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Association Between Self-related Cognition and Mathematics Performance: The Case in Hong Kong

Esther Sui-Chu HO
Department of Educational Administration and Policy,
The Chinese University of Hong Kong

This article investigates the association between students' self-related cognition and mathematics performance in Hong Kong, a region that has excelled in mathematics performance in previous international studies. The five constructs of self-related cognition are: self-concept, self-efficacy, interest and enjoyment, instrumental motivation, and anxiety.

The data were obtained from the second cycle of the Programme for International Student Assessment (PISA), an international assessment measuring the performance of 15-year-old students from over 40 countries/regions around the world. Multilevel analysis was used to examine the relationship between self-related cognition and mathematics performance.

The study found that self-efficacy and self-concept were significantly associated with mathematics performance even after controlling background factors of both students and schools. High level of mathematics anxiety might not have direct effect on mathematics achievement; however, it might reduce the self-concept and self-efficacy of girls, which in turn, might affect their mathematics performance.

Introduction

For the first cycle of the Programme for International Student Assessment (PISA), the Organisation for Economic Co-operation and

Development (OECD) constructed cross-curricular competences to assess the self-regulated learning strategies, self-beliefs, motivation, and learning preferences of 15-year-old students from over 40 countries/regions around the world (Peschar, 2004; Trier & Peschar, 1995). This was done in 2000. These factors are believed to be essential aspects of the broader non-cognitive competences that focus on students' approaches to "Self Regulated Learning" (SRL) — that is, the way students address and handle learning tasks in school, and the extent to which they are able to achieve their learning goals by applying strategies, motivating themselves, and controlling and regulating their own learning processes (Marsh & Hau, 2004).

In the second cycle of the PISA program, which was conducted in 2003, approaches to SRL were assessed for each subject area, although the primary focus was on mathematics performance as this was the main domain assessed in the PISA 2003 program (OECD, 2004). This article focuses on five constructs of self-related cognition in relation to students' mathematics performance. The constructs of self-related cognition are believed to direct the aims and processes of action that help students overcome difficulties in learning mathematics. The five constructs are: self-concept, self-efficacy, interest and enjoyment, instrumental motivation, and anxiety.

Literature Review

Over the last two decades, numerous studies that investigated both cognitive processes and approaches to information processing have alerted educators' attention to the process of learning. On the whole, these studies have found that students' perception of their competence has an influence on their academic performance. Furthermore, it has been discovered that effective learners are more likely to use different strategies to deal with learning tasks than less effective learners. Thus, it appears that learning is not simply a process of collecting and memorizing information because different strategies are involved in the learning process (Greeno, Collins, & Resnick, 1996). The positive impact of self-related cognition and effective learning strategies on academic achievement has been well documented in both Asian and Western societies (e.g., Ho et al., 2003; Pintrich & De Groot, 1990; Pressley et al., 1994; Zimmerman, 2001; Zimmerman & Martinez-Pons, 1990).

With regard to self-related cognition, previous studies suggest that an individual's perception of self (i.e., self-concept) is important for predicting and explaining behavior (Shavelson, Hubner, & Stanton, 1976). Research on self-concept has shown that one's perception of self is multidimensional and includes academic, social, and physical aspects (Marsh & Hattie, 1996). Examination of academic performance should therefore focus on students' own impressions of their academic competence, and academic self-concept has been shown to be related to specific school subject areas such as English, Mathematics, and Science (Marsh, 1990, 1992). In the present study, the mathematical self-concept of students was measured to investigate further the content-specific relationship between mathematics performance and self-concept.

A review of the literature revealed that a positive association between mathematical self-concept and mathematics performance has consistently been found across different countries (Dai, 2001; Marsh & Hau, 2004; Marsh & Koller, 2004; Pajares & Graham, 1999). That is, students with high levels of mathematical self-concept generally show greater engagement, persistence, and effort in tasks relating to mathematics and in turn perform better than students with lower levels of mathematical self-concept.

Students' own judgments of their mathematical ability can also affect performance, as numerous studies have shown that self-efficacy is highly correlated with academic performance (e.g., Chemers, Hu, & Garcia, 2001; Multon, Brown, & Lent, 1991; Pajares & Graham, 1999). Self-efficacy refers to the belief in one's capabilities to organize and execute courses of action required to produce given attainments (Bandura, 1997), and represents an individual's convictions and expectations of what he or she can accomplish in a given situation (Bong & Skaalvik, 2003).

It has been found that students with high levels of positive self-efficacy perform academic tasks more successfully, and are more likely to try difficult tasks and be motivated to use different strategies to solve obstacles and problems than students who do not believe that they can master these tasks. Furthermore, across different ability levels, students with high self-efficacy have been found to be more accurate in their mathematical computations and show greater persistence on difficult items than students whose self-efficacy is low (Pajares & Graham, 1999).

Similar to the situation of self-concept, an individual's self-efficacy is domain-specific. Students with positive academic self-efficacy expectations have been found to have higher performance expectancies and achieve higher scores than students with less positive academic efficacy (Bouffard, Boileau, & Vezeau, 2001; Chemers et al., 2001). Hence, mathematical self-efficacy, defined as students' belief in their own ability to handle learning situations and overcome difficulties in mathematics effectively, was measured in the present study.

While self-concept and self-efficacy have captured the attention of educators due to their crucial influence on student learning, studies have also found that positive academic self-concept and self-efficacy can facilitate students' academic engagement and motivation (Bong & Skaalvik, 2003; Turner, Steward, & Lapan, 2004).

Motivation has also been found to be a critical predictor of students' learning and performance. According to self-determination theory (Deci & Ryan, 1985; Grolnick, Deci, & Ryan, 1997), motivation is categorized into two main types: intrinsic and extrinsic. Intrinsic motivation is defined as "an innate, rather than derivative, propensity to explore and master one's internal and external worlds" (Ryan, Connell, & Grolnick, 1992, p. 169). Extrinsic motivation refers to behaviors that are driven by the need to attain external rewards or meet socially prescribed demands (Ryan, Connell, & Grolnick, 1992).

Students who are intrinsically motivated learn mathematics to satisfy their own interests so that, for them, attending mathematics lessons or engaging in mathematical activities is enjoyable. Conversely, students who are extrinsically motivated learn mathematics to gain an external reward such as to increase their chances of obtaining university entry. Both types of motivation orientation increase students' effort in learning, as they allow students to become more involved in academic activities and enable them to interact with their teachers to a larger extent. Given that both intrinsic and extrinsic motivation influence learning and academic performance (d'Ailly, 2003; Tavani & Losh, 2003), the present study sought to assess the relationship between these factors and mathematics performance.

Although a large proportion of students enjoy learning mathematics, it is not uncommon for some students to exhibit "mathematics anxiety." Mathematics anxiety is commonly regarded as a feeling of tension or fear when dealing with mathematics. Students with high levels of mathematics anxiety usually feel stressed when engaging in

mathematical computations, express a tendency to avoid mathematics, and show higher emotional arousal, but slower cognitive processing, during problem-solving (Ashcraft, 2002; Ashcraft & Kirk, 2001; Miller & Bichsel, 2004). In short, these responses interfere with a student's ability to learn mathematics.

Mathematics anxiety is also directly related to students' perceptions of their mathematical ability and performance expectancies (Meece, Wigfield, & Eccles, 1990). As a result, achievement motivation is negatively affected if students evaluate themselves as having lower abilities and expect to perform poorly. As previously stated, students who suffer from mathematics anxiety often feel tense and stressed, which causes them to be exposed to less mathematics in school and to learn less of what they are exposed to. As a result, mathematics performance and achievement is severely affected.

Research has also shown that there are gender differences with regard to the incidence of mathematics anxiety, with girls exhibiting higher levels of mathematics anxiety than their male counterparts (Hembree, 1990; Meece et al., 1990; Miller & Bichsel, 2004). Furthermore, these differences appear to account for sex-related differences in mathematics performance and subject selection. Given that anxiety is detrimental to learning and performance in mathematics (Miller & Bichsel, 2004), the present study also examined the mathematics anxiety of students and its relationship to mathematics performance.

To summarize, previous studies have investigated the importance of self-related cognition on performance. However, only a few studies have investigated the nature and impact on performance of self-related cognition of students in Asian societies like Hong Kong (Ho, 2004; Marsh & Hau, 2004; Rao, Moely, & Sachs, 2000). Hence, this study examines these issues with a large sample of Hong Kong secondary school students. Specifically, the study addresses the following main questions:

1. What are the characteristics of Hong Kong students in terms of their self-concept, self-efficacy, interest and enjoyment, instrumental motivation, and mathematics anxiety? How does this compare with that of OECD countries?
2. What is the relationship between the five constructs of self-related cognition and the mathematics performance of Hong Kong students?

It was hypothesized that students who possess higher levels of mathematical self-concept, mathematical self-efficacy, interest and enjoyment, and instrumental motivation, together with lower levels of mathematics anxiety, will outperform those students who do not possess such traits.

Methods

The primary database used in this study was derived from the second cycle of the PISA program conducted in 2003. PISA is a large international assessment program which assesses the reading, mathematical, and scientific performance of 15-year-old students across more than 40 countries/regions around the world. PISA constitutes one of the most comprehensive and rigorous international assessments of student performance to date. It is conducted under the auspices of OECD.

In PISA 2003, the major subject domain is mathematics, and therefore, about two-thirds of testing time was devoted to this domain. The assessment focuses on the functional use of mathematics, and the ability to recognize, formulate, and solve mathematical problems in various situations (OECD, 2004). The performance scores are scaled with the mean performance of OECD student set at 500 and a standard deviation of 100.

Sampling in HKPISA 2003

The data were collected from May to July 2003 in Hong Kong. For sampling, schools were stratified based on the following criteria: type of school (government, aided, and independent/private) and student intake (high, medium, and low academic ability) according to the information provided by the Education and Manpower Bureau of the Hong Kong government. The stratified sampling method ensures the appropriate proportion of each type of school in the sample (Table 1). A total of 4,478 students from 145 schools were accepted for final analysis according to OECD sampling standard. In this study, we focus our analyses on students from these 145 schools.

Table 1: Selected and Participating Schools for Each Sampling Stratum in HKPISA 2003

Explicit strata	Implicit strata	Total no. of schools	No. of schools sampled by OECD	No. of schools accepted by OECD
Government	High ability	17	8	8
	Medium ability	9	3	3
	Low ability	10	4	4
Aided	High ability	127	51	50
	Medium ability	124	41	41
	Low ability	107	34	33
Independent/ private*	Local/DSS#	29	5	5
	International	20	4	1
Total		443	150	145

* There is no intake classification for independent/private schools.

\# DSS refers to schools under the Direct Subsidy Scheme.

Operationalization of Self-related Cognition

In the PISA 2003 study, a total of 26 items were incorporated into a questionnaire measuring students' self-related cognition (OECD, 2005). Participating students in Hong Kong were required to complete the questionnaire and rate on a 4-point Likert scale the extent to which they agreed with various statements relating to the five constructs listed in Table 2. Each construct consisted of four to eight items, with an index being computed for each construct. Because each index consisted of multiple questions and responses, it was scaled using a weighted maximum likelihood estimate method (OECD, 2005).

Each index was then standardized, with the average score across OECD countries set at zero and the standard deviation set at one. A positive value on an index indicates that scores obtained in Hong Kong were higher than the OECD average, which indicates in turn that students in Hong Kong employed a particular self-related cognition or learning strategy more often (on average) than students from other OECD countries. Table 2 shows that the Cronbach's alphas for the five constructs of self-related cognition ranged from 0.803 to 0.905, indicating good reliability.

Table 2: Measures of Self-related Cognition and Learning Strategies in PISA 2003 (*n* = 4,478)

Self-related cognition in mathematics	Sample items in student questionnaire: To what extent do you agree with the following statements?	No. of items	Reliability (Cronbach's alphas)
Mathematical self-concept	I have always believed that Mathematics is one of my best subjects.	5	0.869
Mathematical self-efficacy	How confident do you feel about having to do the following Mathematics tasks? Understanding graphs presented in newspapers.	8	0.887
Interest in and enjoyment of mathematics	I do Mathematics because I enjoy it.	4	0.905
Instrumental motivation in mathematics	Learning Mathematics is worthwhile for me because it will improve my career prospects.	4	0.882
Mathematics anxiety	I feel helpless when doing a Mathematics problem.	5	0.803

Note: Details of the 26 items are listed in *PISA 2003 Technical Report* (OECD, 2005, pp. 289–299).

Results and Discussion

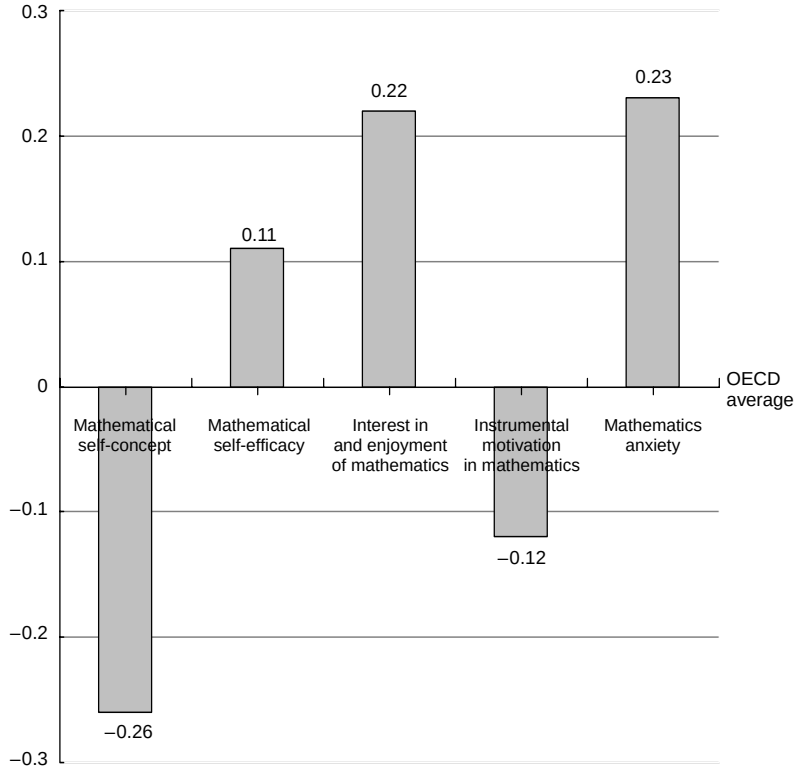
Characteristics of Hong Kong Students

As previously stated, the OECD average for each of these indices is 0, with the standard deviation being 1. It is clear from Figure 1 that Hong Kong students' mathematical self-concept was well below the OECD average, despite having the highest scores for mathematics performance in the PISA 2003. This result suggests that students who report high levels of self-concept in mathematics do not necessarily outperform students with lower levels of self-concept. One possible explanation for this result is that self-concept is related to factors such as classroom context, parental expectations, and teacher feedback. Students typically perceive their attitudes and behavior within a frame of reference shaped by their school and classroom culture. Students in academically

segregated schooling systems are more likely to have a lower self-concept, because higher-achieving students are placed in higher-achieving schools. With the frame of reference being outstanding peers, even high achievers may underestimate their real ability. Within the Hong Kong context, however, high-achieving students tend to display higher levels of self-concept in mathematics than low achievers.

It can also be seen from Figure 1 that the index representing instrumental motivation is also below the OECD average. Interestingly, the indices for mathematical self-efficacy and interest and enjoyment were slightly higher than the OECD average, with the index for anxiety also being above the OECD average for students in Hong Kong.

Figure 1: Five Indices of Self-related Cognition of Hong Kong Students Compared With the OECD Average



Note: The OECD average for each of these indices is set at 0.

Correlations Among Self-related Cognition Indices

The following section focuses on the association between self-related cognition and performance. Correlations among the five indices were examined prior to examining their relationship between mathematics performance.

Table 3 shows the relationship between each of the self-related cognition indices. As seen in Table 3, the indices of self-concept, self-efficacy, interest and enjoyment, and instrumental motivation in mathematics are highly correlated with one another, with correlation coefficients ranging from 0.345 to 0.714. It can also be seen that there is a significant negative correlation between students' level of anxiety in mathematics and the four self-related cognition indices. These findings suggest that students' anxiety toward mathematics can significantly hinder self-belief and the motivation to learn.

Table 3. Correlations Among Indices of Self-related Cognition (*n* = 4,478)

	Mathematical self-concept	Mathematical self-efficacy	Interest and enjoyment	Instrumental motivation	Mathematics anxiety
Mathematical self-concept	1	.508**	.714**	.445**	–.674**
Mathematical self-efficacy		1	.450**	.345**	–.387**
Interest and enjoyment			1	.613**	–.473**
Instrumental motivation in mathematics				1	–.263**
Mathematics anxiety					1

** $p < .01$

Correlation Analysis of Self-related Cognition and Mathematics Performance

Table 4 shows the correlation between the indices representing self-related cognition and the mathematics performance of Hong Kong

students. All correlations were found to be significant, but less than 0.30, with the exception of the self-efficacy index where a correlation coefficient of 0.50 was obtained. Across the five indices, self-efficacy was found to have the largest positive correlation with performance, with anxiety toward mathematics having the only negative correlation with mathematics performance.

Table 4: Correlations of Self-related Cognition and Mathematics Literacy Performance (*n* = 4,478)

Self-related cognition	Correlation coefficient with mathematics
Mathematical self-concept	.320**
Mathematical self-efficacy	.504**
Interest in and enjoyment of mathematics	.278**
Instrumental motivation in mathematics	.198**
Mathematics anxiety	–.244**

** $p < .01$

Multilevel Analysis of Self-related Cognition and Literacy Performance

Table 5 shows the association between self-related cognition and students' mathematics performance after controlling for background variables via the use of multilevel regression models. Background factors include both student factors (i.e., gender, immigrant status, family structure, and socio-economic status [SES]) and school-level factors (i.e., student composition in terms of percentage of single parents, percentage of immigrant students in the school, school mean parent SES, and school average academic intake). It is important to note that the regression coefficient of a variable simply indicates the predicted change in scores when there is a change in that particular variable. The regression coefficient should not be regarded as an indication of simple causation.

From Table 5, it can be seen that two models were created from the analysis, with model 1 showing the effects of background variables. At the student level, gender and ethnicity were found to have a significant impact on mathematics performance, with girls and immigrant students obtaining significantly lower scores than boys and local students.

Table 5: Association Between Self-related Cognition and Mathematics Performance (*n* = 4,478)

	Model 1		Model 2	
	Coefficient	*SE*	Coefficient	*SE*
Intercept	555.684***	2.703	556.779***	2.329
School contextual factors				
% of girls	7.461	10.733	3.334	9.252
% of immigrants	–30.041	30.420	–16.075	25.331
% of single parent	–94.331**	34.312	–82.732**	28.927
Mean SES	25.344***	6.349	21.064***	5.637
Mean Intake	59.119***	3.732	47.523***	3.202
Student background factors				
Girl	–21.227***	2.994	–4.476	2.732
Immigrant	–24.464***	3.386	–24.049***	3.005
Single parent	–4.433	3.026	–2.833	2.674
SES	–0.170	1.628	–0.968	1.481
Self-related cognition				
self-concept			8.037***	2.075
self-efficacy			26.853***	1.669
interest and enjoyment			2.932	1.714
instrumental motivation			0.167	1.458
anxiety			–2.816	1.843
Between-school variance	744.841		507.1689	
Within-school variance	4819.792		3865.522	
Total variance	5564.633		4372.691	
% of between-school variance explained	83.4%		88.7%	
% of within-school variance explained	3.4%		22.5%	
Total variance explained	41.3%		53.9%	

** $p < .01$; *** $p < .001$

However, the results also show that the contextual effects of gender and ethnicity are not significant at the school level, as percentage of single parents, school average SES (mean SES), and school average academic intake (mean intake) were found to be the three major factors affecting students' mathematics performance. That is, schools with a higher percentage of single parents tend to produce lower scores, whereas

schools with a higher percentage of parents with strong academic backgrounds and a higher SES tend to produce higher scores. Table 5 shows that model 1 explains about 83% of the between-school variance, and only about 3% of the within-school variance. The total variance explained by model 1 was approximately 41%.

Model 2 shows the association between self-related cognition and mathematics performance after controlling for student-level and school-level background factors. Of the five self-related cognitive factors, self-concept and self-efficacy were found to have a significant positive association with mathematics performance. From Table 5, it can be seen that one unit increase in each of self-concept and self-efficacy is accompanied by an increase of 8.0 points and 26.9 points on the mathematics performance scale respectively. These findings suggest that both the ability to perceive oneself highly (self-concept) and the belief that a learning task is manageable (self-efficacy) are positively associated with students' mathematics performance. It appears that self-efficacy is the most important dimensions of self-perception associated with mathematics performance. The relative contribution of self-efficacy is three times that of self-concept. This finding is consistent with the study by Bong and Clark (1999), who argued that self-efficacy better predict actual academic performance than self-concept, whereas self-concept might better predict affective outcomes such as anxiety and satisfaction. In the present PISA study, self-efficacy is assessed by presenting specific mathematics problems to students and asking them to judge how confident they feel about solving the problem or task. It is reasonable that this measure of self-efficacy better predict achievement related to particular tasks or test at this moment. In contrast, self-concept reflects perception of more general ability related to specific domains and may therefore better predict attitudes, interest, and long-term effort and future learning. More research is needed for analyzing the similarities and differences between self-concept and self-efficacy and their relative contribution to the cognitive and affective learning outcome in future studies.

Moreover, another research area in the study of self-perception and achievement is the "chicken or the egg" question. Whether self-concept and self-efficacy "cause" achievement or it is the other way round, or if there is reciprocal effects between self-perception and achievement (Marsh & Yeung, 1997) are important and interesting avenues for further studies.

The influences of external-instrumental motivation, internal-interest and anxiety were not found to be significant once the background factors were accounted for. Table 5 shows that model 2 explains approximately 89% of the between-school variance, and 23% of the within-school variance, with approximately 54% of the total variance being explained by this model. The results also show that self-related cognition increases the explaining power within school substantially, especially for the gender difference in mathematics achievement.

On the whole, results from model 2 suggest that self-concept and self-efficacy have the strongest association with mathematics performance.

Conclusions and Implications

Overall, Hong Kong students' reported relatively low levels of self-concept and external-instrumental motivation, and relatively high levels of self-efficacy and interest in learning mathematics by international standards. In addition, levels of mathematics anxiety of Hong Kong students were found to be higher than the OECD average.

According to students' responses in the PISA 2003 survey, about 68% of Hong Kong students often worry about the difficulties in mathematics learning, and 72% worry that they may get poor results for the subject. Although parents and teachers in Asian societies typically believe that certain levels of anxiety are the driving force for academic achievement, the results in the present study suggest that the level of anxiety is not effective for enhancing students' mathematics performance. On the contrary, results from correlation analysis indicated that mathematics anxiety has a strong relationship with mathematical self-concept and self-efficacy. The high level of anxiety might have detrimental effect on students' self-concept and self-efficacy, which in turn indirectly have negative effect on students' learning.

As previously mentioned, Hong Kong students were found to have very low levels of self-concept in mathematics, despite displaying outstanding mathematics performances. This finding is consistent with previous international studies, including PISA 2000 and TIMSS (Third International Mathematics and Science Study) (Martin et al., 2000; Mullis et al., 2000). The low levels of self-concept found in Hong Kong students could be viewed as a major weakness in mathematics education in Hong Kong. One possible explanation for the low levels of

self-concept reported in Hong Kong students might be related to the high levels of anxiety experienced by these students as a result of high-stakes testing.

In sum, this article focused on the association between psychological processes of self-related cognition and mathematics performance. Although the present study has tried to include essential student background factors into the analysis, it is important to state that socio-cultural differences have not been fully taken into account in the above discussion. Moreover, the causal or reciprocal effects among self-concept, self-efficacy, and achievement are important avenues for further analysis by more advanced analytical tools such as multilevel structural equation models. Overall, the results of this study suggest that there is room for Hong Kong teachers to foster student learning by promoting self-confidence in a less anxious learning environment, especially for the girls, in mathematics. Strengthening student self-efficacy and self-concept by arranging challenging learning tasks and minimizing the test anxiety seems to be the most important challenge for fostering mathematics education in Hong Kong.

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