

Examining the relationship between student academic achievement
and self-concept in the I/E, BFLPE, and combined models -
Evidence from East Asian countries' data in TIMSS 2007

Yi-Chen Hung

Pey-Yan Liou, Ph.D.

National Central University

Please address all correspondence to:

Yi-Chen Hung

Graduate Institute of Learning and Instruction

National Central University

No.300, Zhongda Rd., Zhongli City, Taoyuan County 320, Taiwan (R.O.C.)

Email: 100127002@cc.ncu.edu.tw

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Abstract

The aim of this study was to examine the relationship between student achievement and self-concept of science/mathematics by using a combined model consisting of the internal/external frame of reference (I/E) and the big-fish-little-pond effect (BFLPE) models in three high-performing East Asian countries. The samples were from the Trends in International Mathematics and Science Study (TIMSS) 2007 eighth-grade and fourth-grade student data in Taiwan, Japan, and Hong Kong. Multilevel structural equation modeling (MSEM) was used to analyze whether the data fit the combined models, and to examine the relationship between student self-concept and achievement at different levels. The results suggest that the combined model fitted the data well, and most of the predictions of the combined model were supported by the data from these three countries. Furthermore, the results also show that the effects of the BFLPE and the I/E were generally larger in grade 8. Finally, implications of the findings and suggestions for future research are discussed.

Keywords: the internal/external frame of reference model, the big-fish-little-pond effect model, TIMSS, multilevel structural equation modeling (MSEM)

Introduction

Student academic self-concept and its relations with other factors have been the focus of education and have attracted much attention over the past two decades (Abu-Hilal & Bahri, 2000). Academic self-concept refers to the individual evaluating and judging his/her performance in school (Shavelson, Hubner, & Stanton, 1976). The notion of academic self-concept has become increasingly important because it is recognized as a crucial component of academic literacy (American Association for the Advancement of Science [AAAS], 1990; Shavelson & Bolus, 1982). Thus, in recent years, many nations' education authorities have shown an active attitude towards students' performance in basic disciplines including reading, math and science for the purpose of increasing individual achievement and self-concept.

Students in East Asian countries have participated in some international large-scale assessments such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA). For the past several assessments, East Asian students' performance was particularly noteworthy. Taking TIMSS for example, the math achievement of 8th grade students in Taiwan and 4th grade students in Hong Kong both ranked number one in the world in TIMSS 2007; the math and science performance of Japanese students has also ranked in the top 5 in the last two TIMSS assessments.

However, despite such brilliant performances, there are some underlying problems in East Asian countries' science and math education (Chang, Wu, & Wu, 2011). First, East Asian students showed a general aversion to science or math learning and reported almost the lowest interest level compared to the international average. Second, East Asian students showed a lack of confidence in their academic self-concept (Martin, Mullis, & Foy, 2008), even though they were the top performing students in the world. These problematic situations might interfere with students' future willingness, performance and careers in science and math learning. Thus, one of the purposes of the study is not only to investigate why and how this paradoxical phenomenon has taken shape, but also the relationship between student achievement and self-concept.

It is believed that academic self-concept has a positive relationship with academic achievement based on psychology theories; however, this does not seem to be consistent with the situation of East Asian students who have high academic achievement but express low self-concept or confidence. Considering the relations between student academic achievement and self-concept, two theories are discussed here and used as the main theoretical framework of the combined model (Chiu, 2012) in the study: the Internal/External Frame of Reference Model (the I/E model) (Marsh, 1986) and the Big-Fish-Little-Pond Effect Model (the BFLPE model) (Marsh, 1984a,

b; 1987; Marsh & Parker, 1984).

Chiu (2012) integrated these two theories into a combined model to investigate the relationship between mathematics/science self-concepts and achievement by using multilevel (regression) analysis. The samples in Chiu's study were taken from 8th grade students of 27 countries that participated in TIMSS 2003. The results found that most of the 27 countries supported the hypothesis of the combined model. However, this issue is still worthy of further in-depth examination. First, Chiu took data from all of the countries as examples to test the hypothesis of the combined model; however, it did not illustrate the patterns of East Asian countries deeply or clearly. Second, Chiu used multilevel (regression) analysis which failed to take the measurement error into account. Third, the dataset was derived from TIMSS 2003 while this present study is based on TIMSS 2007; there may therefore be a difference in the 2003 and 2007 data for East Asian countries. Furthermore, Chiu only used 8th grade students as samples, while in the present study, the 4th and 8th grade students were simultaneously examined in order to compare patterns. Thus, it is necessary to further investigate this issue using the new trend dataset in TIMSS to revisit the patterns.

The Internal/External frame of reference model

Students may show different levels of self-concept for different academic subjects. To explain the construct of student self-concept from multiple facets, Marsh (1986) developed the I/E model to account for the reciprocal relationship between student math and verbal achievements as well as math and verbal self-concepts. The model posited an opposite pattern of relations between achievements and self-concepts in distinct subjects. That is, math achievement was positively related to math self-concept while having a negative effect on verbal self-concept.

The I/E model is based on the theory of Shavelson, Hubner, and Stanton (1976) that self-concept is hierarchal and multifaceted in contrast to the underdeveloped perception of one-dimensionality prior to the 1970s. More specifically, the self-concept hierarchy is divided into academic and nonacademic self-concepts, and each hierarchy could be further divided into multiple self-concepts (e.g., math, verbal, and science self-concepts). Moreover, based on the theory of Shavelson, Hubner, and Stanton (1976), Marsh and Shavelson (1985) proposed the Marsh/Shavelson model which focuses on math and verbal self-concept. The result showed that the correlation between the two was significantly lower than the correlation between math and verbal achievement. This "high correlation of the achievements and low correlation of the self-concepts in the different domains" is one of the theoretical assumptions of the I/E model (Marsh & Shavelson, 1985).

The social comparison process that focuses on external comparison is also a

theory underpinning the I/E model. The social comparison theory was proposed by Festinger (1954) who held that individuals evaluate themselves by comparing with others in a biased situation. Social comparison can elevate an individual's self-confidence and reasonably leads to self-improvement. However, in comparing with others who perform better than oneself, the individual's self-concept declines. Taking the example of math and verbal self-concept, if the individual performs better than others in verbal ability, his/her verbal achievement and verbal self-concept are positively correlated. Conversely, if the individual feels worse in his/her verbal ability after comparison with others, his/her verbal achievement would negatively affect his/her verbal self-concept. On the other hand, from the perspective of individual internal comparison, if an individual feels better about his/her math ability than verbal ability, it would have a positive effect on his/her math self-concept and a negative effect on verbal self-concept.

It can be seen from the arguments above that an individual undergoes two comparison processes to construct his/her verbal and math self-concept according to the I/E model (Marsh, 1986; Marsh, 1990). One is the external comparison process in which the individual compares him/herself with others. The other is the internal comparison in which the individual distinguishes his/her own ability in different subjects. Therefore, the formation of a subject's self-concept is influenced simultaneously by internal and external comparison processes as posited by the I/E model. The model assumes a positive correlation between the achievement and self-concept for the same subject and a negative correlation for distinct subjects (Figure 1).

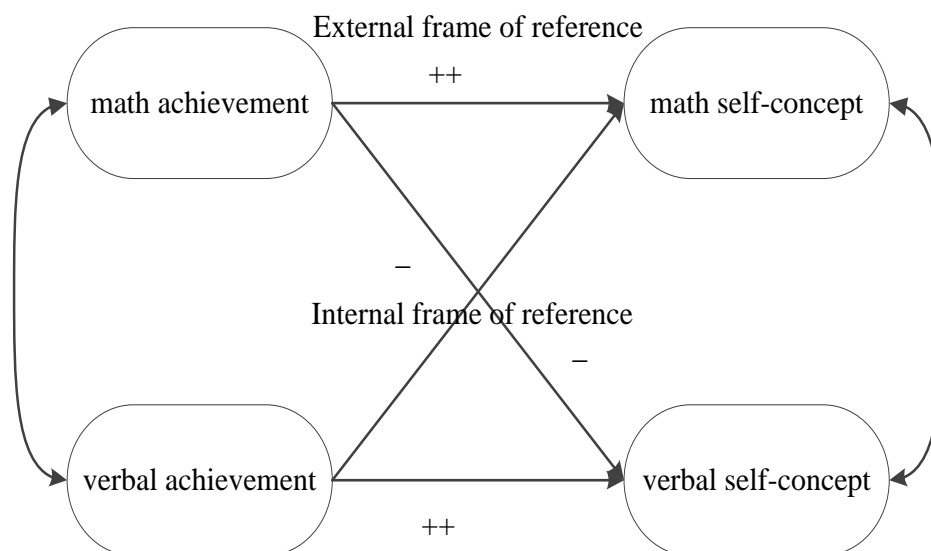


Figure 1. Internal/External frame of reference model (adopted from Marsh & Hau, 2004)

The Big-Fish-Little-Pond Effect

Similar to the I/E model, the theoretical background of BFLPE is based on the multifaceted self-concept and social comparison theories. In terms of social comparison, students compare their academic achievements with others. Such social comparison results in the basis of students' individual academic self-concepts. Many studies confirm the cross-cultural consistency of BFLPE (e.g., Marsh, Trautwein, Lüdtke, Baumert, & Köller, 2007; Zeidner & Schleyer, 1999). For example, Marsh and Hau (2003) took the 26 countries' data from PISA 2000 and found that all these countries showed the BFLPE, thus validating the prediction of the authors: that is, the cross-cultural consistency of BFLPE.

Marsh and his colleagues (Marsh, 1984a, b; 1987; Marsh & Parker, 1984) developed the BFLPE model by using small samples at first and then extending to include the samples of large-scale assessments. The original concept of BFLPE was that if a high-achieving student in a nonselective school transferred into a selective and competitive environment, their achievement would be relatively medium or low, and further they would have a lower academic self-concept. Due to the features and sampling method of large-scale assessment, however, it is impossible for researchers to see the pattern of environment transformation. Thus, the definition of BFLPE was modified to "if students are in a high-achieving or competitive class or school, their academic self-concept will be lower than the students who are in a general environment."

Marsh and Hau (2003) utilized 26 countries' data to test the negative effect of students attending a selective school, and the results supported the BFLPE, as these students had relatively lower academic self-concept. Furthermore, the authors also provide evidence for the cross-cultural generalizability of the BFLPE by investigating these 26 countries. Although the BFLPE seems to be a robust phenomenon and has cross-cultural generalizability in general, some studies (e.g., Nagengast & Marsh, 2012; Seaton, Marsh, & Craven, 2009) have also found a minor exception in that some East Asian countries, such as Taiwan, Japan, and South Korea did not show a significant BFLPE. Up to now, there has been no study examining the BFLPE in East Asian countries; thus, the present study serves to fill this gap in the literature about the BFLPE on East Asian students.

Research questions

This study intends to examine the relationship between academic achievement and academic self-concept of the fourth grade and eighth grade students in three East Asian countries based on a combined model. The research questions are proposed as

follows:

1. Do the data of the selected East Asian countries fit the combined model which consists of the I/E and the BFLPE models?
2. Are the relationships between science/math achievement and science/math self-concept of the three East Asian countries' grade 4 and grade 8 students consistent with the predictions of the combined model?

Methods

Data Source and Samples

The present research is based on the data from the Trends in International Mathematics and Science Study 2007 (TIMSS 2007). TIMSS has been administered since 1970 by the International Association for the Evaluation of Educational Achievement (IEA). In 2007, 36 countries participated at the fourth grade level and 49 countries participated at the eighth grade level in both math and science. Details of the data, tests and sampling procedures can be found in the general and technical reports (Olson, Martin, & Mullis, 2008). The present study selected three East Asian countries, Taiwan, Japan, and Hong Kong. South Korea also belongs to the East Asian area, but it did not participate at the 4th grade level in TIMSS 2007, so it is excluded from the analysis. The detailed samples (including weighted samples) of the three East Asian countries in this study are shown in Table 1.

Table 1. Descriptive statistics of the samples in East Asian countries

		# of student	# of weighted student	# of school	# of weighted school
Taiwan	G4	4,131	308,536	150	2,649
	G8	4,046	307,288	150	959
Japan	G4	4,487	1,149,805	148	19,489
	G8	4,312	1,153,745	146	11,163
Hong Kong	G4	3,791	69,095	126	578
	G8	3,470	82,514	120	448

Measures

Four measures were used to examine the combined model which consists of the I/E and the BFLPE models. The indicators were science and math achievement at student and school level, and self-concept at student level.

Science & math achievement

The achievements were computed based on item response theory (IRT) which

estimated the student latent ability (Olson, Martin, & Mullis, 2008). Since students were administered only a few items in each specific content area due to time constraints, the TIMSS 2007 developed plausible values as a computational approximation to obtain consistent and precise estimates of students' ability (IEA, 2009). According to Wu (2005), "plausible values are multiple imputations of the unobservable latent achievement for each student" (p. 114). The student-level achievements were obtained by taking a mean score of the five plausible values.

Science & math self-concept

There were 8 items regarding the student attitude of each domain in the fourth-grade and 12 items in the eighth-grade. Based on the notion of the I/E and BFLPE models, the study chose the 4 items regarding the social comparison theory (Festinger, 1954). The chosen items are shown in Table 2.

Table 2. The chosen items of academic self-concept

G4	<ol style="list-style-type: none"> 1. I usually do well in mathematics (science) 2. Mathematics (science) is harder for me than for many of my classmates 3. I am just not good at mathematics (science) 4. I learn things quickly in mathematics (science)
G8	<ol style="list-style-type: none"> 1. I usually do well in mathematics (science) 2. Mathematics (science) is more difficult for me than for many of my classmates 3. Mathematics (science) is not one of my strengths 4. I learn things quickly in mathematics (science)

The current study used these items to measure the relationship between achievement and self-concept. All items were rated on a four-point Likert scale ranging from 1 (agree a lot) to 4 (disagree a lot). The first and the fourth items were recoded based on the degree of self-concept. A higher score indicated a more positive self-concept regarding science and math.

Theoretical framework and hypotheses

Figure 2 shows the theoretical structural model for the present study. The model consists of two levels: a within-level (student) and a between-level (school) model. For the within-level model, the student science and math scores were the exogenous variable that had direct relations with student self-concept of science and math. For the between-level model, school science and math scores were the exogenous variables and the student self-concept of science and math were the endogenous variables.

There are several theoretical hypotheses as described below:

1. Student math score has a significantly positive relationship with math self-concept, but has a significantly negative relationship with science self-concept.
2. Student science score has a significantly positive relationship with science self-concept, but has a significantly negative relationship with math self-concept.
3. School math score has a significantly negative relationship with student math self-concept.
4. School science score has a significantly negative relationship with student science self-concept.

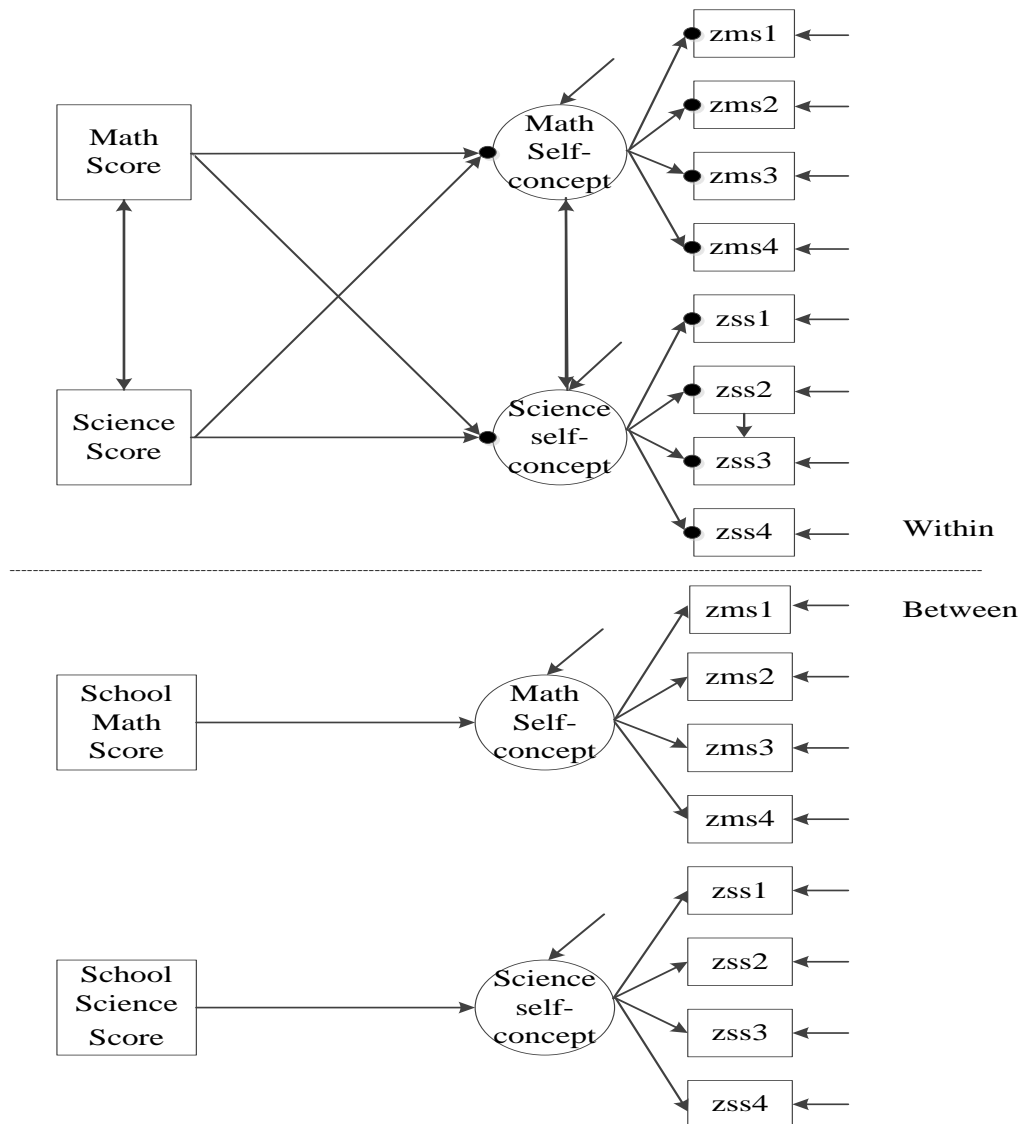


Figure 2. Theoretical structural model of the combined model consisting of the internal/external frame of reference (I/E) and the big-fish-little-pond effect (BFLPE) models

Statistical Analysis

Multilevel structure equation modeling (MSEM) was used in this study. There are two-stage procedures (Anderson & Gerbing, 1988) in the data analysis. Confirmatory factor analysis (CFA) was used to verify the measurement model and to test whether measures of the construct were consistent with the theoretical construct or previous analytical research. Then multilevel path analysis was simultaneously used to exam the hypothesized relationships among variables at different levels. Mplus 6.12 software (Muthén & Muthén, 1998-2010) was utilized.

Educational studies commonly have a nested structure, in that the student is nested in the class and the class is nested in the school. Because there are multilevel influences, using multilevel modeling that takes into account the multilevel, hierarchical structure of the data is suitable (Raudenbush & Bryk, 2002). Moreover, as recommended in the TIMSS 2007 technical report (Olson, Martin, & Mullis, 2008), analyses were conducted using total student weights and school weights to obtain unbiased estimates of population parameters.

Fit indices provided in Mplus (Muthén & Muthén, 1998-2010): Chi-square test, Standardized Root Mean Residual (SRMR), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA), were used to compare the fit for models consisting of differing numbers of factors. The Chi-square test is quite sensitive to sample size; however, it can test the difference in fit between a given over-identified model and a just-identified version after taking degrees of freedom into consideration (Kline, 2011). SRMR is smaller than 0.08 and CFI should achieve a value of 0.95 for the model to be deemed good; a value between 0.90 and 0.95 is considered acceptable. The RMSEA is the average of the residuals between the observed covariance/correlation from the sample and the expected model estimated from the population (Kline, 2011). The smaller the RMSEA, the better the model fit. An RMSEA value lower than 0.05 suggests close approximate fit, while a value between 0.05 and 0.08 indicates reasonable error of approximation (Kline, 2011). These are the indices used to judge the goodness-of-fit of a model to the data.

Results

The CFA model showed that the total samples mostly had a good fit to the proposed framework for the combined model (e.g., Taiwan G4: RMSEA= .05 and Chi Square was significant; Japan G8: RMSEA= .08 and SRMR= .07). Table 1 shows the results from the multilevel SEM. Most of the coefficients were consistent with the predictions of the combined model.

Results of TIMSS 2007 G4

In the sample from Taiwan, the results show that the four hypotheses were supported and the combined model fit the model predictions. However, the results for Japan showed that although the relations between math/science school achievement and math/science self-concept were negative, it was not significant. In terms of Hong Kong, it did not show a significant negative relation between science school achievement and science self-concept. Besides these exceptions, other predictions and assumptions are supported by the three East Asian countries for the grade four students.

Results of TIMSS 2007 G8

The results for the 8th grade students indicate that only Taiwan exhibits an inconsistency in the prediction of school science score having a significantly negative relationship with student science self-concept. The other two countries (Japan and Hong Kong) matched the hypotheses of the combined model.

Results of the I/E and the BFLPE models

In terms of the I/E model, (1) math achievement has a negative path to science self-concept and science achievement has a negative path to math self-concept; (2) math achievement has a positive path to math self-concept and science achievement has a positive path to science self-concept. In terms of the BFLPE model, Table 1 shows that both the math and science BFLPE of G4 and G8 are negatively significant, which is consistent with the past studies and theory. The results also show a pattern that the BFLPE increases from G4 to G8 (except for math in Taiwan). The reason for this phenomenon is worthy of future investigation.

Table 1. The results of the combined model in the three East Asian countries

	Taiwan				Japan				Hong Kong			
	G4		G8		G4		G8		G4		G8	
	<i>Est</i>	<i>SE</i>	<i>Est</i>	<i>SE</i>	<i>Est</i>	<i>SE</i>	<i>Est</i>	<i>SE</i>	<i>Est</i>	<i>SE</i>	<i>Est</i>	<i>SE</i>
Within level												
MSC on MAC	.89**	.05	.99**	.04	.86**	.04	1.00**	.03	1.05**	.04	.83**	.04
MSC on SAC	-.30**	.07	-.38**	.05	-.32**	.03	-.40**	.04	-.52**	.04	-.14**	.03
SSC on MAC	-.39**	.06	-.92**	.16	-.45**	.04	-.29**	.05	-.46**	.05	-.51**	.05
SSC on SAC	.69**	.05	1.24**	.11	.71**	.04	.79**	.05	.66**	.05	.90**	.05
Between level												
MSC on SMCH	-.72**	.14	-.70**	.08	-.26	.24	-.74**	.07	-.85**	.05	-.96**	.02
SSC on SSCH	-.29*	.12	.34	.29	-.18	.21	-.55**	.11	-.03	.20	-.73**	.07

Additional parameters												
BFLPE-math	-.97**	.08	-.86**	.10	-.67**	.09	-1.15**	.06	-.98**	0.05	-1.15**	.07
BFLPE-science	-.69**	.11	-.78**	.11	-.54**	.09	-.91**	.08	-.46**	0.07	-.86**	.05

** $p < .01$, * $p < .05$

Note: MSC=math self-concept, SSC=science self-concept, MAC=math achievement, SAC=science achievement, SMCH=school mean math achievement, SSCH= school mean science achievement, BFLPE=Big-Fish-Little-Pond Effect

Conclusions and Implications

The main purpose of the present study was to use multilevel SEM to examine the relationship of the three East Asian countries' students' achievement and self-concept using a combined model that integrated the I/E and the BFLPE models. The results show that the combined model is solid and that most of the predictions were the same as the theories and consistent with previous studies (e.g., Nagengast & Marsh, 2012; Seaton, Marsh, & Craven, 2009). Moreover, the BFLPE increased from G4 to G8 (except for math in Taiwan). This implies that students' self-concept will be lower when they are in a higher grade and in a higher achieving environment. Similarly, the effects of the I/E model also increased from G4 to G8 (except for Hong Kong which has a minor exception). It should be noted that the effects of math/science achievement on math/science self-concept would be positively enhanced. On the other hand, the influences of achievement on self-concept would be negatively strengthened as well. No previous studies have found changes in the BFLPE or the I/E between G4 and G8; thus, explanations for the phenomenon need to be further investigated in future studies.

Self-concept is an important predictor for student academic choice and long-term engagement (Nagengast & Marsh, 2011); however, the findings from the TIMSS results are alarming for the East Asian countries' educational authorities and teachers who may need to make further consideration of the relationship between student achievement and self-concept. The results from the TIMSS 2007 questionnaire data show a lack of confidence in doing science and math among East Asian students. Although the achievement in these countries is outstanding, student academic self-concept is very low. It should be noted that this negative pattern may be due to the high stress of academic performance and the virtue of humility in the shared culture of East Asia (Leung, 2002). This study has only focused on the three East Asian countries which have lower motivation regarding learning science and math; however, due to differences in culture or values, it is worth comparing the pattern of East Asian countries with that of Western countries in the future.

Teachers and educational authorities play a crucial role in the relations between

student achievement and self-concept. Teachers should improve students' knowledge of their strengths on the one hand and on the other, place emphasis on the importance of their relatively weaker domains. Most important is to enhance student self-concept of the subjects for which they lack confidence.

In the present study, the relationship between student self-concept and achievement was analyzed based on TIMSS 2007 which provides cross-sectional data. It is important to caution that the data are not from a longitudinal study or experimental study and therefore cannot be used to make causal statements. However, based on the initial concept of BFLPE, it is suitable for future study to use a longitudinal study (such as the Taiwan Education Panel Survey, TEPS) to investigate the BFLPE or combined model.

In brief, this study provides new literature on the relationship between student self-concept and science achievement based on the East Asian countries' data, which have not been previously examined in depth. The results of this study can be a reference for policy-makers and educational researchers to re-think the role and the relation of student self-concept and student academic achievement.

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