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DIFFERENTIAL PSYCHOLOGICAL PROCESSES UNDERLYING THE SKILL-DEVELOPMENT MODEL AND SELF-ENHANCEMENT MODEL ACROSS MATHEMATICS AND SCIENCE IN 28 COUNTRIES

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ABSTRACT. The skill-development model contends that achievements have an effect on academic self-confidences, while the self-enhancement model contends that self-confidences have an effect on achievements. Differential psychological processes underlying the 2 models across the domains of mathematics and science were posited and examined with structural equation modeling using the data of grade 8 students from the Trends in International Mathematics and Science Study across 28 countries ($N=$ 144,069), which generated 2 major findings. In statistical terms, (1) there were *negative* cross-domain paths leading from achievements to self-confidences, controlling for the positive matching domain paths, as predicted by the skill-development model across domains; (2) there were *positive* cross-domain paths leading from self-confidences to achievements, controlling for the positive matching domain paths, as predicted by the self-enhancement model across domains. There were, however, qualitative variations in the degrees of support for the 2 models across countries.

KEY WORDS: achievement, domain learning, self-confidence, structural equation modeling, survey research

Introduction

The development of self begins with the reciprocal relation between the self and the world. Students' domain-specific ability- or achievement-related self-beliefs, as responses to evaluations from the outside world (e.g. school examinations), have become one of the most widely researched affective constructs in diverse subfields of education, though with slightly different terms. For instance, "self-confidence" and "confidence" are widely used terms as part of self-beliefs (Kloosterman, 2002; Kloosterman & Stage, 1992; McLeod, 1992; Op't Eynde, De Corte & Verschaffel, 2002; Schommer-Aikins, Duell & Hutter, 2005), attitudes (Juter, 2005), and conceptions (Chiu, 2011b) in mathematics education (Leder & Forgasz, 2002). Science "confidence" and "self-esteem" are terms as part of attitudes toward learning science (Chiu, 2011a; Dhindsa & Chung, 2003; Osborne, Simon & Collins, 2003). Similar terms in educational psychology include

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"competence beliefs" as part of motivations (Pintrich, 2003) and "self-concepts" as part of self-beliefs in specific domains or the general academic domain, and "self-esteem" as a term for the general self-belief (Marsh, Trautwein, Lüdtke, Köller & Baumert, 2006; Shavelson, Hubner & Stanton, 1976). Self-confidence, confidence, competence beliefs, and self-concept are viewed as synonymous terms in the present study, and in order to increase readability, the term "self-confidence" is consistently used even if the original literature uses the other terms. "Self-confidence" refers to students' perceptions of their capacities (1) to learn a particular domain, if indicated, e.g. "mathematics and science self-confidences," or (2) to learn the academic domain as a whole, if no domain name is indicated, e.g. "self-confidence," in the present study. The reasons for choosing the term "self-confidence" include: (1) It directly expresses the meaning of ability/achievement-related self-beliefs. (2) It is a term widely used in both the fields of mathematics and science education, the two major domains studied in the present study. (3) It is also a term used in the Trends in International Mathematics and Science Study (TIMSS; IEA, 2005; Martin, Mullis, Gonzalez & Chrostowski, 2004; Mullis, Martin, Gonzalez & Chrostowski, 2004), data from which conducted in 2003 are used in the present study.

The relation between self-confidence and achievement in mathematics and science is widely supported by researchers of mathematics and science education. Mathematics self-confidence has positive relations with mathematics achievement (Chiu, 2009a; Grootenboer & Hemmings, 2007; Malmivuori, 2006; Meyer & Koehler, 1990; Pietsch, Walker & Chapman, 2003; Seegers & Boekaerts, 1996; Vermeer, Boekaerts & Seegers, 2000), desirable mathematical problem-solving behavior (Gómez-Chacón, 2000; Mason, Burton & Stacey, 1996; Whitebread & Chiu, 2004), and participation in advanced mathematics studies (Brown, Brown & Bibby, 2008). Similar findings are found in science education, with science self-confidence showing positive relations with science achievement and participation in advanced science studies (Chang & Cheng, 2008; Glynn, Taasoobshirazi & Brickman, 2007).

While researchers of mathematics and science education support the relation between self-confidence and achievement, educational psychologists suggest that the psychological process leading from achievement to self-confidence is different from that leading from self-confidence to achievement in theoretical and statistical terms. Green, Nelson, Martin & Marsh (2006) assume that the reciprocal relation between self-confidence and achievement may be divided into two parts: (1) a skill-development model, in which achievements have an effect on academic self-confidences (i.e. the achievement effect), and (2) a self-enhancement model, in which self-confidences have an effect on achievements (the self-confidence effect). The achievement effect is found to be predominant starting in children from as young as age 5 (Chapman & Tunmer, 1997; Muijs, 1997). The self-confidence effect is also supported by research (Drew & Watkins, 1998; Guay, Larose & Boivin, 2004). Some studies, however, find neither effect to be significant (Hoge, Smit & Crist, 1995; Pottebaum, Keith & Ehly, 1986). In addition, evolution or progress in academic achievements is found to be unrelated to that in academic self-confidences from grades 7 to 10 (De Fraine, Van Damme & Onghena, 2007). A possible solution to these inconsistent research findings is likely to decompose this reciprocal relation and look at the differential psychological processes underlying the two models in depth.

Past research on reciprocal relations and psychological processes of self-confidence and achievement has generally focused on one domain of knowledge, e.g., mathematics, science, or language, but a comparison between domains of knowledge is likely to produce an effect on the relations and psychological processes. Research has indicated that the effect of self-confidence in mathematics is larger and more systematic than that in either science or English (Marsh & Yeung, 1997). The effect of self-confidences in mathematics is also more accurate than that in verbal ability (Ackerman & Wolman, 2007). The reason for more stable relations between self-confidence and achievement in mathematics than those in science may be that mathematics tend to be a single domain of knowledge that focuses on pattern and logic (Burton, 1994), which forms one of the major bases of science (Chiu, 2008). Science, on the other hand, contains several domains of knowledge, e.g. earth science, life science, physics, chemistry, and environmental science, a system used by the TIMSS (IEA, 2005). The differential contents of knowledge between mathematics and science suggest that the psychological processes leading from achievements to self-confidences (the skill-development model) and that from self-confidences to achievements (the self-enhancement model) across mathematics and science are very likely to be different.

The purpose of the present study was to depict and examine the psychological processes underlying the skill-development model and the self-enhancement model, respectively, across the domains of mathematics and science. A well-developed model, Marsh's (1986) *internal/external frame of reference* (I/E) model, describes the likely psychological processes underlying the skill-development model across domains of knowledge. An *explicit/implicit self-enhancement* (E/I) model, with reference to the I/E model, is posited in the present study for the convenience of explaining the psychological process underlying the operation of the self-enhancement model across domains of knowledge. In addition, examinations of the two models based on the data from different countries can further our understanding of the generalization of the two models across cultures (Marsh & Hau, 2004). The two models are depicted in Figure 1, and related issues are described in detail as follows.

A Skill-Development Model Across Domains, i.e. Marsh's I/E Model

The I/E model describes the psychological process leading from achievements to self-confidences across domains. According to Marsh and his colleagues, there are two major psychological processes underlying the I/E model. To use mathematics vs. science as an example, (1) the process of external (normative-like) comparison drives students to

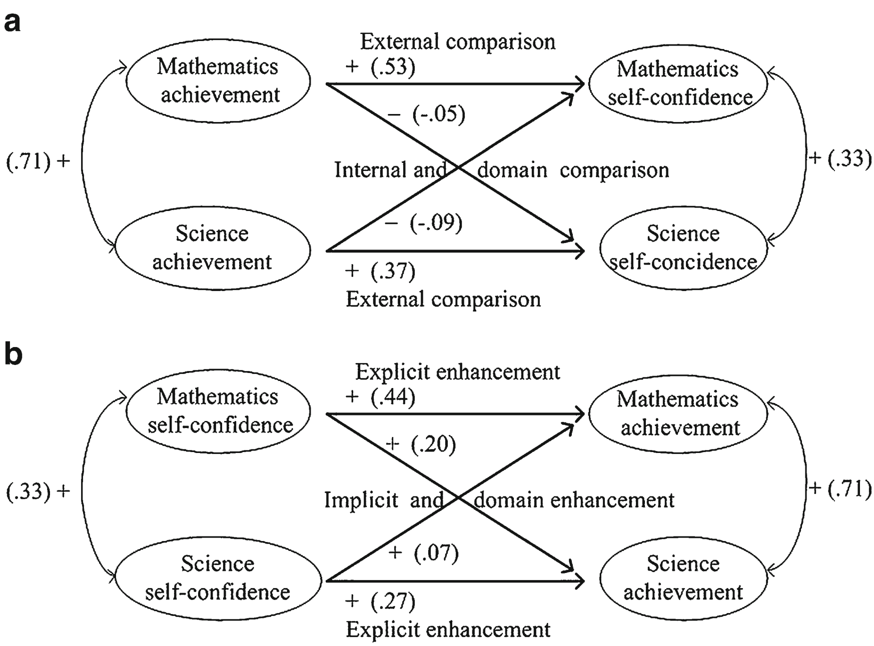

Figure 1. The skill-development model and the self-enhancement model across mathematics and science. Note: In statistical terms, the I/E model predicts negative (−) paths leading from mathematics (science) achievements to science (mathematics) self-confidences, and the E/I model predicts positive (+) paths leading from mathematics (science) self-confidences to science (mathematics) achievements, controlling for positive (+) matching-domain paths, respectively. The *numbers in parentheses* are obtained from the result of analysis presented in Table 2. **a** The skill-development model or the internal/external frame of reference (I/E) model across mathematics and science (cf. the Diagram B of Figure 1 in Chiu (2008)). **b** The self-enhancement model or the explicit/implicit self-enhancement (E/I) model across mathematics and science (posited by the present study)

compare their own mathematics (or science) achievement with others' or a norm, i.e. a frame of reference outside the students themselves. This psychological process is operationally predicted and evidenced by the fact that a higher mathematics achievement contributes to a higher mathematics self-confidence and a higher science achievement contributes to a higher science self-confidence and vice versa. (2) The psychological process of internal (ipsative-like) comparison drives students to compare the relative strengths of their achievements in at least two domains, e.g. mathematics vs. science. This psychological process is operationally predicted and evidenced by the fact that a higher mathematics achievement contributes to a lower science self-confidence and a higher science achievement contributes to a lower mathematics self-confidence (diagram A in Figure 1; Marsh, 1986; Marsh & Hau, 2004; Möller, Pohlmann, Köller & Marsh, 2009; Möller, Streblow, Pohlmann & Köller 2006).

Obviously, the psychological process underlying the I/E model is a *cognitive comparison* or *contrast* of multiple internal and external targets at the domain-specific level (Skaalvik & Skaalvik, 2002). This claim is further supported by the following research results: (1) Skaalvik & Rankin (1995) showed that the use of domain-specific comparison, rather than that of a sub-domain-specific one, succeeded in supporting the I/E model. (2) Marsh, Walker & Debus (1991) and Skaalvik & Skaalvik (2004) showed that the I/E model was supported at the level of domain-specific self-confidence.

The I/E model is widely supported with data from diverse cultures in research for distinctly different domains, e.g. mathematics vs. verbal skills (e.g. Goetz, Frenzel, Hall & Pekrun, 2008; Marsh, 1989; Plucker & Stocking, 2001; Skaalvik & Skaalvik, 2004) and native vs. foreign languages (Marsh & Yeung, 2001; Marsh, Kong & Hau, 2001). The predictions of the I/E model are also supported for the related domains of mathematics and science, although the correlations between mathematics and science self-confidences are slightly larger than those between mathematics and verbal skills, and the correlations between mathematics and science achievements are similar to those between mathematics and verbal skills (Chiu, 2008).

A Self-Enhancement Model Across Domains, i.e. the E/I Model

The E/I model posited by the present study predicts that multidimensional self-confidences boost matching domain achievements through the psychological process of *explicit* enhancement and the non-matching-domain achievements through the psychological process of *implicit* enhancement (diagram B in Figure 1). Individuals actively seek self-enhancement, which triggers a psychological process of positive integration and overgeneralization. This psychological process is especially salient for the relation of self-confidences to achievements in relevant domains, e.g. mathematics and science.

To use mathematics vs. science as an example, (1) the psychological process of explicit self-enhancement drives students to increase their mathematics (or science) achievement based on their positive self-confidence in mathematics (or science). This psychological process is formulated as a higher mathematics self-confidence contributing to a higher mathematics achievement and a higher science self-confidence contributing to a higher science achievement and vice versa. (2) The psychological process of implicit self-enhancement drives students to increase their achievements in mathematics (or science) based on their self-confidence in science (or mathematics). This psychological process is formulated as a higher mathematics self-confidence contributing to a higher science achievement and a higher science self-confidence contributing to a higher mathematics achievement and vice versa (diagram B in Figure 1).

The self-enhancement model in one domain is supported by research results that mathematics self-confidence can predict later mathematics achievement (Hannula, Maijala & Pehkonen, 2004); mathematics and science self-confidence (combined) can also positively predict mathematics and science achievement (combined) in statistical terms (Koutsoulis & Campbell, 2001). There is, however, a lack of studies or theories focusing on the psychological process underlying the self-enhancement models across domains of knowledge, e.g. mathematics and science. The prediction of the E/I model posited as shown in the previous paragraph, therefore, is based on the results of studies on self-enhancement in personality, social, and cross-cultural psychology as follows.

Research on self-enhancement indicates that relevant messages that raise people's concerns may boost the effect of self-enhancement, e.g. presenting idealized body images to dieters (Mills, Polivy, Herman & Tiggemann, 2002) and indicating task importance to people (Campbell, Reeder, Sedikides & Elliot, 2000), by which self-confidence is enhanced and actions are taken to achieve desirable goals. People are also likely to undergo a psychological process of self-enhancement in some domains, but not in the others (Yik, Bond & Paulhus, 1998).

There are debates regarding whether self-enhancement is a pan-cultural phenomenon. Some researchers insist that Westerners (e.g. Americans, Canadians, and Israeli Jews) self-enhance more than Easterners (e.g. Chinese in China, Hong Kong, and Singapore, Ethiopians, Israeli Druze, Japanese, and Koreans; Chang & Asakawa, 2003; Chang, Sanna & Yang, 2003; Hamamura, Heine & Takemoto, 2007; Kurman, 2001). Some researchers contend that self-enhancement is a universal human motivation which is discouraged by collectivist cultural norms (Brown & Kobayashi, 2003; Kurman, 2003). These researchers further argue that it is a culturally valued domain that gives rise to cultural differences in the degrees of self-enhancement; Westerners value individualism and Easterners value (vertical) collectivism, modesty, and interpersonal relationships (Cai, Brown, Deng & Oakes 2007; Kurman & Sriram, 2002). This phenomenon was termed "tactical self-enhancement" by Sedikides, Gaertner, & Vevea's (2005, p. 547). A similar finding and explanation is that Norwegians self-enhance less than Americans because Norwegians emphasize modesty more than Americans (Silvera & Seger, 2004).

These results suggest that "value" or "importance" is one of the major themes of self-enhancement and that culture may at least partly determine what is to be valued. To return to the self-enhancement model across the domains of knowledge (diagram B in Figure 1), students may self-enhance across domains of knowledge if the domains of knowledge, e.g. mathematics and science, are valued and perceived as being related by students.

The Present Study

The above review of the literature suggests that there are differential psychological processes underlying the skill-development model and the self-enhancement model across the two domains of mathematics and science. The two research questions are:

Research question 1. What are the psychological processes leading from mathematics/science achievements to mathematics/science self-confidences?

Research question 2. What are the psychological processes leading from mathematics/science self-confidences to mathematics/science achievements?

Furthermore, two hypotheses in statistical terms are also posited as follows:

Hypothesis 1. There are *negative* cross-domain paths leading from achievements to self-confidences in mathematics and science, controlling for the positive matching-domain paths (i.e. the prediction of the skill-development model across domains or the I/E model, as depicted in diagram A of Figure 1).

Hypothesis 2. There are *positive* cross-domain paths leading from self-confidences to achievements in mathematics and science, controlling for the positive matching-domain paths (i.e. the prediction of the self-enhancement model across domains or the E/I model, as depicted in diagram B of Figure 1).

Method

Data Source and Sample

The TIMSS of 2003 provided the data on mathematics achievements, science achievements, and mathematics self-confidences for grade 8 students from 47 countries (IEA, 2005). There were, however, only 28 countries with data on science self-confidences. As a result, only the data from the 28 countries, including in total 144,069 students, were analyzed in the present study. The numbers of students for the 28 countries are presented in the second column of Table 3.

Chiu's (2008) study has answered Research question 1 using the same database and statistical methods as the present study. Thus, some findings from Chiu (2008) were used in addressing the issue of Research question 1 in "Results"; some findings were further analyzed and interpreted when answers for Research questions 1 and 2 were compared, as presented in Tables 2 and 3.

Indicators

The posited hypotheses were examined using four sets of indicators: mathematics self-confidence (four items) and science self-confidence (four items), and mathematics achievement (five items) and science achievement (five items), in total 18 items. Students indicated their levels of agreement for the items of self-confidences on a four-point Likert scale (1 = *agree a lot* to 4 = *disagree a lot*). To facilitate data interpretation, the self-confidence scores were re-coded so that a larger number could represent a more positive self-confidence. The score range of the achievement scores was between 5.00 and 973.01, which were the estimates of students' latent abilities obtained by the use of the item response theory. All of the 18 items individually were transformed into standardized z scores ($M = 0$, SD = 1) based on the total student sample from the 28 countries in order to facilitate data analysis and interpretation without eliminating cultural differences in the analysis. Similar standardization procedures have been successfully used by other studies, e.g. Chiu (2008), Marsh, Kong & Hau (2000), and Wilkins (2004), based on similar rationales. Detailed descriptions of the four sets of indicators are as below.

Mathematics Self-Confidence

Students indicated their degree of confidence in their capacity to learn mathematics with the following four items: "I usually do well in mathematics," "I learn things quickly in mathematics," "Mathematics is more difficult for me than for many of my classmates (negatively worded)," and "Mathematics is not one of my strengths (negatively worded)" (TIMSS variables bsbmtwel, bsbmtqky, bsbmtclm, and bsbmtstr, respectively).

Science Self-Confidence

Students indicated their degree of confidence in their capacity to learn science with the following four items: "I usually do well in science," "I learn things quickly in science," "Science is more difficult for me than for many of my classmates (negatively worded)," and "Science is not one of my strengths (negatively worded)" (TIMSS variables bsbstwel, bsbstqky, bsbstclm, and bsbststr, respectively).

Mathematics Achievement

Mathematics achievement consisted of achievements in algebra, data, fractions/numbers, geometry, and measurement (TIMSS variables bsmalg01, bsmdap01, bsmfns01, bsmgeo01, and bsmmea01, respectively).

Science Achievement

Science achievement consisted of achievements in earth science, life science, physics, chemistry, and environmental science (TIMSS variables bsseas01, bsslis01, bssphy01, bssche01, and bsseri01, respectively).

Statistical Analysis

The major analysis here, i.e. the examination of the hypotheses and the models (Figure 1), was conducted using structural equation modeling (SEM) with the LISREL 8.72 software (Du Toit & Du Toit, 2001; Jöreskog & Sörbom, 2001, 2005). Comparative fit index (CFI), non-normed fit index (NNFI), and root mean square error of approximation (RMSEA) were selected as the major fit indexes, which indicated the goodness of fit of the models (Figure 1) to the data. Values of CFI and NNFI larger than 0.900 and of RMSEA smaller than 0.100 indicate an acceptable fit. It is reasonable to choose a less strict standard when the sample sizes are large (Hair, Black, Babin, Anderson & Tatham, 2006; Schumacker & Lomax, 1996). The most traditional goodness-of-fit index of SEM analysis is χ^2; however, the value of χ^2 is normally very large when the sample sizes are large, which prevents χ^2 from being a suitable index here (Bollen & Long, 1993; Browne & Cudeck, 1993). CFI, NNFI, and RMSEA, therefore, are the indexes used to judge the goodness of fit of a model to the data, though χ^2 is also presented, as shown in Tables 1 and 3.

SEM is able to detect a lack of construct equivalence across groups by multigroup confirmatory factor analysis (CFA; Van de Vijver & Leung, 1997). SEM can also be used to identify a lack of scalar equivalence by the inclusion of the intercept term for each measured variable, which would allow for the estimation of the means among data from different countries in the SEM measurement model (Hair et al., 2006). In other

TABLE 1

Goodness-of-fit indexes for the measurement model fit to the total group and the E/I model fit to the total group and multiple groups

Model	χ^2	*df*	*CFI*	*NNFI*	*RMSEA*	*Model description*
The measurement model						
TG1	87,580.831	127	0.983	0.979	0.069	CFA single (student) level
TG2	262,742.492	505	0.983	0.985	0.060	CFA 3-level
The E/I model						
TG3	87,580.830	127	0.983	0.979	0.069	SEM Single (student) level
TG4	262,742.489	505	0.983	0.985	0.060	SEM 3-level
MG1	403,769.489	4,393	0.919	0.921	0.133	SEM Inv. = FL; Free = FV, PC, IT, Uniq.
MG2	410,561.175	4,420	0.918	0.921	0.134	SEM Inv. = FL, FV; Free = PC, IT, Uniq.
MG3	430,004.192	4,528	0.916	0.920	0.135	SEM Inv. = FL, FV, PC; Free = IT, Uniq.
MG4	1,052,270.859	5,014	0.815	0.842	0.201	SEM Inv. = FL, FV, PC, IT; Free = Uniq.
MG5	1,094,588.480	5,230	0.808	0.842	0.201	SEM Inv. = FL, FV, PC, IT, Uniq. (total invariance)

N = 144,069

CFA confirmatory factor analysis, *SEM* structural equation modeling, *TG* total group, *MG* multiple group (or multigroup), *CFI* comparative fit index, *NNFI* non-normed fit index, *RMSEA* root mean square error of approximation, *Inv*. invariant, *Free* free estimation, *FL* factor loadings, *FV* factor variance–covariances, *IT* construct intercept terms, *PC* path coefficients, *Uniq*. uniqueness words, this procedure is able to take into account the meaning of each construct for each country. Multilevel SEM can take account of data from different levels, although single-level SEM remains the typical procedure used by most related studies. Three kinds of SEM are used in Chiu (2008) and in the present study: (1) *Single*- or *student-level SEM* uses the total student sample as a whole to examine the hypotheses. (2) *Multilevel SEM* deals with the total group data as a whole, but also takes the hierarchical structure of the data into account by analyzing the covariance matrices from several sampling levels. Detailed discussions of multilevel analysis can be found in Bryk & Raudenbush (2002), Raudenbush, Bryk, Cheong, Congdon & Du Toit (2004), and Snijders & Bosker (1999). For detailed procedures for multilevel SEM using LISREL, please see Du Toit & Du Toit (2001) and Stapleton (2002). (3) *Multigroup SEM* is a useful technique to examine the equivalence or invariance of parameter estimates across groups and is regarded as a suitable technique for investigating the external validity of theory-based models (Sue, 1999). Hair et al. (2006) pointed out that there were three degrees of invariance between groups by setting certain combinations of invariant and free parameters to be estimated across groups. (a) Tight cross-validation: All parameter estimates are invariant across groups. (b) Partial cross-validation: Some parameter estimates are set invariant and some are set free across groups. (c) Loose cross-validation: The same model is examined for each group data separately. Similar SEM procedures have been successfully used in cross-cultural research, e.g. Marsh & Hau (2004).

Missing data are an inevitable problem for studies relying on databases (Trautwein, 2007) and need to be dealt with before SEM analyses. The procedure of expected maximization method of imputation (Olinsky, Chen & Harlow, 2003; Schafer, 1997) was implemented in this study using the LISREL software.

Measurement issues also have to be addressed before SEM analyses. The two latent variables of mathematics and science achievements in this study were set related, as were the two latent variables of mathematics and science self-confidences, according to suggestions from the research on the I/E model. The two negatively worded items for mathematics self-confidences and those for science self-confidences were set correlated in order to increase the degrees of the goodness of fit to the measurement model. Similar procedures were used by Marsh (1994). The Cronbach's alpha coefficients were calculated for each separate country as the indicators of internal consistency reliability (not shown here). These alpha coefficients were consistently very high for mathematics achievement ($M = 0.95$, $\mathrm{SD} = 0.03$)

and science achievement ($M = 0.95$, SD = 0.02) and acceptably high and varied across countries for mathematics self-confidence ($M = 0.69$, SD = 0.15) and science self-confidence ($M = 0.67$, SD = 0.14).

The results of both the student-level and three-level CFA for the total group sample verified a clear structure of four latent factors (i.e. the four sets of indicators: mathematics self-confidence, science self-confidence, mathematics achievement, and science achievement), with all the values of CFI and NNFI larger than 0.900 and the RMSEA values smaller than 0.100 (TG1 and TG2 in Table 1). In contrast, the results of multigroup CFA showed a poor fit: (1) All of the RMSEA values were larger than 0.100. (2) The values of CFI and NNFI were smaller than 0.900 when the construct intercept terms and the uniqueness were not set freely estimated (cf. MG1–MG5 of Table 2 in Chiu (2008)). The results reveal that the construct validity of the items are a good fit to the total world sample, but not when we take account of the variation of countries.

Results

Research question 1 has been answered by Chiu (2008), which successfully extends the I/E model from the relatively different domains of mathematics and verbal skills to the relatively similar domains of mathematics and science. Her results show that the I/E model is generally supported for the domains of mathematics and science across 28 countries. As such, some findings from Chiu (2008) are used to answer Research question 1 and compared with the findings obtained from answering Research question 2, which is only addressed in the present study.

Single and Three-Level SEM

The data of the total student sample ($N = 144{,}069$) as a whole were used to examine the skill development model (or the I/E model) and the self-enhancement model (or the E/I model) across mathematics and science (Figure 1) by the use of single-level SEM and three-level SEM, respectively. The results of the analyses indicated that the obtained parameter estimates were a good fit to the data, as can be seen by their respective fit indexes, with the values of CFI and NNFI all above 0.900 and those of RMESA all below 0.10 (cf. the TG1–TG2 of Table 2 in Chiu (2008) for the I/E model and TG3–TG4 of Table 1 here in the present study for the E/I model).

The path coefficients obtained from the total group SEM analysis based on the I/E model were consistent with its predictions (diagram A in Figure 1), with two negative cross-domain paths (−0.49 and −0.15) controlling for two positive matching domain paths (0.20 and 0.34; Table 1 in Chiu, 2008). However, the results for the E/I model were inconsistent with the predictions. Both the matching domain and cross-domain paths should be positive according to the predictions of the E/I model (diagram B in Figure 1), but here, an unusual pattern was obtained, with the two paths leading from mathematics self-confidence being positive (0.21 and 0.07) and those leading from science self-confidence being negative (−0.29 and −0.10).

The factor loadings of the 18 items and the matrix of the variance–covariances between the factors based on the I/E model were the same as those based on the E/I model. The factor loadings of the ten items of the mathematics and science achievements (MAch1–MAch5 and SAch1–SAch5) were consistently very high (above 0.90), those of the four positively worded items of self-confidences (MSC1, MSC2, SSC1, and SSC2) were high (above 0.71), and those of the four negatively worded items ((MSC1, MSC2, SSC1, and SSC2) were slightly low (0.29–0.40; Table 1 in Chiu, 2008).

Multigroup SEM

Multigroup SEM was used to examine whether the obtained parameter estimates were invariant across the 28 countries based on the I/E model (MG6–MG10 of Table 2 in Chiu, 2008) and the E/I model (MG1–MG5 of Table 1 here in the present study). The results of the analyses based on the models with all parameters being set invariant (MG10 in Chiu and MG5 in Table 1) and those with only the uniqueness being set freely estimated (MG 9 in Chiu and MG4 here) across the countries revealed that the models were a poor fit to the data (CFI and NNFI $<$ 0.900, RMSEA $>$ 0.100). The models with at least the uniqueness and the construct intercept terms being set freely estimated across the countries (MG6–MG8 in Chiu and MG1–MG3 here) were still not acceptable, with the value of RMSEA being larger than 0.100, although the values of CFI and NNFI are larger than 0.900.

The parameter estimates obtained from the multigroup SEM based on stricter models (i.e. MG9–MG10 in Chiu, 2008 and MG4–MG5 here) were the same as those obtained from the total group SEM (TG1–TG2 in Chiu, 2008 and TG3–TG4 here), except for the estimates of uniqueness (cf. Table 1 in Chiu, 2008 and the *single*- and *three-level SEM* shown in

"Results" here). For the less strict models (i.e. MG6–MG8 in Chiu, 2008 and MG1–MG3 here), both the predictions of the I/E and the E/I models were supported. To take MG8 in Chiu (2008) and MG3 here as examples (Table 2), the coefficients of the cross-domain paths based on the I/E model were all negative and small (−0.05 and −0.09) and those based on the E/I model were all positive, with the coefficient of the path leading from mathematics self-confidences (0.20) being larger than that leading from science self-confidences (0.07).

Since the multigroup SEM analyses did not generate desirable results of a fit to the models, it was reasonable to use the procedure of loose cross-validation whereby the data of each separate country were examined based on the proposed models (Chiu, 2008; Hair et al., 2006). As such, the proposed two models (Figure 1) were examined for the 28 countries, respectively, as follows.

Two-Level SEM for Each Country

The data of each separate country were investigated for their goodness of fit to the I/E model and the E/I model, respectively, using the two-level SEM. The results revealed that the obtained parameter estimates were a good fit to the data (all CFI and NNFI > 0.900 and RMSEA < 0.100; Table 3 in Chiu, 2008 for the I/E model and Table 3 here for the E/I model). All the matching domain paths were positive, which was consistent with both the predictions of the I/E and E/I models. The two mean cross-domain path coefficients of the 28 countries based on the I/E model were negative (−0.07 and −0.06), with a small difference between the two mean coefficients, and those based on the E/I model were positive (0.19 and 0.06), with the path leading from mathematics self-confidence being larger than that leading from science self-confidence. This result was also consistent with the predictions of both the I/E and the E/I models.

Furthermore, the percentage of the countries with an orientation of complete contrast (two negative non-matching domain paths) or partial contrast (one negative and one non-significant non-matching domain paths) was 50% (14/28) for the results based on the I/E model and 5% (1/28) for the results based on the E/I model (cf. the last two columns of Table 3). On the other hand, the percentage of countries with an orientation of complete integration (two positive non-matching domain paths) or partial integration (one positive and one non-significant non-matching domain paths) was 25% (7/28) for the results based on the I/E model and 75% (21/28) for the results based on the E/I model. It is clear that most countries carried out a contrasting process in the form of the I/E model and an integrating process in

TABLE 2

Selected parameter estimates obtained from multigroup SEM analyses based on the I/E and E/I models

	The I/E model				*The E/I model*			
Factor	*MAch*	*SAch*	*MSC*	*SSC*	*MAch*	*SAch*	*MSC*	*SSC*
Factor loading								
MAch1	0.63				0.63			
MAch2	0.57				0.57			
MAch3	0.64				0.64			
MAch4	0.60				0.60			
MAch5	0.59				0.59			
SAch1		0.63				0.63		
SAch2		0.65				0.65		
SAch3		0.61				0.61		
SAch4		0.63				0.63		
SAch5		0.62				0.62		
MSC1			0.66				0.66	
MSC2			0.66				0.66	
MSC3			0.47				0.47	
MSC4			0.56				0.56	
SSC1				0.65				0.65
SSC2				0.65				0.65
SSC3				0.40				0.40
SSC4				0.49				0.49
Path coefficient								
MAch							0.44	0.07
SAch							0.20	0.27
MSC	0.53	−0.09						
SSC	−0.05	0.37						
Variance–covariance								
MAch	1.00				1.00			
SAch	0.71	1.00			0.71	1.00		
MSC	0.46	0.29	1.00		0.46	0.29	1.00	
SSC	0.21	0.33	0.33	1.00	0.21	0.33	0.33	1.00

All parameter estimates are common metric standardized solutions. The solutions for the I/E model are based on the MG8 of Table 2 in Chiu (2008), and those for the E/I model are based on the MG3 of Table 1 in the present study. Uniqueness is freely estimated for each country and so is not presented

MAch mathematics achievement, *SAch* science achievement, *MSC* mathematics self-confidence, *SSC* science self-confidence

the form of the E/I model. The results obtained from the loose validation analyses (Table 3 in Chiu, 2008 for the I/E model and Table 3 here for the E/I

TABLE 3

Goodness-of-fit indexes and selected parameter estimates obtained from two-level SEM per country based on the E/I model and the C/I situations for the E/I and I/E models

		E/I								*C/I*	
		Path coefficient				*Goodness of fit*					
Country	***N***	*MSC to MAch*	*MSC To SAch*	*SSC to MAch*	*SSC To SAch*	$\chi^2(316)$	*CFI*	*NNFI*	*RMSEA*	*E/I*	*I/E*
Australia	4,791	0.56	0.33	*0.01*	0.21	5,593.652	0.984	0.984	0.059	PI	C
Bahrain	4,199	0.53	0.26	0.05	0.25	5,816.738	0.975	0.975	0.064	I	PI
Botswana	5,150	0.20	−0.08	0.04	0.29	7,982.960	0.961	0.962	0.069	CI	C
Chile	6,377	0.40	0.25	−0.02	0.13	8,768.572	0.976	0.977	0.065	IC	PC
Taiwan	5,379	0.60	0.40	*0.01*	0.21	8,322.644	0.982	0.982	0.069	PI	PC
Palestinian Nat'l Auth	5,357	0.42	0.19	0.18	0.39	5,456.271	0.984	0.984	0.055	I	I
Ghana	5,100	0.15	*−0.02*	0.32	0.50	6,302.760	0.966	0.967	0.061	PI	I
Hong Kong	4,972	0.46	0.20	−0.07	0.22	6,069.084	0.981	0.982	0.061	IC	C
Islamic Republic of Iran	4,942	0.44	0.20	0.07	0.24	6,075.221	0.975	0.976	0.061	I	PI
Israel	4,318	0.49	0.30	0.10	0.31	6,611.343	0.979	0.980	0.068	I	CI
Italy	4,278	0.51	0.30	0.03	0.21	4,972.958	0.982	0.983	0.059	I	N
Japan	4,856	0.51	0.21	0.08	0.37	7,087.797	0.977	0.977	0.066	I	N
Jordan	4,489	0.41	0.15	0.18	0.42	5,142.093	0.983	0.984	0.058	I	I
Republic of Korea	5,309	0.62	0.32	0.08	0.36	4,535.453	0.990	0.990	0.050	I	N
Malaysia	5,314	0.62	0.24	−0.21	0.18	8,875.608	0.970	0.971	0.071	IC	C
Morocco	2,943	0.27	*0.02*	0.06	0.26	3,662.145	0.967	0.968	0.060	PI	PI

New Zealand	3,801	0.52	0.23	0.06	0.31	5,659.296	0.978	0.979	0.067	I	C
Norway	4,133	0.66	0.39	*−0.01*	0.23	5,090.455	0.982	0.983	0.061	PI	CI
Philippines	6,917	0.18	−0.12	−0.06	0.21	7,724.141	0.976	0.977	0.058	C	C
Saudi Arabia	4,295	0.38	0.11	*0.03*	0.26	4,228.629	0.972	0.973	0.054	PI	N
Singapore	6,018	0.42	0.18	*0.01*	0.25	7,896.793	0.982	0.983	0.063	PI	C
South Africa	8,952	0.15	*−0.02*	*−0.01*	0.14	10,131.366	0.978	0.978	0.059	N	C
Syrian Arab	4,895	0.34	0.12	−0.04	0.14	4,929.909	0.971	0.972	0.055	IC	PC
Tunisia	4,931	0.45	0.22	0.04	0.30	4,902.393	0.969	0.970	0.054	I	PC
Egypt	7,095	0.44	0.26	0.24	0.41	8,291.095	0.984	0.984	0.060	I	I
USA	8,912	0.45	0.25	0.18	0.31	10,771.087	0.984	0.984	0.061	I	C
England	2,830	0.41	0.19	0.11	0.32	2,867.597	0.986	0.986	0.053	I	C
Scotland	3,516	0.40	0.18	0.23	0.42	3,061.461	0.989	0.989	0.050	I	IC
M		0.43	0.19	0.06	0.28						
SD		0.14	0.13	0.11	0.09						

The parameter estimates are common metric standardized solutions. The solutions for each separate country are obtained from a two-level SEM analysis. The italicized estimates are not significant at the 0.05 level. The goodness-of-fit indexes and selected parameter estimates obtained from two-level SEM per country based on the I/E model can be found in the Table 3 of Chiu (2008)

C/I contrasting/integrating (*PC* partial contrasting, *PI* partial integrating, *N* neither contrasting nor integrating), *CFI* comparative fit index, *NNFI* non-normed fit index, *RMSEA* root mean square error of approximation, *MAch* mathematics achievement, *SAch* science achievement, *MSC* mathematics self-confidence, *SSC* science self-confidence model) supported the predictions of the I/E and the E/I models more than those obtained from the single-level analyses (cf. the *single-* and *three-level SEM* shown in "Results") or the multigroup analyses (cf. the *multigroup SEM* in "Results"), as indicated by the fit indexes (Table 1) and the parameter estimates. Thus, most of the following discussion will focus on the results obtained from the analysis of the data in this section.

Discussion

Past studies on mathematics and science education generally focus on their own domains for the relations between self-confidences and achievements even when cultural backgrounds are considered (Papanastasiou & Zembylas, 2004; Wang, 2007). In the present study, the juxtaposition of the skill development and self-enhancement models across the domains of mathematics and science has broadened our understanding of the cross-domain relationship between self-confidences and achievements. In addition, the differential national variations between the skill-development model and the self-enhancement model suggest that the two models are different in their degrees of cultural dependence. This juxtaposition fits to the complexity of educational practices. By going beyond an affect-as-psychological perspective (in the present study) to an affect-as-social one (inference based on the present findings with assistance from relevant literature; Hannula, 2007), we are likely to generate specific suggestions for teaching practices in mathematics and science.

The Psychological Process Underlying the Skill-Development Model Across Mathematics and Science

Hypothesis 1 is supported in that both the cross-domain paths leading from achievements to self-confidences are *negative*, controlling for the two matching domain paths in statistical terms (Figure 1 and Table 2). This result is consistent with the predictions and research results of the I/E model, which views the two negative cross-domain paths as the result of a comparison based on an internal frame of reference, i.e. ipsative-like comparison (e.g. Marsh & Hau, 2004). In other words, the psychological process underlying the skill-development model is that students appear to have a tendency to compare their own mathematics and science achievements. After making this comparison, students with high mathematics achievement will lead to low science self-confidence, and students with high science achievement will lead to low mathematics self-confidence, controlling for the effect that their high mathematics (science) achievement still lead to high mathematics (science) confidence at the same time.

For educational practice, the findings suggest that students tend to enlarge the gaps between their own relative strengths in mathematics and science, which are known by students as "abilities," "achievements," "credits," "grades," "performances," and "right problem solving" (Burton, 2004; DeBellis & Goldin, 2006; Grootenboer & Hemmings, 2007). These "objective facts," provided by the educational authorities (e.g. teachers, schools, and national examination boards), serve as the major information sources for students to set the psychological boundaries for themselves by reducing a non-matching domain self-confidence.

The psychological process may result in desirable or undesirable outcomes and is worthy of consideration in the educational practice. In the negative aspect, students may have negative feelings because of a "comparison" between "the objective facts (i.e. achievements or abilities)," by which students identify their "weak" and "strong" domains, and inevitably some students will focus on the weak one (Whitebread & Chiu, 2004). In the positive aspect, students may develop a sense of unique self and use their time and effort effectively based on an understanding of their weaknesses and strengths. This may help generate a quick and creative achievement for the individual. Teachers should lead students to the positive direction and avoid the negative one.

Teachers may have to use different teaching and assessment strategies to provide students with differential messages and suggestions for their time and effort invested in weak or strong domains along the trajectory of educational development (cf. Beswick, 2005; Hansson, 2010). For instance, children at the stages of primary and early secondary education are generally expected to master all school subjects, especially mathematics and official languages, which are viewed as the basics of later studies (Whitebread & Chiu, 2004). Students at the stages of late secondary and higher education are gradually expected to master one single specific domain of knowledge. As such, primary school teachers may have to provide interesting teaching and suitable assessments (or even not to provide any norm-based assessment) in order to encourage children who dislike or are poor at mathematics to learn more basic mathematics (Brown et al., 2008; Chiu, 2009b). Teachers may also have to integrate mathematics and science (or other school subjects) in their curricula and assessments if they want students to have similarly high self-confidences and similar time and effort investment in both (all) school subjects. On the other hand, late secondary school teachers may wish to provide domain-specific teaching and norm-based assessment if their aim is to help students identify their differential abilities, build differential self-confidence, and invest different amounts of time and effort in their strong and weak domains in order to prepare their students for higher education, which is much more domain-specific.

The Psychological Process Underlying the Self-Enhancement Model Across Mathematics and Science

Hypothesis 2 is supported in that both the cross-domain paths leading from self-confidences to achievements are *positive*, controlling for the two matching domain paths. In other words, based on the psychological process of self-enhancement, (1) a high mathematics self-confidence will contribute to a high science achievement and (2) a high science self-confidence will contribute to a high mathematics achievement (Figure 1 and Table 2). Self-enhancement tends to integrate, link, or extend the strength (or weakness) of self in one domain to that in another (related) domain. Self-enhancement is a necessary ability for students to go beyond the boundaries of the domains of their knowledge and trigger the courage to try for innovations or adventures if they are aware of or reminded of their strength in one single specific domain.

Self-confidence closely relates to participation and achievement in mathematics and science learning (Brown et al., 2008; Chang & Cheng, 2008). Research on educational programs in relation to the enhancement of domain-specific self-confidences also demonstrates a positive effect of the programs on achievement (Craven, Marsh & Debus 1991; Marsh & Peart, 1988). The present finding further suggests likely increases in student learning outcomes by organizing mathematics and science classrooms into more complex systems in which mathematics and science may serve as affective and life tools for each other (Andrews & Hatch, 2000; Chiu, 2007; Davis & Simmt, 2003). There is a possibility that an increase in the self-confidence in one domain, e.g. mathematics, can contribute to achievement in a related domain, e.g. science. As such, teachers can raise students' mathematics (science) self-confidence when teaching science (mathematics) because mathematics (science) self-confidences have additional effects on science (mathematics) achievement, even controlling for the effect of matching domain self-confidences. For instance, when students need to invest their time and effort in weak domains, teachers may have to remind students of their achievement/ ability in the strong domains, which will increase students' self-confidence in their strong domains, based on which students will be much likely to take action to improve their ability in weak domains. For instance, graduate students studying genetics may need to use advanced mathematics to model the patterns of genes. The students may need courage to restudy secondary mathematics and then to study advanced mathematics based on their high confidence/ability in genetics, medicine, or biology.

National Variations on the Support for the Two Models

There are variations in the degrees of support for the two models. In other words, there are qualitative differences in the variations between the two models.

The Skill-Development Model. The skill-development model (or the I/E model) across mathematics and science is *supported* in terms of (1) the results obtained by the single-level SEM analysis for the total group (cf. the *single-* and *three-level SEM* in “Results”) and (2) the results obtained by the multigroup analyses for the less stringent models (cf. the *multigroup SEM* in “Results”). (3) However, if we let the countries state their own stories, the I/E model is completely or partially supported for only half (14 out of 28) the countries (Table 3). The ten countries completely supporting the model are Australia, Botswana, Hong Kong, Malaysia, New Zealand, the Philippines, Singapore, South Africa, the USA, and England. The four countries partially supporting the model are Chile, Taiwan, Syrian Arab, and Tunisia. The results from the data for Palestinian Nat’l Auth, Ghana, Jordan, and Egypt are far from supporting the predictions of the I/E model in that each showed two positive cross-domain paths. The above three findings are interpreted as follows.

For the first finding, the generalizability of the I/E model has been largely confirmed by the single-level and multigroup SEM analyses over 26 countries across the domains of mathematics and verbal skills (Marsh & Hau, 2004). Similar findings are found in Chiu’s (2008) study, also discussed in the presented study, for the domains of mathematics and science. The psychological process of a comparison between achievements in different domains of knowledge is likely to be a phenomenon based on some generalizable aspect of behavior common to human beings, i.e. a tendency to compare achievements between different domains. The above seemingly common phenomenon among human beings, however, turns into a different picture if we take into account cultural differences.

The second finding based on multigroup analyses suggests that there are differences between the 28 countries in their achievements and interpretations of the questionnaire items on self-confidences, and the third finding indicates that only half of the 28 countries support the model. An interesting question may be: Why does the result based on the total sample (the first finding) support the skill-development model, but only half of the countries support it? The answer may be that all people as a whole are not equal to the sum of all countries. This issue may be further addressed based on the interpretation of the second and third findings and their methodologies, respectively, as follows.

Based on the second finding and methodology, if we use a global frame but take into account national differences, then we will see that there are significant differences between the 28 countries in mathematics and science achievements and in mathematics and science self-confidences (Martin et al., 2004; Mullis et al., 2004). In addition, high-achieving countries may have lower self-confidences in mathematics and sciences than low-achieving ones (Papanastasiou, 2002). This is an issue of national differences in measurements.

Based on the third finding and methodology, if we use a local (national) frame, the global result/trend is not necessarily transferrable to each country as group effects may intervene in the psychological process of the skill-development model. For instance, students in some countries may not pay much attention in distinguishing differences in achievements between mathematics and science, which may be a reflection of teaching and learning styles, and the curriculum and examination systems in a country (Boaler, 1998; Chiu, & Whitebread, 2011; McCaffery et al., 2001). This is beyond the scope of the present study; future research taking a sociocultural approach can delve into this issue further.

Consistent with results of past research on the I/E model, Australia, Hong Kong, New Zealand, and the USA are the countries showing best support for the I/E model, though the present study focuses on the domains of mathematics and science and past research on those of mathematics and verbal skills (e.g. Marsh & Hau, 2004; Möller et al., 2009). The I/E model are also completely supported for the data from Botswana, England, Malaysia, Philippines, Singapore, and South Africa and partially supported for those from Chile, Taiwan, Syrian Arab, and Tunisia in the present study. This has extended the I/E model to some more cultures.

The Self-Enhancement Model. Three major findings are also obtained regarding the self-enhancement model (or the E/I model) across mathematics and science in the present study. (1) The model is *not supported* by the results obtained by the SEM analysis at the single level using the total student sample as a whole, as indicated by the parameter estimates of the cross-domain paths (cf. the *single-* and *three-level SEM* in "Results"). (2) The model is *supported* in terms of the results obtained by the multigroup analyses for the less stringent models, as shown by the fit indexes (Table 1) and the path coefficients (Table 2). (3) The model is generally supported by the two-level analysis for each separate country, as indicated by the fit indexes and the fact that the E/I model is completely or partially supported for most (21 out of 28) countries (Table 3). The 14 countries completely supporting the model are Bahrain, Palestinian Nat'l Auth, Islamic Republic of Iran, Israel, Italy, Japan, Jordan, Republic of Korea, New Zealand, Tunisia, Egypt, the USA, England, and Scotland. The seven countries partially supporting the model are Australia, Taiwan, Ghana, Morocco, Norway, Saudi Arabia, and Singapore. The results for the Philippines are far from supporting the predictions of the E/I model in that they show two negative cross-domain paths (Table 3). The dichotomy of individualist and collectivist countries, though much researched (e.g. Cai et al., 2007; Kurman & Sriram, 2002), does not appear to be a critical reason for the national differences observed in the present study. The above three findings are interpreted and compared with the results for the skill-development model as follows.

The first finding indicates that the self-enhancement model fails to be supported for the data of all the students in the world sample as a whole. The result suggests either that the model fails to fit the data or that some significant moderators, e.g. countries, fail to be taken into account.

The second finding obtained by multigroup analyses indicates that students from different countries differ in their achievements and interpretations of the items on self-confidences. This second finding is the same as the second finding for the skill-development model. This result is reasonable as the measurement items used for examining the two models are the same.

The third finding suggests that most countries fit the prediction of the E/I model if we let each country tell its own story. In other words, students from most countries can self-enhance across the domains of mathematics and science, controlling for self-enhancing the same domains, i.e. high mathematics/science self-confidences leading to high mathematics/science achievement. Research has indicated that self-enhancement is influenced by cultural values (e.g. Kurman, 2003). The pattern of cultural values may be different across countries. It appears to be improper to use the aggregate data of all students from different countries in a single-level SEM analysis for the E/I model. To compare the first and third findings between the skill development and self-enhancement models, we may infer that the skill-development model appears to be more a pan-cultural phenomenon by nature, while the self-enhancement model tends to be more a cultural-dependent phenomenon by nurture. Future research can examine this proposition.

Past psychological research on self-enhancement suggests that Westerners may self-enhance more than Easterners, which, however, appears not to be supported by the present findings. The countries completely or partially supporting the self-enhancement model in the present study include both Western (e.g. the USA) and Eastern (e.g. Japan, Republic of Korea, Taiwan, and Singapore) countries, indicated by past psychological studies on self-enhancement (e.g. Chang & Asakawa, 2003; Hamamura et al., 2007). The dichotomy of Westerners and Easterners appear to fail to be an effective moderator for the self-enhancement model.

A final note to make is that only three countries, New Zealand, the USA, and England, completely support the predictions of both the skill development model and the self-enhancement model. The three countries are typical English-speaking ones in the world (Australia, another English-speaking country, nearly supports the two models). A theory-driven study, like the present study, may have this embedded limitation: The two models originated in the English-speaking culture and, thus, may be best evidenced in the same culture (Green et al., 2006). Future qualitative studies are needed to develop an in-depth understanding of the meanings of the two models in different cultures. Unique theories are likely to emerge based on this understanding.

Limitations of the Present Study and Suggestions for Future Research

The models depicted in the present study (Figure 1) suggest an evolution of reciprocal relations between self-confidences and achievements over time. The data used here, however, are obtained from one wave of data collection, as provided by the TIMSS, which actually presents a static picture of relations between self-confidences and achievements in a particular time. Future research can use longitudinal data to address the issue of evolution of relations between self-confidences and achievements in a much valid way, although SEM can formulate causal relations, effects, and paths in statistical terms, as performed in the present study.

Cross-cultural studies normally have difficulty in achieving a measurement of equivalence, especially scalar equivalence, i.e., equivalent means across countries (Van de Vijver & Leung, 2000), which is also found in the present study. Caution should always be exercised when statistical analysis uses aggregate data from different countries or cultures as the explanations of the measured constructs are very likely to differ for people from different countries or ethnic backgrounds.

One of the major focuses of the present study is on cross-domain relations between self-confidences and achievements, which has not normally been a focus in past research on academic self-confidences. Cross-domain learning appears to be a promising area of research at this time in that it emphasizes authentic and creative learning beyond the boundaries of the domains of knowledge. An extension of the two models to other domains, e.g. mathematics vs. verbal skills, can produce further elaboration of the conceptions of the psychological processes underlying the skill-development and self-enhancement models across domains.

The reasons for the national differences in the fit to the two models appear to be of interest. The nature of the specificity of national curricula, pedagogical approaches, calculator and computer use, teacher education and certification, and mathematics and science topics, as surveyed by the questionnaires of the TIMSS in 2003, may play a role in the specific patterns of the models concerning the relation between academic self-confidences and achievements across domains. Future case studies can address this issue in depth based on the unique characteristics of particular nations; for example, the connections between mathematics and science may be stronger in a country where mathematics and science are taught by the same teachers, for which the generalization of the posited models may need to be examined. Furthermore, the relation between the patterns of the models and those of national specificity may be quantified when the sample size of nations is large enough for statistical analysis.

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