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Gender reality regarding mathematic outcomes of students aged 9 to 15 years in Taiwan

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ABSTRACT

This study uses a comprehensive modeling framework to explore gender similarities and differences in mathematic outcomes of students aged 9 to 15 years. Based on data from 3157 students, we established latent structural equation modeling (SEM) models incorporating 22 latent factors across 3 age levels. Gender had small to moderate effects on math achievement and math-related career intentions. All gender effects were indirectly mediated by intervening factors. Math achievement and career intentions were moderately related, but were influenced by diverse factors. Gender exhibited distinct and salient personality characteristics that were stable with development. Although girls allocated more effort to study and were perceived as receiving more support, boys excelled in many mathematical learning-related domains. Gender differences in mathematics grew stronger as students aged. Finally, gender began to directly affect math self-efficacy between ages 9 and 12 years. These ages could be a critical period for salient increases in gender difference in math.

1. Introduction

Mathematics involves a diverse array of crucial skills and knowledge. Although the gender gap in standardized mathematic performance is gradually closing (Ackerman, 2006; Else-Quest, Hyde, & Linn, 2010; Hyde, Lindberg, Linn, Ellis, & Williams, 2008), women are still underrepresented in mathematics- and science-related careers (American Federation of Teachers, 2011; National Science Foundation, 2011). Consistent with international findings, the male/female ratio for the number of college students enrolled in the science- or mathematics-related programs in Taiwan is approximately 2:1 (Ministry of Education, 2012). These facts suggest that math achievement and math-related career choices are related but distinct constructs.

Gender differences in mathematic achievement or math-related career intentions are associated with multi-domains of variables (Betz, 2005; Betz & Fitzgerald, 1987; Chrisler & McCreary, 2010; Gallagher & Kaufman, 2005; Lippa, 2006). For example, frequently cited variables are cognitive and spatial abilities (Geary, Saults, Liu, & Hoard, 2000; Royer, 2003), stereotype threats (Cvencek, Meltzoff, & Greenwald, 2011; Davis & Spencer, 2005), family background and social support from parents, peers, or teachers (Eccles, 2005; Walberg, 1981; Walberg, Pascarella, Haertel, Junker, & Boulanger, 1982), study effort (Chouinard, Karsenti, & Roy, 2007), and psychosocial factors such as self-efficacy, interest, anxiety, and outcome expectancy (Betz, 2007; Betz & Hackett, 1981, 1983, 2006; Deci & Ryan, 1987, 2008; Eccles et al., 1983; Hackett, 1985; Hackett & Betz, 1981, 1989, 1995; Lent, Brown, & Hackett, 1994, 2000). As Halpern et al. (2007, p.41) stated, “There is no single factor by itself that has been shown to determine sex differences in science and math. Early experience, biological constraints, educational policy, and cultural context each have effects, and these effects add and interact in complex and sometimes unpredictable ways.” A model that incorporates as many comprehensive factors as possible, though not easy to develop, would help resolve underlying effects.

In the literature, gender differences in affective attributes are pervasive and stable across age levels and cultures (Costa, Terraccuano, & McCrae, 2001; Turner et al., 2008). On average, boys and girls show relatively distinct personality styles, and gender differences in personalities and interests expressed at young ages seem to remain unchanged as children develop. Chen, Chen, Chang, Lee, and Chen (2010) found that boys have more flexible and thinking-oriented styles, whereas girls are more feeling- and human-oriented, less flexible (thus, more likely to follow rules or organized schedules), and have more negatively oriented emotions. Considering such salient and steady gender differences across age levels and cultures, it is surprising that fundamental individual differences on personality styles are rarely incorporated in empirical studies of modeling the gender reality[1] of math. Woods and

[1] Instead of using the term “gender difference,” we followed the recommendation by Lippa (2006) in seeking a balanced perspective when recognizing both gender differences and gender similarities, or so-called gender reality.

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Hampson (2010) found that gender moderates the association of personality traits with vocational interests. They proposed that childhood personality traits and gender are critical early influences on eventual occupational choices and should be incorporated into longitudinal studies. Keith (2006) warned that the danger of omitting common causes is the greatest threat to the causal conclusions of path modeling. When a common cause is omitted from a model, the magnitude of the effect of one variable on another is often overestimated. Because personality is known to be crucial and predictive for human achievement and life choices (Betz, Borgen, & Harmon, 2006; Larson, Wei, Wu, Borgen, & Bailey, 2007), personalities could play a vital role in the common cause for other math-related factors when all of these variables are incorporated in one comprehensive model.

Many theoretical models were developed by recognizing the importance of fundamental individual differences in achievement-related choices and performance (Eccles, 2005). Nevertheless, few empirical gender–math models fully include comprehensive individual cognitive and affective attributes. In addition, there are many other concerns about gender-comparison research in the literature. First, exploring sex differences from youth into early adulthood by using comprehensive measures is desired (Camarata & Woodcock, 2006). Second, identification of developmental trends in the magnitude of gender differences is required (Halpern, 2000; Hyde, 2005). Finally, cross-culture data are valuable for solving the nature–nurture puzzle (Lippa, 2005; Williams & Williams, 2010).

Therefore, the purpose of this study was to investigate the effect of gender on math achievement, math-related career intentions, and other mediated factors for school-age children in Taiwan. Particularly, we were interested in the magnitude of gender reality on math outcomes when the effects of relevant common causes are effectively controlled in a comprehensive model. Data with comprehensive measures were collected from large samples to ensure reliable and valid results. Moreover, these comparisons were made across three age levels to provide a clear view of developmental trends.

2. Method

2.1. Participants

This study included data from children aged 9, 12, or 15 years in public schools in Northern Taiwan. The age 9 sample consisted of 818 children (429 boys and 389 girls) from four elementary schools. The average verbal intelligence (VIQ) was 106.2, with an SD of 14.0. The mean performance intelligence (PIQ) was 101.6, with an SD of 14.0. The age 12 sample consisted of 1102 adolescents (568 boys and 534 girls) from three junior high schools. The average (SD) VIQ and PIQ were 102.6 (15.5) and 102.1 (16.5), respectively. The age 15 sample consisted of 1237 young adults (717 boys and 520 girls) from three senior high schools. The average (SD) VIQ and PIQ were 107.2 (12.3) and 107.5 (12.5), respectively.

2.2. Variables

A total of 22 latent factors were carefully designed to be modeled in this study. These factors were targeted either for their showing large gender differences or for being well recognized as critical predictors of math achievement or math career intentions in the literature. Eighty measured variables/items were used to identify these 22 latent factors. Detailed descriptions of latent factors and measured items are listed in Appendix A. Conceptually, these 22 latent factors can be grouped into seven broad categories.

2.2.1. Category I: Background factors

2.2.1.1. Gender. In this study, gender was identified according to a single item, coded 1 for *boy* and 0 for *girl*.

2.2.1.2. Parent level of education. The parent level of education is based on the father's level of education and mother's level of education. Both variables were coded on a 7-point scale: 1 = *did not finish elementary school* to 7 = *MD* and *PhD*.

2.2.1.3. Family involvement. Family involvement, which is defined as the degree of general involvement/relationship parents have with their child, is composed of five items with which students rate their agreement on a 5-point Likert-type scale[2]: 1 = *strongly disagree* to 5 = *strongly agree* (e.g., "parents often ask about school").

2.2.2. Category II: Individual difference attributes — cognitive abilities

2.2.2.1. VIQ and PIQ. VIQ and PIQ are standardized scores based on the Otis–Lennon School Ability Test (OLSAT, Otis & Lennon, 2006, 2008). The OLSAT consists of 60 items. The VIQ (PIQ) reliabilities based on the standardization sample are 81 (.85), .80 (.86), and .79 (.86) for ages 9, 12, and 15 years, respectively.

2.2.2.2. Spatial ability. Spatial ability is the standardized score based on the space relations subtest of the Differential Aptitude Test (DAT, Bennett, Seashore, & Wesman, 1999). This test measures the ability to visualize a three-dimensional object from a two-dimensional pattern and to visualize how this object would look if rotated in space. It assesses the ability to do mental rotation. This subtest consists of 50 items. The reliability is .87, .89, and .92 for ages 9, 12, and 15 years, respectively.

2.2.3. Category III: Individual difference attributes — personal styles

2.2.3.1. Feeling-oriented style. A feeling-oriented style is conceptualized as the opposite of a thinking-oriented style (Oakland, Glutting, & Horton, 1996). Students who score higher on a feeling-oriented style scale are highly sensitive to others' feelings and tend to use less logic and fewer objective standards when making decisions. This factor is estimated based on five items. The students rated their agreement with statements such as "Compared to my friends, I am more easily touched by others."

2.2.3.2. Organized-oriented style. Organized-oriented is conceptualized as the opposite of flexible-oriented style (Oakland et al., 1996). Students who score higher on an organized-oriented style scale prefer a planned lifestyle, and adapt less effectively to changing situations. This factor is estimated based on five items with which students rate their agreement (e.g., "I obey regulations and rules").

2.2.3.3. Negative-oriented style. Negative-oriented is conceptualized as the opposite of positive-oriented style. Students who score higher on a negative-oriented style scale tend to have negative emotions and thinking. Students rated their agreement with five statements such as "I often cannot do things well."

2.2.3.4. Human-oriented style. Students who score higher on a human-oriented style scale prefer to be with people. This factor is estimated based on five items with which students rate their agreement (e.g., "I like interacting with others").

2.2.4. Category IV: Gender–math stereotypes

2.2.4.1. Perception of math–gender stereotypes. This scale is composed of four items and is designed to estimate the degree of math–gender stereotypes students perceive others (e.g., parents, teachers, and friends) to have. The students rated their agreement with statements

[2] The majority of measured items in this study involved using a 5-point Likert-type scale: 1 = *strongly disagree* to 5 = *strongly agree*, with five exceptions only: VIQ, PIQ, spatial ability, parent level of education, and math achievement.

such as "My parents think that boys, not girls, should choose science- and math-related majors."

2.2.4.2. Acceptance of math–gender stereotypes. This scale is composed of four items and is designed to estimate the degree of math–gender stereotypes students themselves have. Students rated their agreement with statements such as "It is hard for girls to outperform boys in math."

2.2.5. Category V: Social supports (mathematic specific)

2.2.5.1. Perceived support from parents. This scale is composed of three items and is designed to estimate the degree to which students rate themselves receiving mathematic support from parents. Sample item: "My parents will find ways to help me with my math homework."

2.2.5.2. Perceived support from peers. This scale is composed of four items and is designed to estimate the degree to which students rate themselves receiving mathematic support from peers. Sample item: "My friends and I encourage each other to learn math well."

2.2.5.3. Perceived support from teachers. This scale is composed of eight items and is designed to estimate the degree to which students rate themselves receiving support from teachers in the math class. Sample item: "I feel that my math teacher makes great effort to teach us math."

2.2.6. Category VI: Other psychosocial factors

2.2.6.1. Math anxiety. Students who score higher on this math anxiety scale tend to feel nervous and uncomfortable when thinking about math. Students rated their agreement with four statements such as "I feel nervous for no reason when seeing numbers, figures, and tables."

2.2.6.2. Math self-efficacy. Students who score higher on this math self-efficacy scale tend to show confidence in their math learning ability. This factor is composed of four items with which students rate their agreement (e.g., "I am good at math").

2.2.6.3. Math interest. This scale is composed of five items and is designed to estimate the degree to which students like math. Sample item: "I feel that learning math is fun."

2.2.6.4. Math outcome expectancy. This scale is composed of four items and is designed to estimate the degree to which students value the importance of math learning outcome. Sample item: "Learning math well is important for my future."

2.2.6.5. Math study effort. Students who score higher on this scale tend to work harder in learning math. Students rated their agreement with four statements such as "I try hard to do math homework."

2.2.7. Category VII: Major math outcomes

2.2.7.1. Math achievement. To assess mathematic achievement, we developed math achievement tests (one form for each age level) with a team of math experts. The process of test development followed standard psychometric procedures: an expert team of six professionals was first grouped. The structure of TIMSS 2007 was followed, with the construct composed of two major domains: the cognitive and content domains. The cognitive domain includes three categories: knowing, applying, and reasoning, whereas the content domain includes five categories: number, measurement, geometry, algebra, and data and chance. Pilot testing was conducted with a sample of 391 students. Problematic items were either deleted or revised. Each of the final forms contains 25 items with multiple types (e.g., multiple choice, fill in the blank, and open-ended questions). The reliabilities for ages 9, 12, and 15 years were .83, .89, and .72, respectively.

2.2.7.2. Math-related career intentions. This scale is composed of four items and is designed to estimate the degree to which students intend to pursue math-related careers in the future. Students rated their agreement with statements such as "I hope I have a math-related job."

2.3. Model

Fig. 1 shows the baseline latent-factor structure model that guided this research. This model involved investigating the interplay of the mentioned 22 latent factors, and is designed mainly based on research on individual differences, gender–math reality, educational productivity, and learning- and achievement-related theories such as career self-efficacy theory, social cognitive career theory, self-determination theory, and the expectancy value model (Bandura, 1977, 1986; Betz, 2007; Betz & Hackett, 1981, 1983, 2006; Deci & Ryan, 1987, 2008; Eccles, 2005; Gallagher & Kaufman, 2005; Hackett, 1985; Hackett & Betz, 1981, 1989, 1995; Keith & Fine, 2005; Lent et al., 1994, 2000; Walberg, 1981; Walberg et al., 1982). In summary, mathematic achievement and math-related career intentions are products of a sequence of effects beginning with gender and family background (parent level of education and family involvement), followed by student's cognitive abilities (VIQ, PIQ, and spatial ability) and personal styles, and then mediated by other psychosocial and environmental factors such as stereotypes, math anxiety, perceived social supports from environment, math self-efficacy, math interest, math study effort, and math outcome expectancy. This structure is consistent with the psychological theory that individual behavior reflects personal attributes, home background, environmental conditions, and the interactions of related psychosocial variables.

2.4. Procedure and analyses

For each participant, data were collected over a 6-month period. Personal abilities such as VIQ, PIQ, and spatial ability were tested at the beginning of fall semester 2009. Proposed mediating psychosocial attitudes were collected in the middle of the same semester. Mathematic achievement was tested at the end of this semester.

Latent variable structural equation modeling (SEM) was used to determine the magnitude of the influence of gender on other factors. Based on the starting model depicted in Fig. 1, we analyzed data from each age level separately. For each age level, a calibration–validation approach was used, where two-thirds of each sample was randomly selected as the calibration sample for testing hypotheses and modifications, and the remaining third was used to cross-validate results. Reparameterization was examined carefully for meaningfulness. The fit of the model was guided by both theoretical meaningfulness and the LISREL modification index. Once the best-fitting solution for each age was calibrated and validated, final parameters were retested using the entire sample for that age. For model parsimony and clarity, only paths showing some effect ($\beta \geqq .05$) were kept for interpretation. Finally, suggestions by Keith (2006) were followed to quantify the magnitude of effects: "β's above .05 are considered small but meaningful; those above .10 are considered moderate, and those above .25 are considered large (p. 62)."

All of the SEM analyses were based on the analysis of covariance structure and used LISREL 8.8 (Jöreskog & Sörbom, 2006). The scale of latent factors was defined by fixing one factor loading for each to one. Multiple indices of model fit (Bentler & Bonett, 1980; Hu & Bentler, 1998, 1999; Kline, 2005) helped evaluate and compare various models. Single models were evaluated using CFI, RMSEA, and SRMR. An RMSEA of less than .05 corresponded to a good fit and with .08 considered an acceptable fit (McDonald & Ho, 2002). An SRMR value of less than .08 was considered acceptable. A value of 0.90 served as the rule-of-thumb lower limit of acceptable fit for CFI (Hoyle & Panter, 1995). Changes in the chi-square ($\Delta\chi^2$) involved evaluating competing and nested models. The AIC and Abic were used

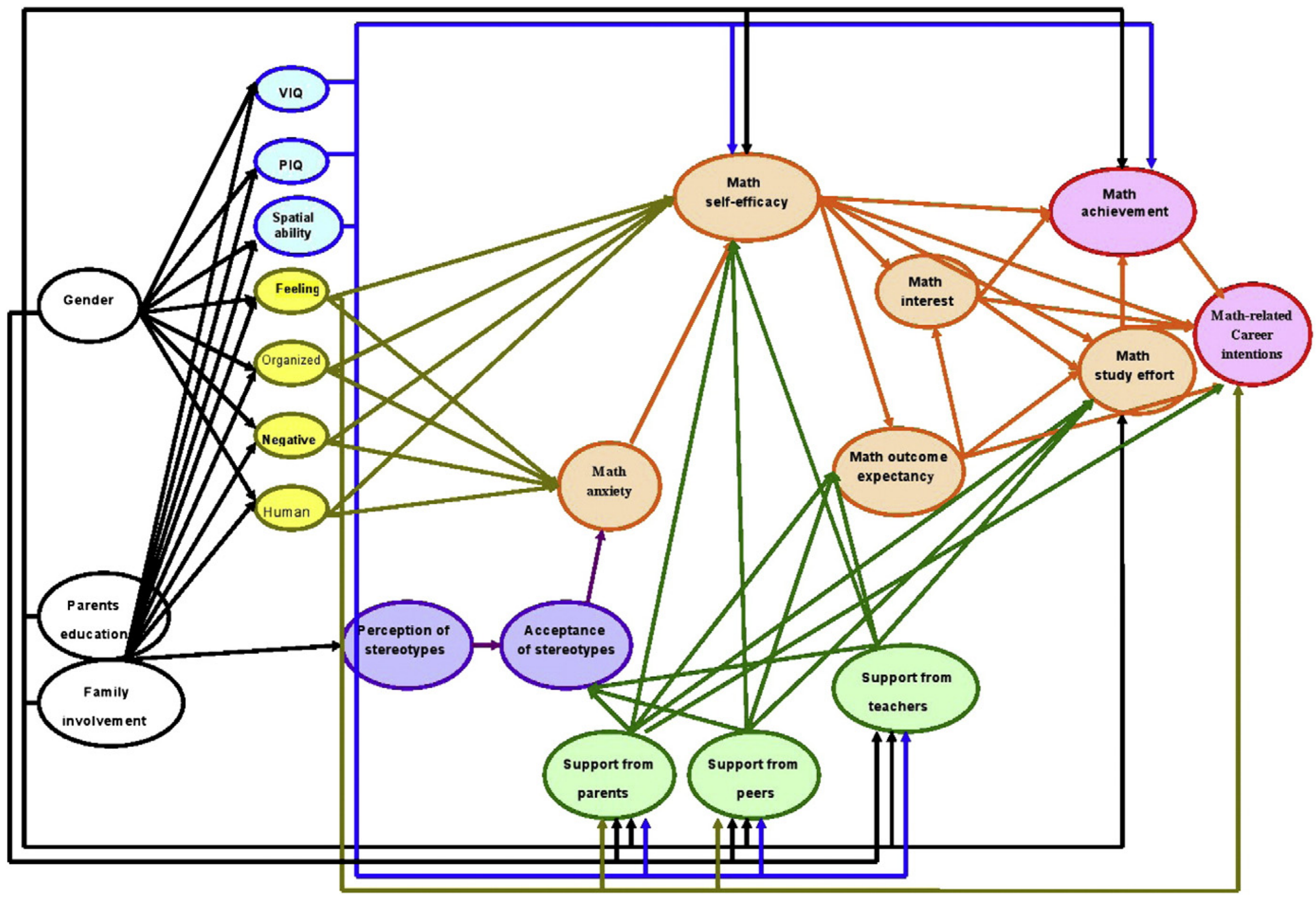

Fig. 1. Hypothesized starting model for tests of effect of gender on math performance and math-related career intentions.

to compare the non-nested models (Kaplan, 2000; Loehlin, 2004), with smaller values indicating better fits.

3. Results and discussion

3.1. The measurement model

The measurement model was specified and tested before interpreting the relationships among latent factors based on structure estimation. Appendix A contains reliabilities of all factors and loadings of each corresponding manifest indicator. All of the reliabilities were within an ideal range. The factor loadings shown (β) are standardized maximum likelihood coefficients. All factor loadings were statistically significant. The moderate to high factor loadings of variables for most factors suggested that these selected variables effectively defined the latent factors, and that factors were measured in a valid manner. An acceptable level of measurement reliability and validity was achieved.

3.2. The structural model

3.2.1. Age 9

Table 1 shows the model testing results for the students in the age 9 group. In the calibration phase, goodness-of-fit indices for the hypothesized starting model (Model 1a) fit the data well. In the following modification process, parameters which need to be modified were examined individually. A total of 36 parameters (many were error covariances) yielded statistically significant improvements in model fit. Goodness-of-fit indices for the modified model (Model 1b) were improved. This model was validated with a different data set (Model 2), resulting in an acceptable fit. We tested this validated model with the entire age 9 sample in Model 3 and found a good fit. For clarification purposes, only paths with $\beta \geqq .05$ were kept in the final model (Model 4), which released more degrees of freedom, and improved parsimony. Model 4 showed a good model–data fit based on indices that value parsimony.

3.2.2. Age 12

Table 1 also shows the procedures similar to those used for age 9. The initial starting model fit the age 12 data well. A total of 26 originally unspecified parameters were identified to yield statistically significant improvement in model fit. Thus, Model 1b was validated (Model 2) with a different data set and with the entire age 12 sample (Model 3) with results showing good fits. To design Model 4, only paths with $\beta \geqq .05$ were kept. This increased degrees of freedom and yielded a final model with better fit.

3.2.3. Age 15

The starting model (Table 2) had an acceptable fit. Forty parameters were added for an improved model (Model 1b). This modified model was validated (Model 2) and then tested using the entire age 15 sample (Model 3). Results showed good fits. The most parsimonious model (Model 4) was derived by removing 27 small and non-significant paths, resulting in a better fit.

For all of these ages, the final models explained all data clearly. The factors explained large portions of the variances. For each age, the final derived model explained 43%–90% of the variance in math performance and over 80% of the variance in math-related career intentions.

3.3. Gender reality on math achievement, and math-related career intentions

Based on the final derived model (Model 4) for each age, Table 2 lists the direct effect and total effect of gender on all latent factors. Math achievement and math-related career intentions were moderately

Table 1
Hypotheses testing procedures.

Model	χ^2	df	CFI	RMSEA	RMSEA 90% CI	SRMR	AIC	aBIC
Age 9								
1a. Calibration sample (N = 545) − starting	7275.02	2984	.94	.051	.050–.053	.074	7787.02	8075.38
1b. Calibration sample (N = 545) − modified	5879.07	2948	.96	.043	.041–.044	.067	6463.07	6791.98
2. Validation sample (N = 273)	4444.84	2948	.93	.043	.041–.046	.080	5028.84	5156.95
3. Total sample (N = 818)	6944.33	2948	.96	.041	.039–.042	.064	7528.33	7975.46
4. Total sample (N = 818) with paths β ≧ .05	6952.59	2977	.96	.040	.039–.042	.064	7478.59	7881.31
Age 12								
1a. Calibration sample (N = 740) − starting	8002.83	2984	.94	.048	.046–.049	.070	8514.83	8881.24
1b. Calibration sample (N = 740) − modified	6596.97	2958	.96	.041	.039–.042	.060	7160.97	7564.60
2. Validation sample (N = 362)	4829.36	2958	.95	.042	.040–.044	.070	5393.36	5596.15
3. Total sample (N = 1102)	7919.58	2958	.96	.039	.038–.040	.057	8483.58	8999.26
4. Total sample (N = 1102) with paths β ≧ .05	7940.95	2991	.96	.039	.038–.040	.058	8438.95	8894.28
Age 15								
1a. Calibration sample (N = 825) − starting	9188.09	2984	.93	.050	.049–.051	.072	9700.09	10,094.27
1b. Calibration sample (N = 825) − modified	6753.81	2944	.95	.040	.038–.041	.055	7345.81	7801.58
2. Validation sample (N = 412)	4923.00	2944	.94	.040	.038–.042	.066	5515.00	5765.95
3. Total sample (N = 1237)	8410.28	2944	.96	.039	.038–.040	.052	9002.28	9577.71
4. Total sample (N = 1237) with paths β ≧ .05	8434.76	2973	.96	.039	.038–.040	.053	8968.76	9487.81

correlated (r = .13 to .42 for each age), indicating that they are related but distinct.

For students at all three age levels, gender did not show a direct effect on either math achievement or math-related career intentions. All gender differences in these two factors were mediated by intervening factors. The total effect of gender on math achievement was .06, .13, and .15 for ages 9, 12, and 15 years, respectively. The total effect of gender on math career intentions was .02, .14, and .22 for these three ages. For junior and senior high school adolescents, gender showed a moderate effect on these two main math outcomes. Generally, the boys had higher math scores in their elementary years and showed stronger math-related career intentions in their adolescent years. The effect of gender increased with age.

A closer look at the model path coefficients details revealed that gender differences in math achievement and math-related career intention were mediated by different types of intervening factors: gender difference in math achievement was mainly mediated by cognitive abilities such as PIQ and spatial ability, whereas other factors, such as math interest, math self-efficacy, peer-support, math anxiety, and negative-oriented personal style, mainly mediated the effect of gender on math-related career intentions. Briefly, the total effect of PIQ on math achievement was approximately .70 for ages 9 and 12, and was approximately .30 for age 15. The total effect of math interest on math-related career intentions was above .70 for all three ages.

Table 2
Direct and total effect (in parenthesis) of gender on other factors.

Factors	Age 9 (N = 818)	Age 12 (N = 1102)	Age 15 (N = 1237)
1. Verbal IQ	– (–)	– (–)	– (–)
2. Performance IQ	– (–)	.12 (.12)	.08 (.08)
3. Spatial ability	.08 (.08)	.07 (.07)	.08 (.08)
4. Feeling-oriented style	−.42 (−.42)	−.39 (−.39)	−.29 (−.29)
5. Organized-oriented style	−.31 (−.31)	−.19 (−.19)	−.15 (−.15)
6. Negative-oriented style	−.14 (−.14)	−.21 (−.21)	−.16 (−.16)
7. Human-oriented style	−.21 (−.21)	−.13 (−.13)	−.10 (−.10)
8. Perceptions of others' stereotypes	.27 (.23)	– (.04)	.35 (.35)
9. Acceptance of stereotypes	– (.15)	– (.01)	−.14 (.06)
10. Perceived support from parents	– (−.07)	.05 (.01)	.06 (.02)
11. Perceived support from peers	.28 (−.13)	– (−.12)	.07 (−.04)
12. Perceived support from teachers	– (−.13)	– (−.05)	.05 (−.05)
13. Math anxiety	−.20 (−.10)	– (−.16)	– (−.08)
14. Math self-efficacy	– (.13)	.19 (.24)	.25 (.30)
15. Math interest	– (.06)	– (.18)	– (.20)
16. Math outcome expectancy	– (−.01)	– (−.05)	– (.01)
17. Math study effort	– (−.08)	– (−.10)	– (−.12)
18. Math achievement	– (.06)	– (.13)	– (.15)
19. Math-related career intentions	– (.02)	– (.14)	– (.22)

Note 1. Gender code: girl = 0, boy = 1.

3.4. Gender reality on other modeled factors

For the 9-year-old boys, compared to the girls, the average VIQ and PIQ were similar, but the boys showed slightly higher spatial ability. Both genders showed distinct personal styles: the boys were less feeling- and human-oriented, they also had more flexibility and less negativity. Considering these fundamental individual differences, the boys in this age group perceived stronger gender–math stereotypes and accepted these stereotypes by believing that boys generally perform higher in math-related fields. Despite the boys expending less effort in studying math and feeling that they received less math support from teachers, peers, and parents, they showed less math anxiety, higher math self-efficacy, and higher math interest, and demonstrated slightly higher math achievement. The boys at this age had not yet indicated stronger math-related career intentions.

For the 12-year-old boys, their VIQ was similar to that for the 12-year-old girls, but the boys had higher PIQ and spatial ability. This indicated that boys process nonverbal information more effectively while learning. The boys at this age showed fewer feeling- and human-oriented styles, more flexibility, and had fewer negative-oriented emotions. Gender differences in perception and acceptance of math–gender stereotypes diminished, but this was mainly because the magnitude of the girls' perceptions of these stereotypes had increased. Although both genders showed similar perceptions of math support from parents, the boys continued to perceive less support from peers and teachers. The boys also continued to allocate less effort to studying math. Nevertheless, the boys continued to show higher math self-efficacy, higher math interest, and less math anxiety, resulting in a gender gap greater than that shown for the 9-year-old children. The adolescent boys at age 12 demonstrated higher math performance and stronger intentions in pursuing math-related careers.

For adolescents aged 15 years, both genders had similar VIQ, but the boys continued to show higher spatial and PIQ abilities. The boys also continued to show fewer feeling- and human-oriented styles, more flexibility, and fewer negative-oriented personal styles. The boys continued to believe that boys are better at math. They also perceived this stereotype more strongly from others. The boys continued to feel less math support from teachers and to apply less effort in math, but they also continued to express less math anxiety, stronger math self-efficacy, and higher math interest. Compared to younger ages, the 15-year-old boys demonstrated even higher math performance and stronger math-related career intentions.

From a developmental perspective, some meaningful trends of gender reality deserve attention. At all three age levels, both genders had similar average VIQ and math outcome expectancy, suggesting that the boys and girls handled verbal reasoning with similar proficiency and both genders valued mathematics. The boys consistently performed higher at spatial ability. They began exhibiting greater non-verbal reasoning ability between ages 9 and 12. Gender differences in personal styles were salient and stable for these age groups. The magnitude of the gender gap in many of these personal styles decreased slightly with age. The only exception was negativity. The girls constantly had higher levels of negative emotions, but the gender gap was greatest at age 12. The boys in all three grades perceived less math support from peers and teachers, but by age 12 both genders felt similar levels of parental support. The boys of all three ages showed lower math anxiety, higher math interest, and higher math self-efficacy, with gender gaps in these variables increasing with age. The boys in all three ages allocated less study effort to math. As age increased, the gender gap in effort also increased.

Ages 9 to 12 were revealed to be a critical period for salient increases in gender differences in math. During this period, the boys' advantages in spatial and nonverbal reasoning abilities became prominent. For this age group, girls showed a jump in both negativity and math anxiety. The girls also began to perceive gender–math stereotypes explicitly. Data in Table 2 also indicate a direct effect of gender on math self-efficacy (.00, .19, and .25 for ages 9, 12, and 15 years, respectively, with a corresponding total effect of .13, .24, and .30). Because gender began to indicate a solid direct effect on math self-efficacy by age 12, gender as a variable may be qualitatively different during a child's development. A stronger bond between 'Math self-efficacy' and 'gender' may have been formed sometime between age 9 and 12, making this a critical period for the formation of gender–math self-efficacy.

4. Conclusions

Our results show the importance of viewing gender–math reality in a comprehensive modeling framework. When background factors and personal attributes are effectively controlled, relationships among factors are more accurately estimated. We found that gender differences in mathematic achievement and math-related career intentions were mediated by intervening factors. Math performance was mainly mediated by cognitive abilities. Math-related career intentions were mainly mediated by interest, self-efficacy, peer-support, math anxiety, and personal styles. Our results supported the findings that boys show more positive math attitudes and affect (Else-Quest et al., 2010), and that adolescent boys demonstrate higher math achievement and have moderately stronger math-related career intentions than adolescent girls do (College Board, 2009; Liu & Wilson, 2009; Watt, 2006).

Our results also support the importance of viewing the gender–math concern as developmental. Fundamental individual differences between genders should not be ignored in the field of gender–math research. The unique personal attributes of each gender are fairly salient and stable during development. In fact, among all of the modeled factors in this study, personal styles showed the largest gender differences. On average, boys had more thinking-, flexible-, and positive-oriented styles, and had less human-oriented attendance. Girls exhibited more feeling-, organized-, negative-, and human-oriented styles. Current findings were also consistent with the literature: personal styles are critical mediators of gender difference regarding math-related career intentions. Personality traits affect choices and career aspirations (Betz et al., 2006; Larson et al., 2007). People in a specific career/profession have unique styles. For example, when considering that academic faculties in the mathematics-related fields of science and engineering are predominantly male, Gridley (2006) suspected that "Some of the disparity may also be due to gender differences in cognitive styles, particularly the styles best matched to science and engineering" (p.724), and the "profession of engineering, for instance, may attract individuals who have thinking styles suited for the job, and because significantly fewer women prefer that style, significantly fewer women go into engineering" (p.725).

With fundamentally higher spatial and non-verbal reasoning abilities, with attributes oriented more toward thinking, flexible, and positive styles, young boys at age 9 perceived more gender–math stereotypes. These traits made the boys less anxious about math learning and improved math self-efficacy. Although the girls constantly applied more study effort and perceived greater support from teachers and peers, the boys consistently showed greater math self-efficacy and interest, higher math performance, and stronger math-related career intentions. This overall trend becomes stronger with age. Ages 9 to 12 seemed to be a critical period during which the gender–math gap increased. For this age group, gender began showing a salient, direct effect on math self-efficacy. Self-efficacy is crucial for performance and career choice (Betz, 2000; Betz & Hackett, 1981, 1983, 2006; Hackett, 1985; Hackett & Betz, 1981, 1989; Hackett, Betz, Casas, & Rocha-Singh, 1992; Hoffman & Schraw, 2009; Lent et al., 1994). Williams and Williams (2010) suggested that self-efficacy and performance in mathematics are reciprocally determined cross-culturally. Self-efficacy helps people approach difficult tasks as challenges to be mastered and to maintain a strong commitment to their goals. Once formed, these beliefs affect performance through their influence on actions taken, persistence, and strategies invoked (Schunk & Pajares, 2002; Zimmerman, Bandura, & Martinez-Pons, 1992). In our study, the boys demonstrated greater math self-efficacy at the beginning of the observation period (age 9); however, these observed gender effects at younger ages were all indirect and were mediated by intervening variables. Gender began showing a direct effect on math self-efficacy between ages 9 and 12. A stronger bond between 'Math self-efficacy' and 'gender' may have been formed during this developmental stage.

Hyde (2005, 2006) suggested that males and females are more similar than different because most effect sizes in her meta-analyses were small or close to zero. We suspect that the cumulative compounding effect of gender differences on many psychological and social factors could accumulate and form a larger effect on a complex outcome, such as life choice. Equal gender representation across all educational–vocational domains, which might be the preferred vision by policymakers, may conflict with what might occur naturally (Webb, Lubinski, & Benbow, 2002).

Some limitations of the present study should be noted. First, current findings were based on cross-sectional, not longitudinal, data. Thus, the cohort effect was not well-controlled. Although our large sample size enabled depicting possible developmental variations, we realize that only solid longitudinal data can mitigate these possibilities. Second, although we attempted to incorporate a data set that was as comprehensive as possible, omission of some factors was inescapable. Third, future research should test the equivalence of models across genders and age groups.

In this study, we report the most current gender reality on mathematic outcomes for students in Taiwan. Objective data revealed that observed gender differences in mathematic performance and career intentions were mediated by several intervening factors, both psychological and social. The roots of gender effects on career intentions were not only in the social factors associated with gender but also in the individual attributes of each child.

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Appendix A. Description and reliability of latent factors and loadings of measured variables

Latent factors	Measured items/item description	Age 9		Age 12		Age 15	
		α	β	α	β	α	β
1. Gender	Gender	.95	.97	.95	.97	.95	.97
2. Parent level of education	Father's level of education	.80	.71	.79	.81	.77	.94
	Mother's level of education	–	1.05	–	.87	–	.68
3. Family involvement	Parents often ask about school	.72	.49	.82	.51	.80	.40
	Parents often discuss life problems with me	–	.51	–	.56	–	.66
	Parents understand me	–	.49	–	.75	–	.80
	Parents try to understand my thoughts	–	.54	–	.75	–	.72
	I can trust my parents	–	.57	–	.75	–	.75
4. Verbal IQ	Standardized OLSAT verbal scale score	.76	.87	.79	.89	.71	.85
5. Performance IQ	Standardized OLSAT performance scale score	.80	.89	.86	.93	.81	.90
6. Spatial ability	Standardized score of Differential Aptitude Test space relation subtest	.87	.93	.89	.94	.92	.96
7. Feeling-oriented style	I feel unhappy when I see that others are unhappy	.54	.36	.69	.50	.71	.58
	I feel touched when watching a sad movie	–	.38	–	.48	–	.56
	I feel sad when my friends receive bad news	–	.41	–	.67	–	.69
	Compared to my friends, I am more easily touched by others	–	.54	–	.68	–	.70
	I often comfort and encourage others	–	.48	–	.47	–	.43
8. Organized-oriented style	I prefer my desk to be neat and well-organized	.57	.41	.69	.57	.62	.47
	I prefer to have work first and fun later	–	.44	–	.62	–	.63
	When I have lots of work, I schedule my tasks and then proceed	–	.56	–	.53	–	.54
	I obey regulations and rules	–	.57	–	.55	–	.49
	I do not do things that break the rules	–	.27	–	.47	–	.27
9. Negative-oriented style	I often feel nervous	.61	.64	.69	.62	.72	.57
	I often feel worried	–	.65	–	.82	–	.78
	I often feel sad	–	.75	–	.74	–	.70
	I am not satisfied with myself	–	.12	–	.27	–	.42
	I often cannot do things well	–	.34	–	.32	–	.44
10. Human-oriented style	Compared to my friends, I am more optimistic	.79	.41	.79	.42	.78	.36
	Others like to be with me	–	.56	–	.49	–	.43
	I like to be with others	–	.77	–	.83	–	.82
	I feel happy helping others	–	.74	–	.72	–	.66
	I like interacting with others	–	.81	–	.85	–	.90
11. Perception of math–gender stereotypes	My parents think that boys, not girls, should choose science- and math-related majors	.77	.55	.78	.62	.75	.68
	Teachers make me feel that math is more important for boys, and it does not matter if girls perform poorly in math	–	.77	–	.69	–	.72
	Most of my friends feel that girls are good at reading and math is not a strong subject for girls	–	.60	–	.59	–	.45
	My parents feel that learning math well is useful for boys, and less useful for girls	–	.72	–	.77	–	.78
12. Acceptance of math–gender stereotypes	Boys can solve math questions faster and more accurately	.83	.72	.90	.77	.87	.76
	Boys are born with higher math ability	–	.84	–	.89	–	.82
	Boys should choose majors related to math, science, or engineering	–	.61	–	.84	–	.77
	It is hard for girls to outperform boys in math	–	.76	–	.83	–	.80
13. Perceived support from parents	My parents care about my math exam scores	.63	.64	.72	.70	.72	.67
	My parents value math learning	–	.77	–	.93	–	1.03
	My parents will find ways to help me with my math homework (either by themselves, using a tutor, or scheduling a class after school)	–	.26	–	.39	–	.39
14. Perceived support from peers	I discuss math questions with my friends	.66	.67	.65	.55	.69	.72
	I often discuss math questions with friends after class	–	.19	–	.37	–	.56
	My friends and I encourage each other to learn math well	–	.62	–	.65	–	.68
	I feel respected and supported by friends in math class	–	.63	–	.52	–	.43
15. Perceived support from teachers	My math teacher tries to understand our thoughts	.82	.66	.86	.70	.88	.79
	I feel we are valued and respected by my math teacher	–	.61	–	.73	–	.84
	My math teacher knows us	–	.40	–	.62	–	.74
	My math teacher encourages us to express our opinions	–	.57	–	.60	–	.65
	In math class, my teacher cares about our comprehension	–	.36	–	.52	–	.68
	My math teacher carefully explains our errors after exams	–	.63	–	.55	–	.51
	My math teacher encourages us to improve	–	.71	–	.61	–	.58
	I feel that my math teacher makes great effort to teach us math	–	.72	–	.72	–	.70
16. Math anxiety	I feel nervous (worried, scared) when thinking about math class	.83	.71	.85	.77	.82	.74
	I cannot understand the math teacher because of feeling nervous and worried	–	.66	–	.74	–	.63
	I feel nervous for no reason when seeing numbers, figures, and tables	–	.74	–	.79	–	.76
	When the math teacher is asking questions, I feel nervous and uncomfortable	–	.78	–	.78	–	.80
17. Math self-efficacy	I am confident in my math learning ability	.78	.68	.88	.75	.89	.78
	I am good at math	–	.61	–	.74	–	.86
	Learning math is easy for me	–	.63	–	.81	–	.76
	I feel my math ability is high	–	.65	–	.77	–	.80
18. Math interest	I want to learn math well because it is interesting	.85	.67	.91	.77	.92	.80
	I want to learn math well because I like to solve math problems	–	.70	–	.77	–	.76
	I like math	–	.77	–	.82	–	.86
	I feel that learning math is fun	–	.73	–	.87	–	.86
	I am interested in learning math	–	.73	–	.78	–	.83
19. Math outcome expectancy	I will have higher ability in college if I study math well	.73	.83	.81	.77	.79	.63
	I may be able to get a higher-paying job if I study math well	–	.77	–	.83	–	.74
	Learning math well is important for my future	–	.35	–	.53	–	.62
	I can have the job I prefer if I study math well	–	.61	–	.71	–	.76

(continued on next page)

Appendix A (*continued*)

Latent factors	Measured items/item description	Age 9		Age 12		Age 15	
		α	β	α	β	α	β
20. Math study effort	I often study math after school	.69	.31	.74	.44	.70	.52
	If my math score is not good, I will work harder	–	.68	–	.76	–	.64
	I try hard to do math homework	–	.70	–	.72	–	.67
	For hard math formulas, I try harder to memorize them	–	.62	–	.62	–	.52
21. Math achievement	Raw total score of a self-developed 25-item math achievement test	.83	.94	.89	.95	.72	.85
22. Math-related career intentions	I hope to take more math-related courses	.80	.72	.86	.72	.88	.79
	I hope to encounter math again after graduation	–	.67	–	.86	–	.83
	I hope to study math-related majors	–	.62	–	.83	–	.82
	I hope I have a math-related job	–	.76	–	.71	–	.71

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