005). According to the bioecological theory (Bronfenbrenner and Morris 2006), human development is determined by person, process, context, and time factors. Of these, process factors are the most influential for human development in both cognitive and affective aspects. Family context and the parent-child-

✉ Mei-Shiu Chiu
chium@nccu.edu.tw; meishiuchiu@gmail.com

[1] Department of Education, National Chengchi University, 64, Zhinan Rd. Sec. 2, Taipei 11605 Taiwan, Republic of China

interaction process (e.g., parenting strategies) can be viewed as the major or most important micro-system, which plays an essential role in human cognitive development, as indicated by the ecological systems theory (Bronfenbrenner 1979, 1989). A representation of the bioecological theory of human development is shown in Fig. 1. A related study on mathematics interest growth over grades 5–9 also examines the roles of gender, family, and school though not clearly using the bioecological approach as a theoretical basis (Frenzel et al. 2010).

Parenting strategies may be the basis of, have a long-lasting impact on, and adjust themselves to adolescent development. Parenting strategies for facilitating adolescent MAch growth need to consider the interaction between two parents' strategy use for cognitive and emotional aspects of learning, along with the rapid changes and severe challenges of adolescent achievement development from middle to high school (Crandall et al. 2015; Muthén and Muthén 2013).

This study uses the Taiwan Education Panel Survey (TEPS; Chang, 2001–2007) data to address the bioecological model of human development (Fig. 1). Most past studies using TEPS data, however, focus on mothers' strategies regarding involvement with the cognitive aspect of learning or on parenting strategies on emotional or mental health aspects (e.g., Yu and Ho 2018). One part that is missing from the literature is to examine the effect of parenting strategies on the emotional aspect of learning. This is what this study aims to supplement, by looking at parents' resolutions for parent-adolescent conflicts. In addition, background factors, such as gender and socioeconomic status (SES), need to be considered because of their consistent relationship with adolescent achievement growth (Catsambis 2001).

While SES may play a continuous contextual role, gender can serve as a contextual moderator in adolescents' mathematics development (Baron and Kenny 1986). Gender is a socially proactive

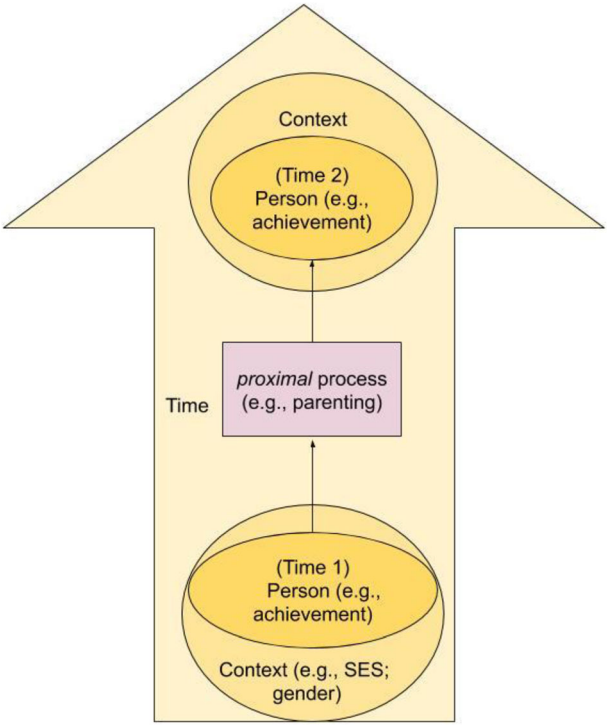


Fig. 1 A bioecological model for human (mathematics achievement) development

factor, rather than a biologically static one ("sex"), interacting with adolescents' MAch development. Cross-cultural studies indicate that gender differences in MAch diminish in gender-equal societies (Guiso et al. 2008), which supports the *gender similarities hypothesis* (Hyde 2005). A meta-analysis study indicates that sociocultural factors determine gender differences in MAch, known as the *gender stratification hypothesis* (Else-Quest et al. 2010).

In summary, this study is based on the bioecological theory on human development (Fig. 1; Bronfenbrenner 1979, 1989; Bronfenbrenner and Morris 2006). Parenting strategies of involvement and conflict resolution are the major process factors. SES and gender are contextual factors. The major purpose of this study is to identify effective fathers' and mothers' parenting strategies in predicting the early (start) and later development (growth) of adolescent MAch. While SES is an essential contextual factor to control for, gender can moderate effective parenting strategies. That is, parenting strategies may function differently for boys and girls.

Adolescent MAch growth and parenting strategies across cultures

Only slight differences between adolescents from different cultural backgrounds are found in the effects of different desirable parenting strategies on adolescent academic achievement. For example, a study that looked at Americans from different ethnic backgrounds found that the best parenting strategies for 8th graders' reading, mathematics, and science achievement of white Americans are parental communication and expectation, showing both start (immediate) and growth (long-term) effects. The best parenting strategies of Asian Americans are parental participation with both start and growth effects, parental expectation with only start effects, and parental communication with only growth effects. For Hispanic Americans, parental communication has only start effects (Hong and Ho 2005).

Most studies tend to find a positive relationship between desirable parenting strategies and adolescent academic achievement without cultural differences (Hentges and Wang 2018). For example, parental expectation positively and physical discipline negatively relate to primary and high school achievements for students from different ethnic groups in the USA (Bodovski and Youn 2010; Fan 2001) and to primary school achievements for students from both Chinese- and English-origin schools in Hong Kong (Phillipson and Phillipson 2007). Compared with low-achieving African-American students, high-achieving African-American students have more parental involvement in school activities, specific strategies for supporting schoolwork, supportive conversations, and engagement in achievement-related activities (Gutman and McLoyd 2000). It is worth researching a sample from a different culture to examine whether the relationships remain the same across cultures.

Cognitive and emotional parenting strategies: involvement and conflict resolution

Past research has indicated that adolescent academic (including mathematics) achievement growth positively relates to desirable parenting involvement and parenting styles such as sensitivity, cognitive stimulation, support, monitoring, democratic or authoritative control, and constructive interaction (Chan and Koo 2011; Chen 2000; Eamon 2005; Jeynes 2012; Morin et al. 2012). Most of the studies, however, examine academic achievement as a whole, whereas relatively few studies focus on MAch. This might be because the effects of parenting

strategies on student achievement in different domains follow similar patterns (Hong and Ho 2005), and general intelligence might be a common higher-order construct of achievement in all academic subjects, including mathematics and languages (Lu et al. 2011).

Studies indicate that parent-adolescent conflicts relate to low reading achievement and MAch (Eamon 2005) and few family conflicts and a positive family climate relate to adolescent emotional development (Castelao and Kröner-Herwig 2014; Herrenkohl et al. 2012). However, to date, there appears to be no research focusing on parenting strategies for resolving parent-adolescent conflicts in relation to adolescent mathematics or general academic achievement growth. Resolving parent-adolescent conflicts may mimic resolving higher-order mathematical problems, which needs thinking, applying, and desirable affective states (e.g., confidence) to study relationships and patterns (Burton 1994, 2004).

Taking this further, parent-adolescent conflicts can either be handled as non-creative, routine mathematics problems with one correct answer and solutions, or as creative, non-routine mathematics problems with many correct answers and solutions (Author 2009; Authors 2011). Including parental strategies for resolving parent-adolescent conflicts may shed light on the effects of the emotional interaction between parents and adolescents on adolescent MAch growth.

Different father and mother parenting roles in adolescent MAch growth

Fathers and mothers may play different roles in adolescent MAch growth along with early and later adolescence. However, distinguishing fathers' and mothers' parenting strategies has been relatively rarely researched (Hsu et al. 2011). Adolescence is a critical period from dependence to independence from parents. Adolescents also face intellectual challenges from secondary education curricula (Author 2016a). Collaborative and supplementary endeavors from both parents may help adolescents to face these challenges.

Relatively few studies distinguish the parenting strategies of fathers and mothers and explore the effect of paternal and maternal strategies on adolescent achievement. Studies have indicated that in Taiwan, mothers' involvement plays a larger role in adolescent MAch at grade 7 than father's involvement does (Hsu et al. 2011). However, when controlling for mother involvement, father involvement *can* play a role in the achievement of children aged 5–12 years (McBride et al. 2005). Using eighth-graders' positive behaviors (low delinquency, low depression, and high school commitment) as criteria, desirable parenting strategies, in descending order, are two authoritative parents, an authoritative mother paired with an indulgent father, an authoritative mother with an authoritarian or uninvolved father, and two un-involved parents in a family (Simons and Conger 2007).

These past studies tend to focus on the relative importance of fathers' and mothers' roles and conclude that there are preferable parenting styles for both parents along the whole span of adolescence. However, no studies focus on parenting strategies for resolving parent-adolescent conflicts and how these strategies relate to adolescent academic achievement growth. This study, therefore, looks in detail at the strategies used by fathers and mothers and investigates the relative importance of these strategies in MAch during early and later adolescence.

Roles of gender and SES in MAch growth

Across countries, gender differences in MAch are small or favor girls by middle school (Else-Quest et al. 2010; Miller and Halpern 2014; Murayama et al. 2013). However, by the time children reach high school, MAch turns to favor boys, as revealed by an early

meta-analysis study analyzing empirical studies published during 1963–1988 (Hyde et al. 1990) and a later one analyzing the results of a national standardized test during 1990–2011 in the USA (Reilly et al. 2015). Teachers' marks, in general, tend to favor girls, although gender differences in mathematics marks are smaller than those in language or science ones (Voyer and Voyer 2014).

Family SES may include cultural aspects (e.g., parental education and home language use) and material aspects (e.g., family income and residence). The cultural SES can be supplemented by educational practices and may be used to reduce the SES-related MAch gap. The reason for this is that the SES-achievement relationship may be affected by environmental factors such as academic stimulation neighborhood, wealth, race, and schooling (Galindo and Sonnenschein 2015) more than by genetics (i.e. IQ; Bowles and Gintis 2001, 2002). In addition, MAch might be affected more by social factors than by IQ and verbal achievement, which is a speculation that needs further research (Engelhardt et al. 2019).

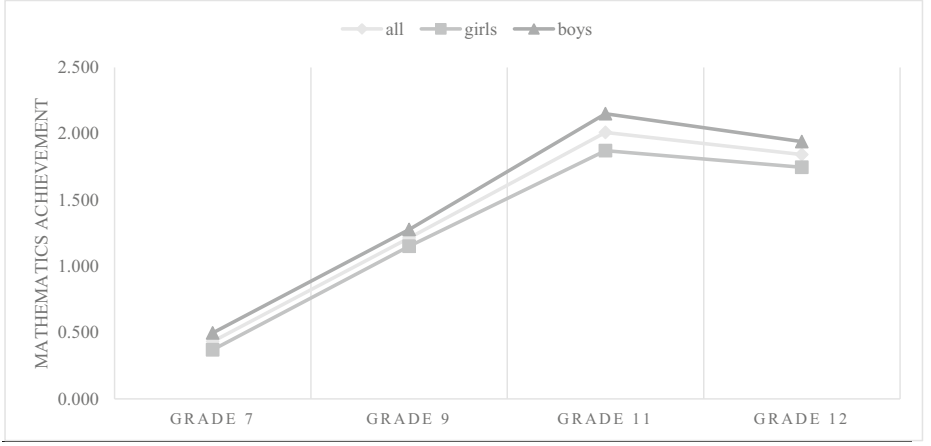
In general, parental education and family income are positively related to academic outcomes for children (Duncan et al. 2011) and adolescents (Sylva et al. 2014). Similarly, family poverty is negatively related to testing scores for children aged 4–18 years (McCulloch and Joshi 2001). Living in a high-quality residence relates to reading achievement, but not to MAch, for Latino Americans aged 10–14 years old (Eamon 2005). Murayama et al. (2013) find that parental vocational status relates to the start of MAch in grade 5 but not to the growth of achievement from grades 5 to 10.

Home language use links to ethnic and immigrant issues. Immigrant students are found to have lower problem-solving achievement than their non-immigrant counterparts do, as indicated by a study based on international datasets (Martin et al. 2012). Despite the low start, ethnic minority students may have a higher growth rate in achievement at a later stage of learning. For example, the growth rate of achievement from the ages of 8–11 years compared with those of 14–16 years for students with Bangladeshi heritage in the UK is higher than their non-immigrant counterparts (Sammons et al. 2014). Although this result may be culture-specific, another explanation is that the gradual adoption of the mainstream or official language by parents with the immigrant background may facilitate parental involvement in their offsprings' learning and thus increase adolescent achievement (Author 2016b; Turney and Kao 2009).

The present study

In summary, the bioecological model (Fig. 1) highlights diverse processes and contextual factors in shaping adolescents' MAch growth. This study focuses on the process factor of parenting strategies and the contextual factor of SES and gender. In the operational model, SES can be a control; gender can be a moderator of effective parenting, which means that boys and girls have different effective parenting strategies. For the time or growth factor, it is important to first explore the trend of outcome variables (MAch) over time. The TEPS provides all the variables suitable for this investigation.

A study also using the TEPS data shows that mathematics ability growth from grades 7–12 follows an increased linear trend but with a slight reverse U-shape (Author 2019). An initial exploration of the trend of MAch development using the TEPS data is presented in Fig. 2 with descriptive statistics. Figure 2 depicts the MAch development for the three samples (all, female



	All			Girls			Boys		
	N	Mean	SD	*N*	Mean	SD	*N*	Mean	SD
grade 7	4156	0.433	0.901	2105	0.370	0.497	2051	0.497	0.914
grade 9	4138	1.214	1.172	2094	1.152	0.497	2044	1.278	1.202
grade 11	4092	2.010	1.269	2074	1.873	0.497	2018	2.151	1.326
grade 12	4041	1.843	1.657	2039	1.747	0.497	2002	1.940	1.734

Fig. 2 Trends of mathematics achievement development and descriptive statistics over four grades for the samples of all, female, and male adolescents. SD = standard deviation

and male adolescents) over the four waves, all following an increased linear with a slight reverse U-shape trend.

As such, a quadratic slope (i.e., the squared values of the linear time score) should be set in the algorithm besides the intercept and linear slope typically included in the latent growth curve modeling (to address further in "Method"). Whether the conditioned, contextual variables predict the linear with quadratic slopes is unknown in the literature.

Given all the above rationales, this study posits an operational model for the present investigation (Fig. 3). Specifically, this study aims to answer the following two research questions.

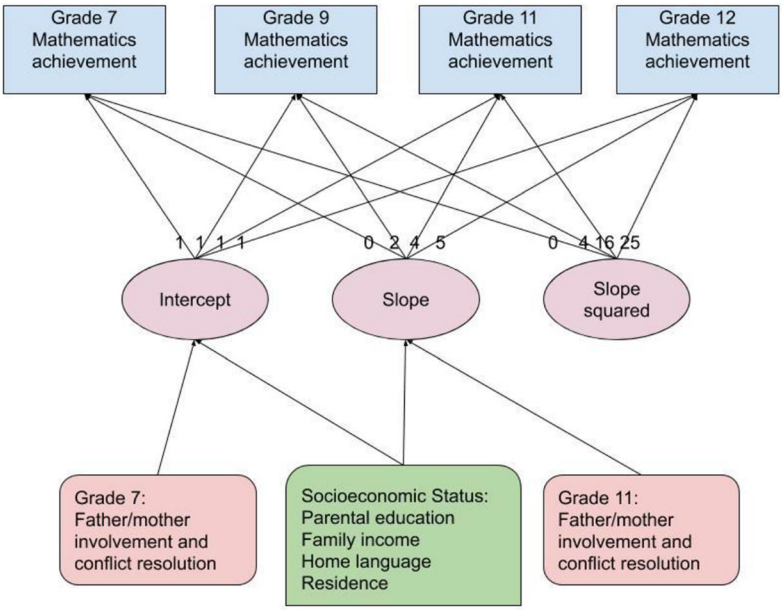
1. How do fathers' and mothers' involvement and conflict resolution predict the start and (linear or quadratic) growth of their offsprings' MAch, controlling for SES during their offsprings' early and later adolescence? (for all students)
2. Are there gender differences in the patterns of the prediction? (gender as a moderator)

Method

Data source and sample

The data used by this study was obtained from the TEPS (Chang, 2001–2007) compiled by the Survey Research Data Archive (SRDA), Taiwan. The TEPS collected data of student test results and reports, parent reports, and teacher reports for secondary

Model A



Model B

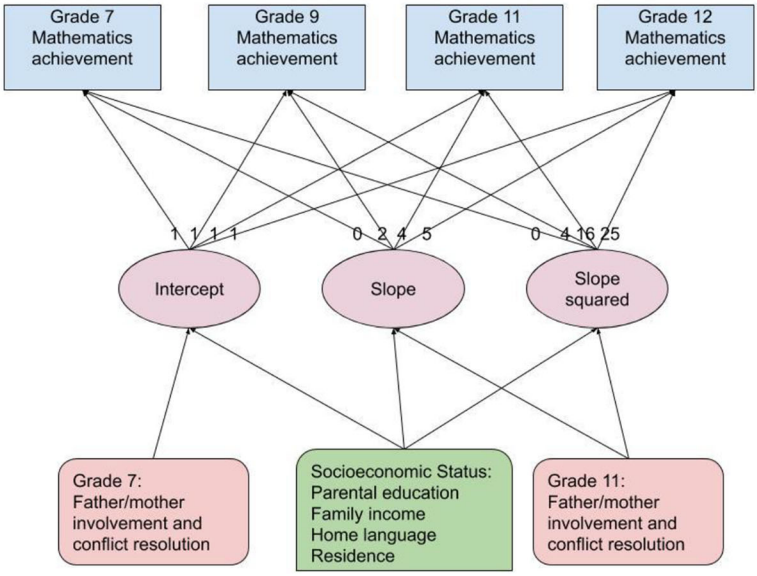


Fig. 3 The operational model of adolescent mathematics achievement growth predicted by father and mother parenting strategies. The intercept, slope, and slope squared are set correlated in the algorithm but not presented

students. Student and parent data from grades 7, 9, 11, and 12 (from 2001 to 2007)

were combined and formed the total sample of 4163 students (2108 girls and 2055 boys) used in this study.

Measures

MAch development data were collected over four-time points in secondary education as indicated in Fig. 2 (with descriptive statistics for all, female, and male students). Parental measures were collected at both grades 7 and 11. Demographics were collected or derived based on data collected in grade 7.

MAch development Student MAch was derived scores provided by the database that combined the scores of student responses to curriculum-based MAch and curriculum-free mathematics analytical tests. All the test item content should be in the curricula experienced by all students from diverse school types. The test items aimed to assess student general analytical ability: thinking, applying, and problem-solving (not memorizing). The test items were developed by mathematics experts and teachers and with reference to existing large-scale tests (Yang et al. 2003). All the items were initially reviewed, piloted, analyzed using classical test theory and item response theory (IRT) models, and further reviewed for final inclusion in the test. The final tests were administered when students were at their grades 7, 9, 11, and 12. The TEPS dataset provided four waves of MAch scores estimated using a three-parameter IRT model (3PL) because 3PL scores had high reliability (compared with 1PL scores) and IRT scores were comparable among waves.

Parental involvement Students rated their fathers' and mothers' involvement in four activities relating to the students' development on a 4-point scale ranging from 1 = *never* to 4 = *often*. The four activities were

(a) discussing my career development with me,
(b) listening to my thoughts,
(c) (monitoring) checking my homework or test results and understanding my learning, and
(d) participating in school activities or becoming parent meeting members or volunteers.

Conflict with parents Students indicated whether they had a conflict with their fathers and mothers separately (1 = *have conflict*; 0 = *no conflict*).

Parental conflict resolution Students were asked about their fathers and mothers separately using the item stem of 'how does your mother (father) resolve conflicts between you and your mother (father)?' and chose one answer from six choices:

(a) mostly follow my opinions,
(b) persuades me to accept her (his) opinion,
(c) force me to accept her (his) opinions,
(d) discuss and accept reasonable opinions
(e) let go of the conflicts without a clear resolution, and
(f) none of the above.

The six choices were dummy coded with '(f) others' as the control (i.e., 1 = *(a)* vs. 0 = *(f)*; 1 = *(b)* vs. 0 = *(f)*; 1 = *(c)* vs. 0 = *(f)*; 1 = *(d)* vs. 0 = *(f)*; 1 = *(e)* vs. 0 = *(f)*).

Gender Gender was provided by the database. Girls were coded as 2 and boys as 1.

SES SES included four indicators. Parent education was obtained by averaging father's and mother's education levels self-reported on a scale ranging from 1 = *until grade 9* to 5 = *postgraduate*. Family income was obtained by parent self-reports on a 6-point scale ranging from 1 ≤ NT$20,000 to 6 ≥ NT$200,000. Home official language use was reported by students, who rated an item asking whether Mandarin (the official language of Taiwan) was used at home (1 = yes; 0 = no). Urban residence was provided by the database with 1 = *rural*, 2 = *town*, and 3 = *urban*.

Data analysis

A latent growth curve modeling analysis was employed to examine the posited model for all, female, and male students (the research questions, Fig. 2; Murayama et al. 2013). The model proposes that grade 7 parenting strategies predict the average initial start (intercept) of MAch at grade 7, and grade 11 parenting strategies predict the average growth (slope) of MAch (from grades 7–12), controlling for the effects of adolescent SES on both the intercept and slope. The latent growth curve modeling analysis was performed by using Mplus Version 7.11 (Muthén and Muthén 2013) with missing data to be handled with the procedure of full information maximum likelihood (Wu and Jia 2013). The rates of missing data were 0.2–2.9% for the four waves of MAch scores (cf. Fig. 2), 0–0.9% for SES, and 1.3–9.7% for parenting strategies except for the strategy of 'listening to my thoughts' for father (39.2%) and mother (20.3%).

Three criteria were used to assess model fit to the data: a smaller than .08 root mean square error of approximation (RMSEA), a larger than .900 comparative fit index (CFI), and a larger than .900 Tucker–Lewis index (TLI; Hair Jr. et al. 2006). Although a non-significant Chi-square (χ^2) is a traditional criterion and needs to be presented, χ^2 becomes significant where there are large sample sizes (Bollen and Long 1993). RMSEA, CFI, and TLI are all derived from χ^2 values. RMSEA is adjusted for sample sizes and viewed as the major criterion in determining the power of an SEM model (Thoemmes et al. 2010). Standardized root mean square residual (SRMR) represents the average standardized residual; similar to RMSEA, a smaller SRMR value represents a better model fit and can be used to compare competing models. CFI and TLI are adjusted for degrees of freedom. CFI and TLI generally have similar results but TLI has a higher penalty for model complexity than CFI does.

An exploratory analysis performed to explore gender differences in MAch using the operational models (models A–B in Fig. 3). As presented in the Appendix, the two models with gender as the only predictor (models 1.A–B) failed to fit the empirical data properly (Table 4). The path coefficients, therefore, were not trustworthy (Table 5). This result partially supported the *gender stratification hypothesis* (Else-Quest et al. 2010), which suggests that gender is not a fixed factor determining MAch difference but a sociocultural factor interacting with other sociocultural (e.g., process and contextual) factors in the society.

Further, the two models with gender as part of the (contextual) predictors (models 2.A–B) fitted data properly (Table 4 in Appendix). Gender differences in MAch start and growth were

not significant except that girls had a lower growth rate than boys in MAch in model 2.A (Table 5). These results generally support the *gender similarity hypothesis* (Hyde 2005), which suggests that boys and girls have similar MAch.

Results

Model fit and selection

The best models for different samples are selected using the indices of RMSEA, SRMR CFI, and TLI (Table 1). Based on the criteria addressed in "Data analysis", both model A and model B fit to the empirical data of all, female, and male students. The only exception is TLI (0.886 < 0.900) for boys' model B. This may indicate that model B is more complex than needed for boys (Thoemmes et al. 2010). This undesirable fit index value (i.e., TLI) suggests that boys' data fails to fit model B. As such, only model A will be used for boys in later analysis and discussion.

For girls, both model A and model B are desirable. However, model B is slightly better than model A. As such, only model B will be used for girls in later analysis and discussion.

For the total student sample, model A is better if using RMSEA and TLI as the criteria. However, model B is better if using SRMR and CFI. Consequently, the next discussion should include results from both model A and model B, also for answering research question 1.

Results for all students

Table 2 presents standardized solutions of the coefficients obtained by latent growth curve modeling. Both results based on model A and model B indicate that the start (grade 7) of adolescent MAch was positively predicted by all the SES indicators. However, SES's impacts on the growth (slope and slope squared) are unstable.

For parenting, stable results from model A and model B are that letting conflict go ending with no clear resolution with fathers (i.e., fathers' letting-conflict-go) and conflict with mothers negatively predict the start of MAch development at grade 7. For later development, mothers' persuasion, discussion, and letting-conflict-go play a positive role.

Table 1 Fit index values for the examined models

Fit indexes/models	χ^2	*df*	*p*	RMSEA	SRMR	CFI	TLI
All students							
Model A	397.157	131	< 0.0005	0.033	0.012	0.947	0.927
Model B	339.470	105	< 0.0005	0.035	0.010	0.954	0.920
Girls							
Model A	257.359	131	< 0.0005	0.033	0.012	0.951	0.932
Model B	201.893	105	< 0.0005	0.032	0.011	0.963	0.935
Boys							
Model A	301.636	131	< 0.0005	0.037	0.014	0.933	0.906
Model B	277.336	105	< 0.0005	0.042	0.013	0.932	0.886

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, *SRMR* standardized root mean square residual, *CFI* comparative fit index, *TLI* Tucker–Lewis index

Table 2 The latent growth curve modeling results for all students

	All (model A)		All (model B)		
Outcomes Predictors	Intercept	Slope	Intercept	Slope	Slope^2
Socioeconomic status					
1. Parental education	*0.204*	*0.038*	*0.202*	0.026	0.003
2. Family income	*0.062*	−0.011	*0.050*	0.023	*− 0.008*
3. Home official language	*0.142*	*0.049*	*0.151*	−0.003	0.012
4. Urban residence	*0.173*	0.004	*0.177*	−0.005	0.002
Parenting in	Grade 7	Grade 11	Grade 7	Grade 11	Grade 11
Father involvement					
1. Career discussion	0.032	−0.004	0.031	0.018	−0.005
2. Listening	0.038	−0.004	0.037	−0.019	0.003
3. Monitoring	−0.008	*0.018*	−0.007	0.002	0.004
4. School participation	−0.003	−0.001	−0.002	0.039	−0.009
Mother involvement					
5. Career discussion	−0.013	0.005	−0.011	0.017	−0.003
6. Listening	−0.032	*0.016*	−0.032	0.020	−0.001
7. Monitoring	*0.112*	−0.001	0.106	0.000	0.000
8. School participation	0.004	−0.010	0.003	−0.029	0.004
Conflicts with factor	0.006	0.004	0.014	−0.035	0.009
Father conflict resolution					
9. Follow me	0.019	−0.011	0.025	−−0.076	0.014
10. Persuade	0.099	−0.014	0.103	*− 0.156*	*0.032*
11. Force	0.108	−0.025	0.117	−0.085	0.014
12. Discuss	0.097	0.001	0.093	−0.095	0.022
13. Let go	*0.211*	−0.004	*0.197*	−−0.048	0.010
Conflicts with mother	*− 0.132*	0.027	*− 0.132*	−0.005	0.007
Mother conflict resolution					
14. Follow me	−0.094	−0.037	−0.083	−0.010	−0.006
15. Persuade	−0.090	*0.072*	−0.083	*0.156*	−0.019
16. Force	−0.047	*0.053*	−0.045	0.109	−0.013
17. Discuss	−0.024	*0.048*	−0.014	*0.133*	−0.019
18. Let go	−0.051	*0.049*	−0.036	*0.168*	*− 0.027*

Note: The coefficients are standardized solutions and the italics are significant at $p < .05$

A note to make is that mothers' no clear resolution plays a negative role in slope squared. This is consistent with its positive role in slope (no squared). It is because the MAch growth follows a linear but reverse U-shaped trend (Fig. 2). The negative role in the slightly decreased trend of MAch from grade 11 to grade 12 (as represented as slope squared) indicates that mothers' letting-conflict-go has an effect to reverse the trend of decrease in achievement. Simply speaking, negative effects on slope squared indicate extra positive effects on achievement near the end of the development and vice versa.

There is one unstable result between model A and model B. Fathers' persuasion to accept his opinions plays a negative role in mathematics development for model B, but not model A.

Results for girls

In SES, parental education and urban residence play positive roles at the start. Family income can reverse or stop the decreased trend of MAch from grade 11 to grade 12.

For parenting, positive parenting includes fathers' participation in school activities, mothers' discussion, or letting-conflict-go if a conflict occurs. Fathers' school participation and mothers' discussion over conflict has extra effects on reversing the decreased trend of achievement.

Negative parenting includes fathers persuade to accept his opinions and discuss when conflict occurs. Both these fathers' parenting strategies have a direct effect (on the linear slope from grade 7 to grade 12) and an extra effect (on the squared slope mainly from grade 11 to grade 12, the turning point that the reverse U-shaped trend occurs) in decreasing MAch.

Results for boys

All SES indicators positively predict boys' achievement growth at different stages. At the start of adolescence, parental education, family income, and urban residence play a positive role. For later development, positive predictors include parental education and home official language use.

For boys, all the significant parenting strategies are positive. Mothers' monitoring works at the start. Fathers' monitoring, mother's listening, and mothers' persuasion when conflict occurs work at later development.

Discussion

Gender differences matter in parenting for MAch growth

The patterns of model fit across the samples of all students, girls, and boys appear to be quite different (Table 1). Especially, girls' performance better fit to the full model (model B; Fig. 2), with contextual factors predicting all of the latent construct (intercept, linear slope, and slope squared); boys better fit to the partial model (model A; without predicting slope squared). This raises a concern whether a one-size-fit-all model is proper for different genders for the present investigation: effective parenting for MAch growth.

The patterns of the significant predictors over the two models (model A and model B; Fig. 3) and the all-student samples may further support the claim that gender differences matter. For the all student sample, model A and model B obtain unstable results in the identified effective predictors. Undistinguished effective predictors between several different mothers' conflict resolution strategies also raise a doubt in the effectiveness of the model use (Fig. 2) even though the fit index results are desirable. Model B suites better the analysis of boys' performance, which may be one of the best reasons for explaining the seemingly meaningful but hard-to-explain results.

This study supports the bioecological model for human development (Bronfenbrenner 1979, 1989; Bronfenbrenner and Morris 2006; Fig. 1). The effect of gender is a contextual factor that interacts over time with MAch development.

As such, it is reasonable to ignore the results obtained from the all student sample. Instead, it is necessary to look at different effective parenting strategies on MAch growth between genders.

Table 3 The latent growth curve modeling results for boys and girls

	Boys (model A)		Girls (model B)		
Outcomes Predictors	Intercept	Slope	Intercept	Slope	Slope^2
Socioeconomic status					
1. Parental education	*0.201*	*0.032*	*0.202*	0.017	0.005
2. Family income	*0.075*	−0.008	0.028	0.028	*− 0.010*
3. Home official language	0.092	*0.078*	0.223	−0.036	0.011
4. Urban residence	*0.127*	0.009	*0.223*	−0.009	0.002
Parenting in	*Grade 7*	*Grade 11*	*Grade 7*	*Grade 11*	*Grade 11*
Father involvement					
5. Career discussion	0.031	−0.013	0.026	0.008	−0.002
6. Listening	0.063	−0.015	0.007	−0.019	0.006
7. Monitoring	0.002	*0.032*	−0.019	−0.017	0.004
8. School participation	−0.033	−0.004	0.037	*0.063*	*− 0.013*
Mother involvement					
9. Career discussion	−0.025	0.003	−0.003	0.009	0.000
10. Listening	−0.026	*0.036*	−0.017	0.014	−0.002
11. Monitoring	*0.089*	−0.005	*0.121*	−0.006	0.001
12. School participation	−0.024	−0.009	0.034	−0.039	0.006
Conflicts with factor	0.004	0.014	0.003	−0.096	0.020
Father conflict resolution					
13. Follow me	−0.009	−0.051	0.050	−0.045	0.014
14. Persuade	0.056	−0.046	0.076	*− 0.215*	*0.053*
15. Force	0.070	−0.024	0.051	−0.167	0.027
16. Discuss	0.036	0.017	0.106	*− 0.154*	*0.031*
17. Let go	0.202	0.002	0.174	−0.120	0.024
Conflicts with mother	−0.135	0.014	−0.136	−0.061	0.018
Mother conflict resolution					
18. Follow me	−0.021	−0.060	−0.151	0.035	−0.010
19. Persuade	−0.127	*0.092*	−0.003	0.150	−0.026
20. Force	0.039	0.065	−0.132	0.108	−0.016
21. Discuss	−0.015	0.030	0.020	*0.198*	*− 0.032*
22. Let go	0.036	0.053	−0.047	*0.175*	−0.030

Note: The coefficients are standardized solutions and the italics are significant at $p < .05$

Effective parenting for boys and girls

Commonality: mothers' monitoring at early adolescence

The findings suggest that mothers' monitoring at early adolescence is the only common effective parenting strategy for both boys and girls (Table 3). Monitoring is part of desirable parenting strategies that relate to adolescent achievement growth across different cultural groups (e.g., Chan and Koo 2011; Fan 2001; Morin et al. 2012).

Gender differences at later adolescence

More diversity of effective parenting strategies occur in later adolescence between genders.

For boys, effective parenting is fathers' monitoring, mother's listening, and mothers' persuasion when conflict occurs. The picture appears to show a traditional role of gender

stereotype that mothers are more considerate, gentle, and warm, while fathers are more demanding, authoritative, and controlling.

For girls at later development, positive parenting is fathers' school participation and mothers' discussion about conflict or letting-conflict-go. Negative parenting includes fathers' persuasion to accept their opinions and discuss when conflict occurs. The picture of parenting for girls appears to be complex especially for fathers' parenting. Fathers' parenting can be desirable if their parenting is peripheral participation rather than direct with girls even with oral communication in a rational way. Mothers appear to be the right persons to talk to especially when conflict occurs.

This finding is consistent with past research indicating that Asian parents have a range of effective parenting strategies for promoting their offsprings' achievements (Hong and Ho 2005). Fathers need to monitor boys but play peripheral roles (e.g., school participation and rescued discussion) for girls. For boys, mothers play direct roles (e.g., listening and persuasion); for girls, mothers need to play a rational or light-minded role (e.g., discussion and letting-conflict-go). Since the findings of this study may be partially explained by cultural factors, future research could use a whole structure approach to the whole system of the family and considering differential effects of fathers' and mothers' parenting strategies on adolescents' development as a global issue (Cabrera et al. 2000).

SES matters mostly at the start

A shred of partial evidence supporting the posited bioecological model (Fig. 1) is the role of SES mostly at the start. There are minor positive roles of SES for boys but one minor role of SES for girls. The results are generally consistent with past findings that desirable SES positively relates to achievement (Eamon 2005; Martin et al. 2012; Sylva et al. 2014).

An interesting result for boys is that culture-related SES indicators (home official language use and parental education) predict their growth rate of MAch. The result implies that the quality of parents' cultural capital matters and suggests that educational practice should focus on enhancing parental cultural capital for their offsprings' cognitive development.

Unfortunately, girls only have a slight impact from family income to stop the decreased MAch at later adolescence. This may be due to parents' less emphasis on girls' mathematics (Author 2018); only affluent families will invest in girls' MAch growth. This speculation, however, needs to be validated by future research.

Disclaimer The funder only provides financial support and does not substantially influence the entire research process, from study design to submission. The authors are fully responsible for the content of the paper.

Funding This work was supported by the Ministry of Science and Technology, Taiwan (MOST 109-2511-H-004-001).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix

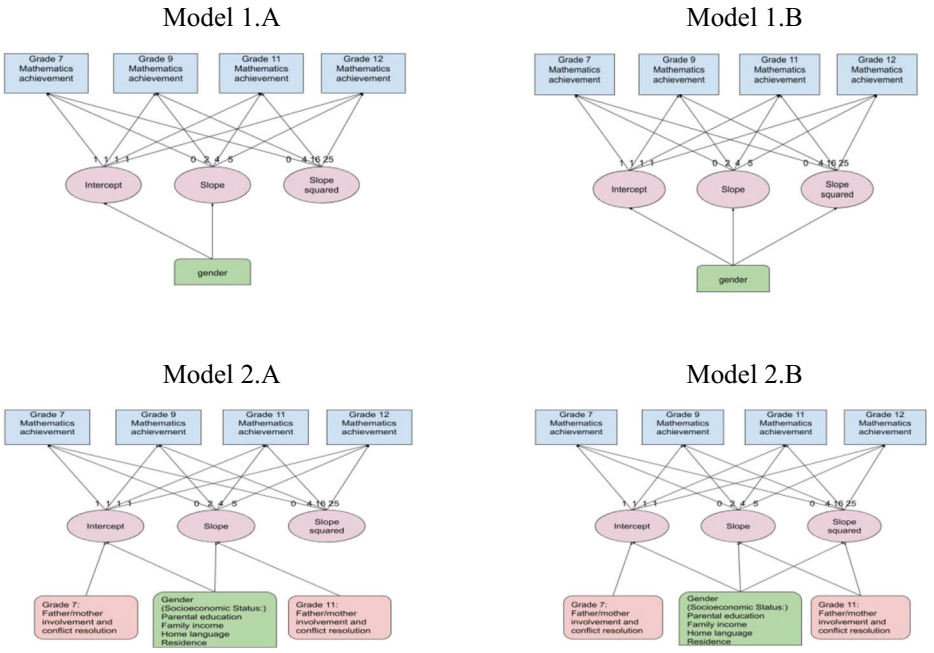


Fig. 4 The exploratory operational models

Table 4 Fit index values for the examined models for all students

Fit indexes Models	χ^2	*df*	*p*	RMSEA	SRMR	CFI	TLI
Model 1.A	559.732	5	< 0.0005	0.163	0.060	0.947	0.895
Model 1.B	474.567	2	< 0.0005	0.238	0.044	0.955	0.776
Model 2.A	411.789	133	< 0.0005	0.034	0.011	0.945	0.923
Model 2.B	351.145	106	< 0.0005	0.036	0.010	0.942	0.915

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, *SRMR* standardized root mean square residual, *CFI* comparative fit index, *TLI* Tucker–Lewis index

Table 5 Path coefficients of gender on the four models in Fig. 4 (and Table 4)

Outcomes Predictors	Intercept	Slope	Slope^2
Model 1.A	*− 0.143*	*− 0.127*	
Model 1.B	*− 0.137*	− 0.014	− 0.003
Model 2.A	− 0.072	*− 0.188*	
Model 2.B	− 0.075	− 0.009	− 0.006

Note: The coefficients are standardized solutions and the italics are significant at $p < .05$

References

Author (2009)
Author (2011)
Author (2016a)
Author (2016b)
Author (2018)
Author (2019)
Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173–1182.
Bodovski, K., & Youn, M. J. (2010). Love, discipline and elementary school achievement: the role of family emotional climate. *Social Science Research, 39*(4), 585–595.
Bollen, K. A., & Long, J. S. (1993). *Testing structural equation models*. Newbury Park: Sage.
Bowles, S., & Gintis, H. (2001). Inheritance of economic status: education, class and genetics. In M. Feldman & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences* (pp. 4132–4414). Oxford: Pergamon.
Bowles, S., & Gintis, H. (2002). The inheritance of inequality. *Journal of Economic Perspectives, 16*(3), 3–30.
Bronfenbrenner, U. (1979). *The ecology of human development: experiments in nature and design*. Cambridge: Harvard University Press.
Bronfenbrenner, U. (1989). Ecological systems theory. In R. Vasta (Ed.), *Annals of child development* (6th ed., pp. 187–249). Greenwich: JAI Press.
Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In Damon, W. & Lerner, R. M. (Eds.), *Handbook of child psychology, Vol. 1: Theoretical models of human development* (6th ed., pp. 793-828). New York: Wiley.
Burton, L. (1994). *Children learning mathematics: patterns and relationships*. Herts: Simon & Schuster Education.
Burton, L. (2004). "Confidence is everything"—perspectives of teachers and students on learning mathematics. *Journal of Mathematics Teacher Education, 7*(4), 357–381.
Cabrera, N., Tamis-LeMonda, C. S., Bradley, R. H., Hofferth, S., & Lamb, M. E. (2000). Fatherhood in the twenty-first century. *Child Development, 71*(1), 127–136.
Castelao, C. F., & Kröner-Herwig, B. (2014). Developmental trajectories and predictors of externalizing behavior: a comparison of girls and boys. *Journal of Youth and Adolescence, 43*(5), 775–789.
Catsambis, S. (2001). Expanding knowledge of parental involvement in children's secondary education: connections with high school seniors' academic success. *Social Psychology of Education, 5*(2), 149–177.
Chan, T. W., & Koo, A. (2011). Parenting style and youth outcomes in the UK. *European Sociological Review, 27*(3), 385–399.
Chang, L.-Y. (2001-2007). *Taiwan Education Panel Survey (*C00124B, C00124H, C00137B, C00175A, C00189A)[Data file]. Available from Survey Research Data Archive, Academia Sinica Web site: http://srda.sinica.edu.tw
Chen, Z. Y. (2000). The relation between parental constructive behavior and adolescent association with achievement-oriented peers: a longitudinal study. *Sociological Inquiry, 70*(3), 360–381.
Crandall, A., Deater-Deckard, K., & Riley, A. W. (2015). Maternal emotion and cognitive control capacities and parenting: a conceptual framework. *Developmental Review, 36*, 105–126.
Duncan, G. J., Morris, P. A., & Rodrigues, C. (2011). Does money really matter? Estimating impacts of family income on young children's achievement with data from random-assignment experiments. *Developmental Psychology, 47*(5), 1263–1279.
Eamon, M. K. (2005). Social-demographic, school, neighborhood, and parenting influences on the academic achievement of Latino young adolescents. *Journal of Youth and Adolescence, 34*(2), 163–174.
Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: a meta-analysis. *Psychological Bulletin, 136*(1), 103–127.
Engelhardt, L. E., Church, J. A., Paige Harden, K., & Tucker-Drob, E. M. (2019). Accounting for the shared environment in cognitive abilities and academic achievement with measured socioecological contexts. *Developmental Science, 22*(1), e12699.
Fan, X. (2001). Parental involvement and students' academic achievement: a growth modeling analysis. *The Journal of Experimental Education, 70*(1), 27–61.
Frenzel, A. C., Goetz, T., Pekrun, R., & Watt, H. M. (2010). Development of mathematics interest in adolescence: influences of gender, family, and school context. *Journal of Research on Adolescence, 20*(2), 507–537.

Galindo, C., & Sonnenschein, S. (2015). Decreasing the SES math achievement gap: initial math proficiency and home learning environments. *Contemporary Educational Psychology, 43*, 25–38.

Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, gender, and mathematics. *Science, 320*(5880), 1164–1165.

Gutman, L. M., & McLoyd, V. C. (2000). Parents' management of their children's education within the home, at school, and in the community: an examination of African-American families living in poverty. *The Urban Review, 32*(1), 1–24.

Hair Jr., J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis* (6th ed.). Upper Saddle River: Prentice-Hall.

Halpern, D. F., Wai, J., & Saw, A. (2005). A psychobiosocial model: Why females are sometimes greater than and sometimes less than males in math achievement. In J. Kaufman & A. Gallagher (Eds.), *Gender differences in mathematics: an integrative psychological approach* (pp. 48–72). Cambridge: Cambridge University Press.

Hentges, R. F., & Wang, M. T. (2018). Gender differences in the developmental cascade from harsh parenting to educational attainment: an evolutionary perspective. *Child Development, 89*(2), 397–413.

Herrenkohl, T. I., Lee, J. O., Kosterman, R., & Hawkins, J. D. (2012). Family influences related to adult substance use and mental health problems: a developmental analysis of child and adolescent predictors. *Journal of Adolescent Health, 51*(2), 129–135.

Hong, S., & Ho, H. Z. (2005). Direct and indirect longitudinal effects of parental involvement on student achievement: second-order latent growth modeling across ethnic groups. *Journal of Educational Psychology, 97*(1), 32–42.

Hsu, H. Y., Zhang, D., Kwok, O. M., Li, Y., & Ju, S. (2011). Distinguishing the influences of father's and mother's involvement on adolescent academic achievement: analyses of Taiwan Education Panel Survey data. *Journal of Early Adolescence, 31*(5), 694–713.

Hyde, J. S. (2005). The gender similarities hypothesis. *American Psychologist, 60*(6), 581–592.

Hyde, J. S., Fennema, E., & Lamon, S. J. (1990). Gender differences in mathematics performance: a meta-analysis. *Psychological Bulletin, 107*(2), 139–155.

Jeynes, W. (2012). A meta-analysis of the efficacy of different types of parental involvement programs for urban students. *Urban Education, 47*(4), 706–742.

Lu, L., Weber, H. S., Spinath, F. M., & Shi, J. (2011). Predicting school achievement from cognitive and non-cognitive variables in a Chinese sample of elementary school children. *Intelligence, 39*(2-3), 130–140.

Martin, A. J., Liem, G. A., Mok, M., & Xu, J. (2012). Problem solving and immigrant student mathematics and science achievement: multination findings from the Programme for International Student Assessment (PISA). *Journal of Educational Psychology, 104*(4), 1054–1073.

McBride, B. A., Schoppe-Sullivan, S. J., & Ho, M. H. (2005). The mediating role of fathers' school involvement on student achievement. *Journal of Applied Developmental Psychology, 26*(2), 201–216.

McCulloch, A., & Joshi, H. E. (2001). Neighborhood and family influences on the cognitive ability of children in the British National Child Development Study. *Social Science & Medicine, 53*(5), 579–591.

Miller, D. I., & Halpern, D. F. (2014). The new science of cognitive sex differences. *Trends in Cognitive Sciences, 18*(1), 37–45.

Morin, A. J., Rodriguez, D., Fallu, J. S., Maïano, C., & Janosz, M. (2012). Academic achievement and smoking initiation in adolescence: a general growth mixture analysis. *Addiction, 107*(4), 819–828.

Murayama, K., Pekrun, R., Lichtenfeld, S., & VomHofe, R. (2013). Predicting long-term growth in students' mathematics achievement: the unique contributions of motivation and cognitive strategies. *Child Development, 84*(4), 1475–1490.

Muthén, L. K., & Muthén, B. O. (2013). *Mplus (version 7.11) [computer software]*. Los Angeles: Author.

Phillipson, S., & Phillipson, S. N. (2007). Academic expectations, belief of ability, and involvement by parents as predictors of child achievement: a cross-cultural comparison. *Educational Psychology, 27*(3), 329–348.

Reilly, D., Neumann, D. L., & Andrews, G. (2015). Sex differences in mathematics and science achievement: a meta-analysis of National Assessment of Educational Progress assessments. *Journal of Educational Psychology, 107*(3), 645–662.

Sammons, P., Sylva, K., Melhuish, E., Siraj, I., Taggart, B., Toth, K., & Smees, R. (2014). *Influences on students' GCSE attainment and progress at age 16*. London: Institute of Education, University of London.

Simons, L. G., & Conger, R. D. (2007). Linking mother–father differences in parenting to a typology of family parenting styles and adolescent outcomes. *Journal of Family Issues, 28*(2), 212–241.

Sylva, K., Melhuish, E., Sammons, P., Siraj, I., Taggart, B., Smees, R., Toth, K., Welcomme, W., & Hollingworth, K. (2014). *Students' educational and developmental outcomes at age 16*. London: Institute of Education, University of London.

Thoemmes, F., MacKinnon, D. P., & Reiser, M. R. (2010). Power analysis for complex mediational designs using Monte Carlo methods. *Structural Equation Modeling, 17*(3), 510–534.

Turney, K., & Kao, G. (2009). Barriers to school involvement: are immigrant parents disadvantaged? *The Journal of Educational Research, 102*(4), 257–271.
Voyer, D., & Voyer, S. D. (2014). Gender differences in scholastic achievement: a meta-analysis. *Psychological Bulletin, 140*(4), 1174–1204.
Wu, W., & Jia, F. (2013). A new procedure to test mediation with missing data through nonparametric bootstrapping and multiple imputation. *Multivariate Behavioral Research, 48*(5), 663–691.
Yang, M., Tan, K., & Huang, M. (2003). *Psychometric report: TEPS2001 analytical ability test*. Taipei: Academic Sinica Retrieved from http://www.teps.sinica.edu.tw/description/TestingReport2004-2-10.pdf (in Chinese).
Yu, Y., & Ho, H. Z. (2018). Parental involvement and adolescent mental health in Taiwan: gender and mediational effects. *International Journal About Parents in Education, 10*(1), 111–123.

Mei-Shiu Chiu, PhD Professor, Department of Education National Chengchi University 64, Zhinan Rd. Sec. 2 Taipei 11605, Taiwan ROC E-mail: chium@nccu.edu.tw; meishiuchiu@gmail.com

Current themes of research

Mei-Shiu Chiu's research interests focus on the design, implementation, and effectiveness evaluation of learning, teaching, and assessment in a variety of areas of knowledge (e.g., mathematics, science, and energy); interactions between emotions, cognition, and culture; and multiple research methods and data analysis methods (including educational and data science methods). She has developed several research-based educational theories, relevant assessment tools, as well as school and teacher development courses for educational and research practices.

Most relevant publications in the field of Psychology of Education

Chiu, M.-S. (2009). Approaches to the teaching of creative and non-creative mathematical problems. *International Journal of Science and Mathematics Education, 7*, 55–79.
Chiu, M.-S. (2016a). The challenge of learning physics before mathematics: a case study of curriculum change in Taiwan. *Research in Science Education, 46*, 767–786.
Chiu, M.-S. (2016b). Using demographics to predict mathematics achievement development and academic ability and job income expectations. *Open Journal of Social Sciences, 4,* 103–107.
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.
Chiu, M.-S. (2019 online first). An ecological approach to adolescent mathematics ability development: differences in demographics, parenting, mathematics teaching, and student behaviors and emotions. *Educational Studies*. https://doi.org/10.1080/03055698.2019.1672522
Chiu, M.-S., & Whitebread, D. (2011). Taiwanese teachers' implementation of a new 'constructivist mathematics curriculum': how cognitive and affective issues are addressed. *International Journal of Educational Development, 31*, 196–206.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.