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Self-Concept and Mathematics Achievement:

Modeling the Relationship under the Language Pressure in Hong Kong*

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Abstract

Located at a meeting place between the West and the East, Hong Kong has been chosen in this comparative investigation to reconfirm a theoretical model of *reciprocal relationship* between mathematics achievement and self-concept using the 8th grade databases from TIMSS and TIMSS-R. During the time between these two projects, Hong Kong experienced a political transition in 1997 to switch from a British colony to a special administrative region (SAR) of China. Pertinent indicators have been selected to reflect key educational changes during the sovereignty handover. Results from this large-scale data analysis may not only help generalize the reciprocal model in a different culture setting, but also facilitate assessment of educational adjustment brought by the political transition.

Self-Concept and Mathematics Achievement:

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Student achievement in mathematics has been an important variable examined in several comparative projects, including the Third International Mathematics and Science Study (TIMSS) in 1995 and a repeat of TIMSS (TIMSS-R) in 1999. On the other hand, mathematical self-concept represents student perception or belief in self-ability to do well in mathematics, and is recognized as a key component of mathematical literacy (NCTM, 1989). A *reciprocal effects* model suggests that academic achievement and self-concept are mutually reinforcing, and changes in academic self-concept can lead to changes in academic achievement or vice versa (Marsh, Byrne, & Teung, 1999). Marsh, Hau, and Kong (2002) observed, "despite some apparent exceptions, the results of previous research provide general support for a reciprocal effects model" (p. 730).

As a basic subject taught in almost all schools, mathematics is an appropriate subject to examine the reciprocal model using an international database. Despite similarities in mathematical symbols, cultural factors need to be considered when investigating mathematics education in an oriental context (Wilkins, 2003). In particular, Holliday and Holliday (2003) noted, "language is an important cultural factor when comparatively assessing students who speak, read, write, and listen using entirely different communication system" (p. 252). In Hong Kong, shortly after termination of its British colony status in 1997, a policy change has been made to switch the language of instruction from English to Chinese in most secondary schools (Evans, 2000). Accordingly, the status of English language has been included in this investigation to examine the relationship between student self-concept and mathematics achievement. Hau, Kong, Marsh, and Cheng (2000) observed, "Hong Kong is an ideal setting

for testing the juxtaposition of self-concept in native and nonnative languages as both Chinese (the native language) and English (the non-native language) are considered extremely important in the high school curriculum and society" (p. 5).

Literature Review

In an attempt to connect self-concept with academic achievement, Shavelson, Hubner, and Stanton (1976) developed a multifaceted, hierarchical model from an extensive literature review. Apex of the hierarchical structure is first split into academic and nonacademic components of self-concept. Thus far, the existing literature seemed to suggest conflicting findings between self-concept and student achievement across nations. For instance, Wilkins, Zembylas, and Travers (2002) analyzed the TIMSS data, and found a positive relationship between self-concept and mathematics achievement for 16 different countries. However, Kifer's (2002) analysis indicated that many of the highest performing countries had some of the lowest overall beliefs in student self-ability. In addition, Marsh et al. (2002) pointed out, "Previous research suggests that Chinese students differ from Western students in ways that may be relevant to how they construct their self-concepts" (p. 728). Therefore, the cultural contexts are important in disentangling relationship between academic self-concept and school achievement.

To date, besides a couple articles developed by Marsh and his colleagues (i.e., Hau, Kong, Marsh, & Cheng, 2000; Marsh, Hau, & Kong, 2000 & 2002), few other researchers examined the relationship between self-concept and mathematics achievement in Hong Kong. The data analyzed by Marsh and his colleagues were gathered from 56 high schools under guidance of Hong Kong's Educational Commission in 1995, an era before the sovereignty switch (see Marsh, Hau, & Kong, 2000, p. 311).). Yip, Tsang, and Cheung (2003) observed, "A problem with the design of the Marsh et al. study, which might affect the validity of data

interpretation, is that many of the so-called English-medium schools used Chinese or mixed code for instruction, so only a small number of the EMI [English Medium Instruction] were truly English medium" (p. 303). House (2000, 2003) noted value of TIMSS in investigating motivation and achievement factors, yet no measurement model was developed from his studies to identify the latent construct of self-concept, and no TIMSS-R data were incorporated to compare the relationship between mathematics achievement and self-concept during Hong Kong's political transition.

A long-term effort has been made by researchers to identify the self-concept construct. The existing literature suggested two major aspects of self-concept, i.e., "the self as a doer" and "the self-as-object" (see Hamachek, 2000; James, 1898). Wilkins (2003) took an approach of "the self as a doer" to choose a single item, "I usually do well in mathematics", in his TIMSS data analysis (p. 7). According to Schumacker and Lomax (1996), "Today, it is commonly accepted that multiple observed variables are preferred over a single variable in defining a latent variable" (p. 55). To incorporate multiple indicators, more investigations are needed to include both aspects of the self-concept factor.

In the past, researchers also agreed on existence of a linkage between instructional language and mathematics instruction (e.g., Cambourne & Turbill, 1990; Flores, 1997; Hirigoyen, 1997; Mirra, 2001). Monroe (1996) cautioned, "When we separate mathematics from its language context, we also miss valuable opportunities to use the child's language as a tool for evaluating progress and diagnosing strengths and needs" (p. 370). To take advantage of the mother-tongue development, "a substantial proportion of schools which claimed to teach in English actually taught either in Cantonese or in mixed code" (Bray, 1997, p.162-163).

Accordingly, the TIMSS and TIMSS-R projects gathered student responses on the importance of using English as perceived by self, friends, and mothers (Supplement 2 of the TIMSS User Guide, section 1). These perceptions can be examined to compare the push for English medium instruction before and after the political transition in Hong Kong. While English might represent a legacy of British colonialism for some Hong Kong residents, the community as whole still relies on English communications to maintain its cosmopolitan status in the world of trade and business (Bray, 1997).

Bilingual educators have discussed the choice of instructional language extensively in the western literature. Researchers generally believe that mother-tongue instruction facilitates protection of student culture heritage, especially for minority groups (see Cummins, 1996; Flores, 1997; Garcia, 1993; Krashen, 1997).). In Hong Kong's context, this assertion seems to support instruction in Chinese. Nonetheless, the consideration of preserving a minority culture is less relevant in Hong Kong because Chinese accounts for more than 98% of the population, and nearly all children receive their primary education in Chinese. In secondary schools, the late-immersion in English instruction has a strong support from many Hong Kong parents (Evans, 2000). After the political transition, instruction in English is provided in a small portion of elite schools. Because of stronger motivation associated with the elite status, it remains to be seen whether the western literature on second language instruction fit the specific situation in Hong Kong.

In summary, this investigation features confirmatory and exploratory components. On the confirmatory side, Marsh et al. (1999) called for further research to examine cultural differences in the evidence for the reciprocal effects model. This study is designed to verify that model in an oriental culture. On the exploratory side, the medium of instruction has been

incorporated in this study, which is particularly pertinent to Hong Kong's situation during the political transition. To date, the TIMSS and TIMSS-R data are yet to be investigated on this dimension. It would be interesting to check if the reciprocal model can be reconfirmed using the TIMSS and TIMSS-R data during the era of political change in Hong Kong.

Research Questions

The National Council of Teachers of Mathematics (NCTM) has recommended that the mathematics curriculum include development of language and symbolism to communicate mathematical ideas and relations (Kolstad & Briggs, 1996). The link between instructional language and mathematics is particularly important in Hong Kong because English has been a second language for majority of Hong Kong students. Given the focus on student learning within a school setting, score variance is partitioned at the student and school levels to facilitate result generalization across the school settings (Marsh, Hau, & Kong, 2002; Wilkins, 2003). Accordingly, research questions that guide this investigation are:

1. What proportion of the variance in mathematics achievement has been distributed at the student and school levels?

2. What is a plausible model of student self-concept and mathematics achievement under the context of reforming English role in instruction during the political transition?

3. What are differences and/or similarities of the empirical model reconfirmed by the TIMSS and TIMSS-R data analyses?

Methods

Variable Selection

To reduce student test burden, each student was tested on a subset of test items at the 8th

grade level in TIMSS and TIMSS-R. As a result, a total of five plausible scores have been

imputed to represent the overall student achievement in mathematics. To enhance comparability

between the TIMSS and TIMSS-R results, TIMSS scores in 1995 have been rescaled using the

TIMSS-R procedure in 1999, and the corresponding data are released at a website

(http://www.timss.org). Gonzalez and Smith (1997) noted, "one set of the imputed plausible

scores can be considered as good as another" (ch. 6, p. 3). On basis of the imputed scores, the

TIMSS and TIMSS-R data are employed in this study to analyze student achievement in

mathematics.

In line with the research literature on self-concept identification (Hamachek, 2000;

James, 1890), indicator variables have been chosen from TIMSS and TIMSS-R to reflect (1)

students' their feeling of getting bored by mathematics and (2) "Students' self-perceptions about

usually doing well in mathematics" (Supplement 2 of the TIMSS User Guide, section 1, p. 8). In

addition, students also reported importance of learning English as perceived by self, friends, and

mothers. Thus, the push for English acquisition can be examined before and after the political

transition.

Statistical Modeling

While variables of self-concept and mathematics achievement were measured at the

student level, their relationship could have been influenced by school characteristics. In a

homogeneous school setting, for instance, variation at the school level could be too small to

account for differences in student performance. Therefore, it is prudent to partition the score

variance at student and school levels (Question 1), and assess the feasibility of generalizing

research findings across different schools. The SAS PROC MIXED program is used for the

variance partition.

The medium of instruction is an important issue related to mathematics education (Evans, 2002).   Accordingly, the English push from self, friends, and mothers should be incorporated in this investigation (Question 2). The use of multiple indicators permits an assessment of measurement errors, and hence, goodness-of-fit indices can be computed to reconfirm fitness of the reciprocal model to the TIMSS and TIMSS-R databases (Question 3). To facilitate interpretation of the research findings, these indicator variables have been scaled in such a way that a higher value represents a more positive response in each dimension. The LISREL software is employed to handle the statistical computing.

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Results

The multilevel analysis revealed that score variances were much smaller at the school level than at the student level (Table 1).

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Goodness of fit indices is listed in Table 2 to assess plausibility of fitting the reciprocal model (Figure 1) to the TIMSS and TIMSS-R databases.

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Table 3 contains parameter estimates for the reciprocal model in Figure 1 using the TIMSS and TIMSS-R databases. The sample sizes involved in this data analysis is 6567 for TIMSS and 5124 for TIMSS-R with a data-retaining rate above 90%.

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The effect sizes of the structural relationships before and after Hong Kong's political

transition are presented in Table 4 to compare the model difference.

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Discussion

Mathematics is a subject chosen in this investigation to examine relationship between

students' self-concept and achievement under a context of promoting mother-tongue instruction

in Hong Kong. To reflect educational changes in this conjecture, multiple indicators from the

TIMSS and TIMSS-R data are employed to measure mathematics achievement, self-concept, and

English pressure as perceived by students, peers, and mothers (Figure 1). Because similar

sampling strategies and data collection techniques have been used in these two projects, results

of the data analyses can be compared to reflect changes during the political transition.

Factor loadings are primary statistics that represent simple correlations between

indicators and latent factors (Sharma, 1996). The similar factor loadings ($\lambda_{y1} ... \lambda_{y5}$) from

TIMSS or TIMSS-R confirm equivalency of the plausible scores in representing student

achievement in mathematics (Gonzalez & Smith, 1997). Moreover, Table 3 indicates a decrease

of the factor loadings from .96 in TIMSS to around .92 in TIMSS-R. Although the gap was not

large, one might still speculate contextual factors that caused such a decrease in TIMSS-R.

"Hong Kong is essentially a mono-lingual society in which Chinese (spoken Cantonese and written Chinese) is used in the home, community, the world of work and the media. English, while important, is restricted to uses within the government, in the law courts and in academic, commercial and financial fields and, as such, it is an 'auxiliary' language'" (Tao, 1994, p. 323). Hong Kong teachers used to adopt both English and Chinese languages in their classroom discourse, creating a mixed-code instruction to facilitate content explanation (Bray, 1997; Lin, 1990; Pennington, 1995, 1999). The mixed-code instruction has somehow blurred the difference between English- and Chinese-medium schools. After the sovereignty handover, it was stipulated in a new policy that "most school should adopt Chinese for teaching all academic subjects" (Evans, 2000, p. 185). The school language tracking might have restricted the mixed-code instruction, and added a confounding variable to sharpen the contrast among schools. In part because of this additional variation after the political transition, slightly lower factor loadings were observed in the TIMSS-R results (Table 3).

Hong Kong has an urban environment with Chinese accounting for 98% of the population, and a strong commitment to child education, as part of Chinese tradition, is commonly shared in almost all families. Therefore, there is little variation in terms of the urban community status, ethnic background, and parental support for education. In addition, "Unlike the case in the UK, there is no official classification of social class in Hong Kong" (Lai, 2001 p. 115). Under a "one China, two-system" policy, no substantial changes happened on these homogeneous conditions, which helped explain the small factor loading ($\lambda_{y1} ... \lambda_{y5}$) difference between TIMSS and TIMSS-R (Table 3). Partition of the score variance also confirmed that the variability was much smaller at the school level than at the student level (Table 1). In addition,

along with the separation schools in terms of their language of instruction, the new Hong Kong

policy seemed to have contributed to the increase of school-level variability in TIMSS-R.

To identify the construct of self-concept, factor loadings (λ_{y6} and λ_{y7}) are presented in

Table 3 for the two indicators depicted in Figure 1. From the doer's perspective, mathematical

skills are useful, and can be applied to other subject areas. On the other hand, in reaction to

mathematics learning, students also expressed their feeling on whether the subject itself is

boring. The data analyses show similar factor loadings (λ_{y6} and λ_{y7}) on both sides from the

TIMSS data analysis (Table 3). However, the TIMSS-R data seemed to suggest a higher factor

loading for the doer's perspective. Besides more emphasis on mathematical reasoning and

applications advocated by some mathematics educators (e.g., Lee & Heyworth, 2000; Mok &

Johnson, 2000), it seemed far-fetched to link this result to political transitions in Hong Kong.

After the sovereignty switch in 1997, Evans (2000) noted that the most dramatic change

in education was implementation of the new language policy in secondary school. Nonetheless,

the impact at an individual level is hinged on perceptions of students and those who had

influence on students. In this study, the perceived importance of English by mothers, peers, and

self has been used to indicate the English push factor (Figure 1). As a result, the self-perspective

had a higher factor loading (λ_{x3}) in the construct identification than the perspectives of peer (λ_{x2})

and mother (λ_{x1}) (Table 3). In part, this was because all those perspectives were gathered from

student surveys. Whereas students could directly report their self-perspectives, the position of

their peers or mothers was speculated through student reporting. In line with this arrangement,

the pattern of $\lambda_{y10} > \lambda_{y8}$ and $\lambda_{y10} > \lambda_{y9}$, suggested that identification of the English push factor

relied more on the direct indicator from students themselves and less on the mother and peer

positions perceived by students (see Table 3).

Despite the adjustment of education policy on instructional language after the sovereignty handover, the four-year gap between TIMSS and TIMSS-R might be too short to change the general school culture. For this reason, the small effect sizes in Table 4 confirmed little change in the structure of the reciprocal modal for the period of political transition. Both TIMSS and TIMSS-R results in Tables 3 and 4 indicated that the reciprocal relation between mathematics achievement and self-concept, while positive, remained weak (β=.06 ~ .07) with little change (i.e., effect size = .01). Under the intervening factor of students' perceived English push (see Figure 1), the invariably weak link could have resulted from a balance of multiple impacts in Hong Kong contexts. On one hand, instruction in English was featured in a few selected schools. The elite status may have attracted better students, and thus, strengthened the positive reciprocal link between mathematics achievement and self-concept. On the other hand, students tended to learn more effectively when taught through their mother tongue (see Cummins, 1996; Garcia, 1993). Therefore, improved mathematics achievement could occur in schools that had less English emphasis (more mother-tongue communication) in instruction, despite the fact that Chinese medium schools were not ranked as high as English-medium schools. Accompanied with the attitude against these underprivileged school settings, a negative link could have been observed between student self-concept and mathematics achievement. On balance of the relations from both sides, a weak link was found in the reciprocal model to articulate mathematics achievement and self-concept (Figure 1).

Among a variety of model fitting indices, Joreskog and Sorbom (1981) advocate the use of goodness-of-fit index (GFI) to measure the relative amount of variances and covariances commonly explained by the model. Marsh, Balla, and McDonald (1988) suggest the adoption of root mean square residual (RMR) to "justify the conclusion that a model adequately fits a

particular set of data" (p. 391). Table 2 contains GFI and RMR indices from fitting the reciprocal model with or without gender separation. The use of multiple fitting indices follows Bollen's (1989) recommendation to confirm the model-data-fit through result triangulations. To check impact of sample size on the model indexes, the RMR and GFI computing has been examined over sub-samples in male and female categories (Table 2). The small RMR and large GFI values consistently suggest a good fit of the reciprocal model to the TIMSS and TIMSS-R databases. In conclusion, this investigation is built on the existing mathematics test scores and self-concept indicators gathered in TIMSS and TIMSS-R before and after Hong Kong's political transition in 1997. During the sovereignty switch, a landmark change was promotion of mother-tongue instruction by the new Hong Kong government. To catch the key component of school change, the perceived importance of English has been included in the reciprocal model. According to Monroe (1996), "In reality, children's language and mathematics are virtually inseparable; mathematics is embedded in the language they use naturally" (p. 369). Inclusion of the language factor is crucial to verification of the reciprocal relation in the non-western culture. Given various contextual factors behind mathematics achievement and self-concept, their relationship could be positive or negative for various reasons. On balance, the author did not find a strong reciprocal relation between mathematics achievement and self-concept from analyses of the TIMSS and TIMSS-R databases. Due to the cultural differences, this result does not necessarily invalidate the existing literature on self-concept and academic achievement developed from the western nations.

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Table 1

Ratio of variances in mathematics plausible scores (PS) distributed at school and student levels[1]

Project	PS1	PS2	PS3	PS4	PS5	Mean
TIMSS	.048	.048	.049	.048	.047	.048
TIMSS-R	.086	.089	.089	.091	.087	.088

[1] The ratio is computed by dividing the partitioned score variance at the school level over the corresponding variances at the student level.

Table 2

Model fitting indices for the TIMSS and TIMSS-R databases

	TIMSS Samples				TIMSS-R Samples	
	Total	Male	Female	Total	Male	Female
RMR	0.10	0.09	0.10	0.10	0.09	0.11
GFI	0.98	0.98	0.98	0.98	0.98	0.97

Table 3

Parameter estimates for the reciprocal model using the TIMSS and TIMSS-R databases

| Estimates	TIMSS	TIMSS-R
Factor Loadings		
λ_{y1}	0.96	0.92
λ_{y2}	0.96	0.93
λ_{y3}	0.96	0.93
λ_{y4}	0.96	0.92
λ_{y5}	0.96	0.93
λ_{y6}	0.61	0.74
λ_{y7}	0.60	0.56
λ_{x1}	0.64	0.61
λ_{x2}	0.61	0.63
λ_{x3}	0.76	0.83
Reciprocal Relation		
β	0.06	0.07
Path Coefficients		
γ_1	0.30	0.32
γ_2	0.22	0.21

Table 4

Effect sizes of the structural relations from the period of Hong Kong's political transition

Structural Parameter	β	γ_1	γ_2
Effect Size	0.01	0.02	0.01

Figure 1

A Structural Model of Self-Concept and Mathematics Achievement from TIMSS
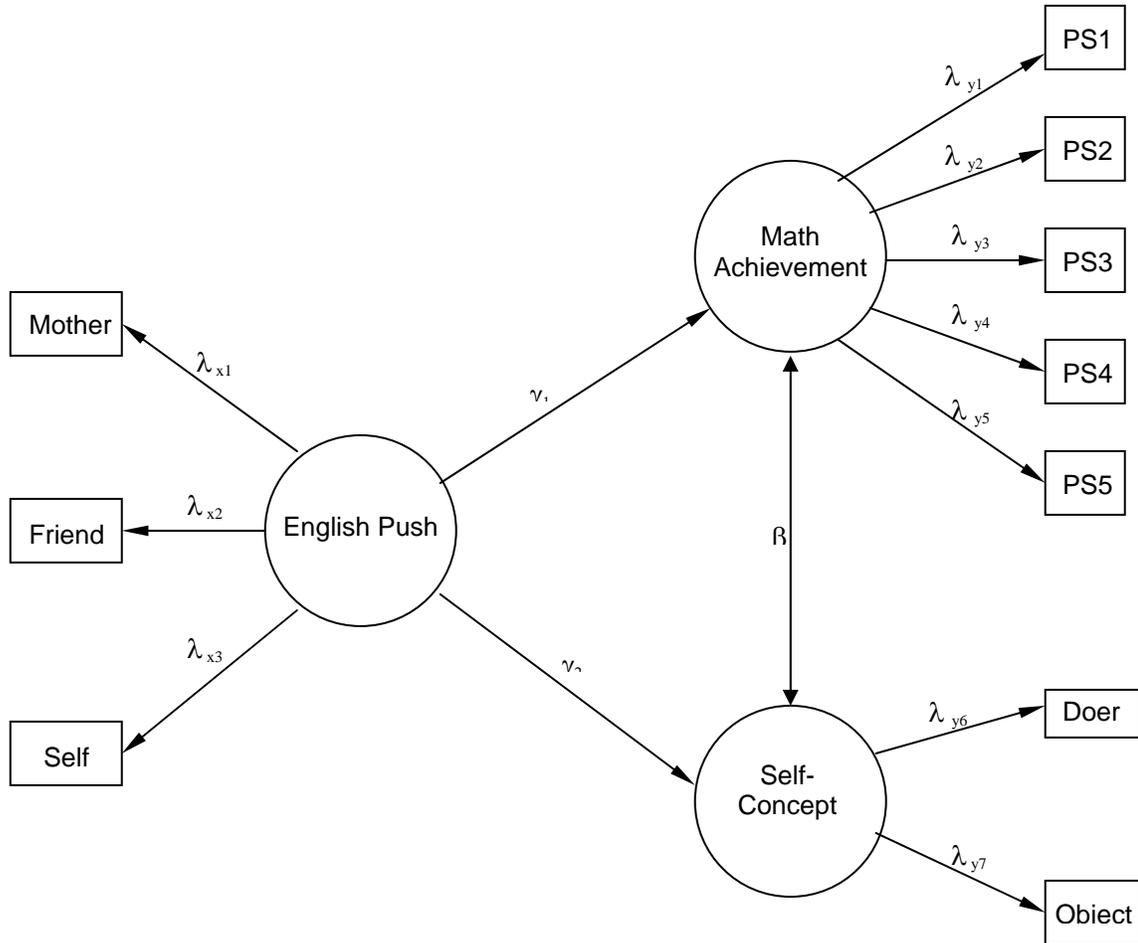
Notes:

1. PS1, … PS5 are plausible mathematics scores imputed from TIMSS or TIMSS-R projects under a three-parameter item response theory (IRT) model.

2. The "doer" and "object" indicators are based on student responses on whether they can do well in mathematics and felt bored about mathematics.

3. Indicators for the "English push" factor are based on student responses on importance of learning English perceived by self, friends, and mothers.