The Differential Effect of Student-Level Factors on Mathematics Achievement of the International Benchmark Groups: A Study Using TIMSS 2011 Mathematics Data of Singapore

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***Abstract*—**International benchmarking is an important device for improving education achievement and interprets the results of an assessment. The international assessment Trends in International Mathematics and Science Study (TIMSS) provides four-point-scale international benchmarks to interpret the characteristics of students' performance on the test results. The cut-off scores for the low, intermediate, high, and advanced international benchmarks are 400, 475, 550, and 625, respectively. This study utilized TIMSS 2011 mathematics grade 8 data of Singapore to investigate the student-level factors that influenced significantly on the mathematics achievement of different groups of international benchmark. Results showed that the factor weekly time spent on mathematics homework influenced the mathematics achievement of all groups of international benchmark significantly and positively. Student confidence with mathematics was the major factor in predicting high mathematics achievement. The key factor affecting the mathematics achievement of lowest level of international benchmark was student bullied at school. Suggestions for future research was discussed.

***Keywords*—**International Benchmarking, International Large-Scale Assessment, Student-Level Factors, TIMSS 2011

I. Introduction

INTERNATIONAL large-scale assessment (ILSA) data are important resources for educational researchers and policy makers to examine their educational systems, to gain profound understanding of the effects of policies, and to be as references for educational reforms, either from national or international perspective. One of the most influential international assessment projects is Trends in International Mathematics and Science Study (TIMSS). It is a highly regarded ILSA of student achievements in mathematics and science at the 4th and 8th grades. It has constantly assessed the participating countries on a 4-year-cycle base since 1995. TIMSS reports indicated that the East Asian countries and regions (e.g. Chinese Taipei, Hong Kong SAR, Japan, Korea and Singapore) have consistently been the top performers among the participating countries over the world [1]-[3].

The admirable performance of the East Asian school systems has drawn a lot of attention internationally and inspired many discussions on their educational spirit, practices, and systems, especially Singapore [4]-[5]. TIMSS provides four-point-scale international benchmarks to interpret the characteristics of students' performance on the test results. The cut-off scores for the low, intermediate, high, and advanced international benchmarks are 400, 475, 550, and 625, respectively. TIMSS reports show that Singapore has very high percentages of students reaching the level of advanced international benchmark [1]-[3]. For example, the percentages of students reaching the advanced international benchmark in TIMSS 2003 and TIMSS 2011 are 44% and 47% for Singaporean 8th graders, respectively. The distribution of mathematics performance of Singaporean students is skewed to the left. This indicates that Singapore has a high percentage of well-achieving students and a lower percentage of low-performing students. For example, in TIMSS 2003, 2007, and 2011, the percentages of 4th graders and 8th graders in the advanced international benchmark levels are around 40%, and those in the low international benchmark levels are only around 8% [4].

With the widely praised high-performing students, the educational issues regarding factors affect different achievement categories seem to have been hardly explored. Understanding the causes that impact individual achievement category is crucial to the improvement of overall educational achievement levels as well as the realization of educational equity. In light of the importance of understanding the factors affecting students' achievement in different levels of international benchmark, this study aimed to use TIMSS 2011 eighth-grade mathematics data of Singapore to investigate the impact of the student-level factors on various international benchmark categories. The specific research questions for this study were (1) what was the quantity of the students in various categories of international benchmark? (2) what student-level factors significantly predicted the status of student on different international benchmark categories?

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II. TIMSS International benchmark

International benchmarking is an important measuring tool for improving education systems since it provides for a comparison of education methods/policies nationally or internationally. It can assess performance objectively, indicate the underlying causes of educational problems, and reveal areas where improvement is needed. Results from benchmarking are closely related to students' performance and thus benchmarking can be seen as a means of evaluation.

TIMSS is a curriculum-based and grade-based sampling assessment. Its mathematics assessment is divided into content domains and cognitive domains. For the TIMSS 2011 eighth grade, topics assessed in the content domain are number, algebra, data and chance, and geometry. The thinking process assessed and cognitive skills expected for students to develop are knowing, applying and reasoning [6]. In addition to the numerical scores, TIMSS provides international benchmarks to describe students' performance on test items. The achievement scores at four points along the scale as international benchmarks are advanced international benchmark (625), high international benchmark (550), intermediate international benchmark (475), and low international benchmark (400). The category is coded as: 1=below 400, 2=at or above 400 but below 475, 3= at or above 475 but below 550, 4= at or above 550 but below 625, 5= at or above 625. The cognitive skills for various categories of international benchmark at the eighth grade are: (1) students at the advanced international benchmark can organize and draw out conclusions from given information, make generalization, solve non-routine/multi-phase problems;(2) students at high international benchmark can interpret statistical graphs, solve simple problems involving probability and make use of knowledge in complex situations ; (3) students at intermediate international benchmark have basic algebraic/geometric concepts and can apply their understanding/knowledge in simple situations; and (4) students at low international benchmark have basic knowledge involving whole numbers, decimals, operations and graphs [6]. More details about the four international benchmarks are given in Table I.

TABLE I
TIMSS 2011 INTERNATIONAL BENCHMARKS OF MATHEMATICS ACHIEVEMENT FOR GRADE 8

Advanced International Benchmark(625)
Students can reason with information, draw conclusions, make generalizations, and solve linear equations. Students can solve a variety of fraction, proportion, and percent problems and justify their conclusions. Students can express generalizations algebraically and model situations. They can solve a variety of problems involving equations, formulas, and functions. Students can reason with geometric figures to solve problems. Students can reason with data from several sources or unfamiliar representations to solve multi-step problems.
Advanced International Benchmark(625)
Students can reason with information, draw conclusions, make generalizations, and solve linear equations. Students can solve a variety of fraction, proportion, and percent problems and justify their conclusions. Students can express generalizations algebraically and model situations. They can solve a variety of problems involving equations, formulas, and functions. Students can reason with geometric figures to solve problems. Students can reason with data from several sources or unfamiliar representations to solve multi-step problems.
High International Benchmark(550)
Students can apply their understanding and knowledge in a variety of relatively complex situations. Students can use information from several sources to solve problems involving different types of numbers and operations. Students can relate fractions, decimals, and percent to each other. Students at this level show basic procedural knowledge related to algebraic expressions. They can use properties of lines, angles, triangles, rectangles, and rectangular prisms to solve problems. They can analyze data in a variety of graphs.
Intermediate International Benchmark(475)
Students can apply basic mathematical knowledge in a variety of situations. Students can solve problems involving decimals, fractions, proportions, and percentages. They understand simple algebraic relationships. Students can relate a two-dimensional drawing to a three-dimensional object. They can read, interpret, and construct graphs and tables. They recognize basic notions of likelihood.
Low International Benchmark (400)
Students have some knowledge of whole numbers and decimals, operations, and basic graphs.

Source: TIMSS 2011 international results in mathematics. (Mullis, et al., 2012, p. 113)

III. Methods

A. TIMSS Data and Sample

TIMSS is directed by the International Association for the Evaluation of Educational Achievement (IEA). It is a project of IEA's TIMSS & PIRLS International Study Center at Boston College. It is conducted on a four-year cycle, beginning in 1995 and with implementing of 2015 underway. TIMSS 2011 involves forty-five participating countries and fourteen benchmarking entities, and with more than 600,000 eighth graders. TIMSS collects data from students, teachers, and principals. The information includes students' background, home/class/school environments, school/home resource, curricula and instructional strategies in mathematics and science [3]. TIMSS official reports, frameworks, user's guides, international database, and related information can be found in TIMSS & PIRLS official website: http://TIMSS.bc.edu. Data for this study are available from http://timssandpirls.bc.edu/timss2011 /international-database.html.

TIMSS 2011 targets populations of the 4th and 8th graders. The average ages of the students at the time of testing are14.4 for Singaporean students [7]. Based on TIMSS sample design, the participant's target population size for Singaporean 8th graders is 50,205 students and 165 schools. The sample size is 5,927 students and 165 schools [8]. Table II listed the numbers of students in each international benchmark category.

TABLE II
THE NUMBER AND THE PERCENTAGE OF STUDENTS IN EACH INTERNATIONAL BENCHMARK LEVEL

International Benchmark	Frequency	Percentage
BELOW 400	59	1
AT OR ABOVE 400 BUT BELOW 475	401	6.8
AT OR ABOVE 475 BUT BELOW 550	889	15
AT OR ABOVE 550 BUT BELOW 625	1849	31.2
AT OR ABOVE 625	2729	46
Total	5927	100

B. Dependent Variable and Independent Variables

The dependent variable was plausible values of students' mathematics achievements in TIMSS 2011. It was assumed that student achievement was affected by the student-level factors. Student learning was influenced by the five key components: student background, environmental support, students' school experience, the amount of homework, and

motivation. According to the five key components, the variables in this study were sex, parents' highest educational level, home educational resources, the number of home study support, students bullied at schools, students engaged in mathematics lessons, weekly time spent on math homework, students like mathematics, students value learning mathematics, and students confidence with mathematics.

TIMSS combines several items into scales and classified those scales to high-, median-, and low- level. The respondents' answers on these variables were originally coded as 1=high, 2=medium, and 3=low, in TIMSS database. The set of items for each scale can be found in [3]. To represent the higher the values, the higher levels of respondents' answers on the scales, the levels of indices were recoded as 3=high, 2=medium, and 1=low. Because the number of students in international benchmark BELOW 400 was small (59 students), this level was combined with level AT OR ABOVE 400 BUT BELOW 475 and renamed as BELOW 475 in this analysis.

IV. Results

Table III showed the number and the percentage of students in each international benchmark level. The very high percentage of students reached the level "AT OR ABOVE 625", indicating most Singaporean students were high performers in mathematics.

TABLE III
THE NUMBER AND THE PERCENTAGE OF STUDENTS IN EACH INTERNATIONAL BENCHMARK LEVEL

Group	Frequency	Percentage
BELOW 475	460	7.8
AT OR ABOVE 475 BUT BELOW 550	889	15
AT OR ABOVE 550 BUT BELOW 625	1849	31.2
AT OR ABOVE 625	2729	46
Total	5927	100

Note. The level "BELOW 400" is combined with the level "AT OR ABOVE 400 BUT BELOW 475" and renamed as "BELOW 475".

Table IV represented the ANOVA results of regression analysis of model for each level of international benchmark. As could be seen from Table IV, the models for each international benchmark level were significant; indicating some of the predictors had effects on mathematics achievement.

TABLE IV
ANOVA RESULTS OF REGRESSION ANALYSIS OF THE MODEL FOR EACH LEVEL OF INTERNATIONAL BENCHMARK

Model		SS	df	MS	F
BELOW 475	Regression	26909.8	3	8969.9	10.2
	Residual	400651.7	456	878.6	
	Total	427561.5	459		
AT OR ABOVE 475 BUT BELOW 550	Regression	8985.7	3	2995.2	6.9
	Residual	383950.5	885	433.8	
	Total	392936.2	888		
AT OR ABOVE 550 BUT BELOW 625	Regression	23673.5	3	7891.2	17.3
	Residual	841041.0	1845	455.8	
	Total	864714.5	1848		
AT OR ABOVE 625	Regression	464350.9	6	77391.8	57.9
	Residual	3641356.3	2722	1337.8	
	Total	4105707.2	2728		

Note. All models were significant at α=0.05

TABLE V
RESULTS OF REGRESSION ANALYSIS OF THE MODEL FOR EACH LEVEL OF INTERNATIONAL BENCHMARK

Model		Coefficients	Standard Error	T-ratio
BELOW 475	Intercept	426.0	5.1	84.2
	Sex	10.8	2.9	3.7
	Weekly time spent on math homework	7.7	2.4	3.2
	Student bullied at school	-3.8	1.8	-2.1
AT OR ABOVE 475 BUT BELOW 550	Intercept	505.8	2.8	183.2
	Sex	3.2	1.4	2.2
	Weekly time spent on math homework	2.8	1.1	2.6
	Student confidence with mathematics	3.6	1.2	3.0
AT OR ABOVE 550 BUT BELOW 625	Intercept	571.7	2.7	213.5
	Weekly time spent on math homework	2.7	0.8	3.5
	Student confidence with mathematics	3.9	0.8	5.1
	Parents highest education	2.0	0.5	4.4
AT OR ABOVE 625	Intercept	619.8	5.1	121.2
	Sex	-2.8	1.4	-2.0
	Weekly time spent on math homework	4.0	1.1	3.5
	Student confidence with mathematics	16.1	1.1	14.5
	Parents highest education	5.0	0.8	5.9
	Student value learning mathematics	-4.3	1.2	-3.6
	Home educational resources	5.7	1.8	3.2

Note. All models are significant at α=0.05

Table V presented the results of regression analysis of model for each level of international benchmark. More in-depth inferences were summarized as follows.

1) There were substantial gaps of mean mathematics achievement between the levels of international benchmark. The intercepts for BELOW 475, AT OR ABOVE 475 BUT BELOW 550, AT OR ABOVE 550 BUT BELOW 625, AT OR ABOVE 625 were 426, 505.8, 571.7, and 619.8, respectively.
2) The number of significant factors for the group BELOW 475 was 2, while it was 6 for the group AT OR ABOVE 625. This indicated that it needed more variables to interpret the causes of high mathematics achievement than those of low achievement.
3) The common factor influencing all of the groups was the variable weekly time spent on mathematics homework. It had positive effects on mathematics achievement.
4) Except the level BELOW 475, the variable student confidence with mathematics had the most positive significant effect on mathematics achievement, especially on the achievement of the group AT OR ABOVE 625. This indicated the importance of self-confidence in learning mathematics and getting higher performance.
5) In addition to the variable weekly time spent on mathematics homework, the only factor affecting the group BELOW 475 was the variable student bullied at school, indicating behavioral problems was a major cause

in influencing the learning of the students in the lower level of mathematics achievement.

V. CONCLUSIONS

International benchmarking is an important device for improving education achievement. The classification of international benchmarking in TIMSS helps educational researchers and practitioners interpret TIMSS scores in more meaningful manners. Linking results to influential factors is necessary. That is, giving the performance results is not sufficient. It is essential to understand the underlying processes that explain different level of performance.

This study utilized TIMSS 2011 mathematics grade 8 data of Singapore to investigate the student-level factors that influenced significantly on the mathematics achievement of different groups of international benchmark. Results showed that the factor weekly time spent on mathematics homework influenced the mathematics achievement of all groups of international benchmark significantly and positively. This signified the importance of assigning homework to assist learning. Homework mainly provides students with an opportunity to review and practice what has been learned at school. It is viewed as an extension of school learning. Generally, the more time students spend on homework, the better students' performances will be. Moreover student confidence with mathematics was a key factor in mathematics learning. It had the most positive significant effect on the high mathematics performance. The major factor affecting the mathematics achievement of the group BELOW 475 was the variable student bullied at school. In improving the mathematics achievement of students in lower level of international benchmark, educators should consider deal with the issues of campus bullying first.

This study used student-level factors to examine the characteristics of mathematics achievement of students on different categories of international benchmark. However it should be noted that students learn most things from schools. Class- and school- level would have import influence on mathematics learning as well. It is suggested that multilevel analysis should be employed to get deeper understanding of the characteristics of student achievement on various levels of international benchmark. By focusing on Singapore, this study makes a starting point to understand the mathematically various-achieving students in the high-performing school systems. Similar efforts can be extended to other high-performing systems, such as Chinese Taipei, Korea, or Japan. Researchers can develop a more comprehensive understanding of issues and identify the key factors regarding achievement gaps in various levels of international benchmark.

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