The Mathematical Achievement of Fourth-Graders of Taiwan in the TIMSS 2003 Field Test

Pi-Jen Lin
National Hsin-Chu Teachers College, Taiwan, R.O.C.

521, Nan-Dah Road. Hsin-Chu City 300
Taiwan, R.O.C.

(Tel) 011-886-3-5213132 Ext 7100
(Fax) 011-886-3-5628462
linpj@mail.nhctc.edu.tw

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Abstract

Taiwan's mathematics curriculum has been undergone three reforms in the last three decades. The Standard of School Mathematics Curriculum, issued in 1993 and implemented in 1996, has been carried out six years. There is a furious debate on what mathematics should be comprised in coming curriculum and on suspecting whether students still maintain mathematical proficiency between proponents and opponents against the reform. For this sack, the achievement students performing in each mathematics strand in the TIMSS 2003 field test was examined. Moreover, the study tended to use curriculum as a source to explain differences in academic achievement. Data were drawn from the fourth-grade test conducted in the TIMSS 2003 field test. Taiwan was sampling 1601 students in 50 classes distributed in 25 primary schools. Two curriculum specialists and two teachers inspected each item of the test whether it was covered in the intended curriculum, issued in 1993.

It is found that Taiwanese students were achieved in mathematics better than the international average. The average performance of Taiwanese students in number, measurement, geometry, and data was higher than international average, while the performance of Taiwanese in algebra was lower than the international average. The study contributed the analysis of curriculum as a resource to explain the differences in academic achievement of mathematics topics. In this time of great interest in mathematics education reform, findings of the field test provided heavily powerful evidence to diminish opponents' blames against the 1993 version reform. The assessment afforded an important marker of the state of students' achievement in the period of reform. The lack of learning the topics measured in the field test, unfamiliarity with assessment format, the context referred to questions unsuitable to Taiwan's cultures were possible factors contributing to Taiwanese students performing poorly in some items.

Key words: TIMSS 2003 field test, mathematics performance, fourth-grade, Taiwan

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Three Curriculum Reforms in Taiwan

Taiwan's mathematics curriculum has been undergone three reforms in the last three decades. These reforms include the Curriculum Standards for Elementary Mathematics issued in 1975, which was revised and re-issued in 1993, and the Nine-Year School Curriculum issued in 1998, implemented in 2001, and revised in 2003. To help you understand the reforms, the paper begins with the school system in Taiwan.

With a population of more than 21 million, Taiwan has roughly 2 millions children aged from 6 to 12 in more than 2,000 elementary schools. Taiwan's population is heavily accumulated in urban areas and, as a result, typical class size with 30-35 students in urban and 25-28 students in suburban. The school system in Taiwan is 6-3-3-4. Education is compulsory from elementary school through junior high school (from ages 5 to 15).

Taiwan's highly centralized education system was unchanged until the curriculum was revised in 1993. Since 1968, the official unified mathematics textbook for the elementary schools was utilized in the national wide of Taiwan. Mathematics is one of the seventh courses offered in elementary schools. The proportion of mathematics classes per week in grade 1-2, grade 3-4, and grade 5-6 are 3/26, 4/33, and 6/35, respectively. Each class is 40 minutes in length. The school day is from Monday morning to Friday afternoon. Every Wednesday afternoon when the teachers attend in-service professional training is school off. A typical school day containing seven classes starts from 7:30 a.m. and run through to 4:00 p.m. The first hour of each day is functioned as a morning pre-session time in which students are educated in ethics and assignments are checked. Elementary school teachers teach regularly 25 classes per week. Two thirds of elementary school teachers are responsible for teaching all subject areas to their home class. The other one third of teachers specializing in courses like art, music, or science teaches their specialization to different classes in school. It means that two thirds of elementary school teachers teach mathematics to their own classes.

However, the revised "Curriculum Standards for Elementary Mathematics", issued in 1993 and implemented in 1996, privatized textbook publishing. The official unified textbook used for nearly past three decades was replaced by the newly published textbooks, which are also examined and approved by review committees from the Ministry of Education. As a result, the activities covered in the textbooks which were published by different publishers are heterogeneous. In addition, the philosophy of underpinning the curriculum issued in 1993 is based on the constructivist's perspective. The standards-oriented teaching has shifted its focus toward the learner-centered approach away from the teacher-centered approach. Teachers

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under the reform of 1993 version faced a complete paradigm shift; as a result, they needed to face the tension of the mathematics contents to be taught in the school schedule in the available time.

Since the "Nine-Year School Curriculum" was re-enacted by the Ministry of Education in 1998 and implemented in 2001, national curriculum standards have been decentralized. It represents one of the largest educational reforms up to date. Courses offered in elementary and junior high schools are shifted from subject-oriented to area-oriented. The indicators to be achieved for students in the newly version of curriculum are presented in a list of competency-driven deviated from the topic-driven in the traditional version. As a consequence, what the mathematics contents should be learned in various grade levels is determined by those committees who write the textbooks in different publishers. Therefore, the same mathematics idea included in different textbooks could be learned in different grade levels. Teachers under the reform are expected to help students to link the connection between two mathematics concepts and abridge the gap from using one textbook changing to another textbook. One new expectation placed on elementary and high school teachers under the reform is to change their role from an executer to a designer of curriculum. The teachers are expected to be an active role of using curriculum.

Mathematics is one of the seven learning areas in the 2001 curriculum version. The proportions of mathematics sessions per week in grade 1-2, grade 3-4, and grade 5-6 are 3/22, 4/28, and 4/30, respectively. The number of mathematics sessions offered in the 1998 version is less than the 1975 version. A school week is reduced into five days from six days. The mathematics contents recommended in the curriculum are not as many as those enacted in the 1975 and 1993 versions.

Up to date, the reform of 1993 version has been carried out six years. In the current educational setting of Taiwan, the six-grade students used the textbook of the 1993 and the first- to fifth-grade students have been replaced by the textbook of the 2001 version. There is a furious debate over mathematics contents comprised in curriculum and the effective way of teaching mathematics. Indeed, a mathematics education community comes up a surprise to hear the thousands of newspaper articles and websites arguing for or against the instructional approach based on the constructivist's perspectives. Some of these involve interviewed with eminent mathematicians or high government officials; others were written by parents and teachers. There have been television programs devoted to mathematics education. Mathematicians who are opponents against the reform of 1993 version wrest control of mathematics education of Taiwan and blame drastically students' poor computation skill but there is no evidence for supporting their suspects. The influence of the reform on students' achievement of mathematics becomes debate issue between the proponents and opponents. Nevertheless, there was no adequate large-scale data during the reform of 1993 version to report to diminish the voice of debate. For this sack, to understand whether students

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performed well under the curriculum reform, it is just the right time to report the data collected from the field test administered to the fourth grade students who only used the 1993 version from their first grade through fourth grade. Thus, the purposes of the study were: 1) to understand how fourth-graders of Taiwanese performed well in mathematics, and 2) to compare the level of fourth grade mathematics achievement of Taiwan to international average. It was also hoped that the study would provide a research basis for future national curriculum reform.

Cross-National Studies in Mathematics Achievement of TIMSS

Many studies distributed in different countries have analyzed the data from the IEA's Third International Mathematics and Science Study (TIMSS) and have produced scholarly work on the contexts that affect students, classroom, and school outcomes. A bunch of dissertations of doctoral students studying on science and mathematics area in different countries analyzed the data collected from the different populations involving in TIMSS. In mathematics, a group of researchers examined the relationship between teachers' personal beliefs about how students learning mathematics and their instructional practices to the mathematical achievement of eighth grade mathematics (Gales, 2000; Gerber, 2000). Results indicate that teachers about how students learning mathematics beliefs and their practices are not related to students' achievement (Gerber, 2000). The second group of the researchers was to determine the factors including home environment, peer influences, school environment, educational aspirations, attitudes toward mathematics and habits on mathematics achievement of three countries including the Republic of South Korea, Singapore, and the United States as measured by TIMSS (Chen, 2001). The third group of the researchers following the video component as part of the TIMSS data examined in depth how mathematics is taught and learned in three high-achieving European countries utilizing the data from filed observations, videotapes, interviews, and questionnaires (Kawanaka, 2000). These followed-up studies of TIMSS studied on the comparative analyses of cross countries. These comparative studies have little contribution to give a direct suggestion to mathematics education for a country involving the TIMSS study. Moreover, there is a little research on TIMSS by using the intended curriculum of a country as a resource to interpret students' mathematical achievement performing in different mathematics strand.

Background to TIMSS 2003 Field Test

The IEA officially launched the Trends in Mathematics and Science Study in 2003 (TIMSS 2003), although teams of researchers had been working on the preparation of the study since the early 2001s. TIMSS 2003 was designed to measure trends in students' mathematics and science achievement. Offered first in 1995, and then in 1999, the regular cycle of TIMSS studies provides to measure progress in educational achievement in

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mathematics and science (Mullis, et al., 2001). TIMSS 2003 field test is a pilot study of TIMSS 2003 main survey, which was very much collaboration among countries. TIMSS 2003 field test includes mathematics and science tests and questionnaires administered eighth-graders in over 40 countries and fourth graders in over 20 countries. Taiwan was one of the countries participating in the field test administering mathematics and science tests to the two grade levels and participating in the TIMSS at fourth grade level for the first time. The data report here is part of the fourth-grade mathematics test conducted in Taiwan in the TIMSS 2003 field test.

TIMSS 2003 is directed and coordinated from the TIMSS International Study Center (ISC), which is located at Boston College, in the United States. The National Research Coordinator (NRC) of, the director of National Taiwan Normal University, is responsible for the implementation of TIMSS 2003 in Taiwan. The NRC of Taiwan set up a research team consisting of eighteen professors and faculties from Taiwan Normal University, Science Education Center, and Hsin-Chu Teachers College. It is the responsibility of the research team, with guidance and assistance from the ISC, to translate all of the tests, questionnaires, scoring guides, manuals, and forms into Chinese, making suitable cultural adaptations as required, and to print the assessment materials and distribute them to the participating schools.

Design of the TIMSS 2003 Field Test

Sampling design

Students participating in TIMSS 2003 field test were sampling in two stages. In the first stage, a sample of school is selected, using an approved random sampling procedure. Taiwan was sampling 25 schools at fourth grade. In the second stage, a single intact 4th grade mathematics class is selected, also using a random sampling procedure. 1601 students in 50 classes distributed in 25 primary schools were assessed.

Instruments

The TIMSS Assessment Frameworks and Specifications 2003, provides an overview of the assessment design and the guidelines for item development. It was framed by two dimensions, a mathematics content dimension and a cognitive dimension. The content domains define the specific mathematics topics covered by the assessment, and the cognitive domains define the sets of behaviors expected of students as they engage with the mathematics content (Mullis, et al., 2001). The five mathematics content domains include number, algebra, measurement, geometry, and data. Each content domain has several topics areas, such as number including whole numbers, fractions, and decimals, and ratio, proportion, and percent. Each topic selected to be embedded into the test item was covered in the intended curriculum at fourth grade of at least 70% participating countries. The mathematics cognitive domains including four cognitive domains, knowing facts and procedures, using

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concepts, solving routine problems, and reasoning. The number (percentage) of items in each content domain was respectively: 85 (37%), 55 (24%), 39 (17%), 17 (7%), and 33 (15%). The data reveals that the number area remains a substantial part of most school mathematics curricula. A large proportion of mathematics items of the field test fall within number topic. Likewise, the number of items in each cognitive domain was respectively: 60(26%), 41(18%), 86(38%), and 42(18%). The items distributed in mathematics content and cognitive domains are summarized as Table 1-1.

Table 1-1 Distribution of the Test Items in Mathematics Domains and Cognitive Domains

Number \ Cognitive of items \ Mathematics	Knowing facts and procedures	Using concepts	Solving routine problems	Reasoning	Total (%)
Number	23	20	42	10	85 (37%)
Measurement	13	2	30	10	55 (24%)
Geometry	19	9	4	7	39 (17%)
Data	2	5	9	1	17 (7%)
Algebra	3	5	11	14	33 (15%)
Total (%)	60 (26%)	41 (18%)	86 (38%)	42 (18%)	229 (100%)

Each student completed just one of the 7 test booklets and a student questionnaire. Each booklet contains a mixture of multiple-choice and constructed-response questions. The field test contains far too many questions for every student to answer in the available time. Accordingly, all test items were distributed across seven test booklets at the 4th grade level. Each booklet contains six blocks of items including three mathematics blocks and three science blocks. Each booklet was designed to be equal difficulty and length and were supposed to be answered in 72 minutes for the assessment and 30 minutes for the questionnaire at fourth grade. The student questionnaire for collecting students' home environment and educational learning activities was to account for the differences in academic achievement. However, the relationship between the affecting factors and mathematics is not the focus of the paper.

Totally 229 items consisting of 104 multiple-choice items and 125 items constructed-responses including 112 short answers and 13 extended-responses were arranged into seven booklets. The number of items in each booklet was respectively: 33, 33, 33, 34, 33, 33, 29, and 35, as described in Table 1-2. The 7 booklets were rotated among the students in each sampled class, according to a predetermined allocation scheme, so that approximately equal proportions of students in the class responded to each booklet. Roughly 220 Taiwanese students completed each question in the field test. Taiwan administered the survey

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instruments in April and scoring in May 2002.

Table 1-2 Distribution of the Test Items in Booklets

Format / Booklet number	Multiple-choice	Constructed-response		Number of items
		Short-answer	Extended-response	
1	18	14	1	33
2	15	16	1	33
3	19	13	2	34
4	12	18	3	33
5	17	14	2	33
6	11	16	2	29
7	12	22	1	35
Total	104	112	13	229

All the instruments were modified for the Taiwan context. Instruments were also translated into Chinese and were verified by the IEA's verification center. To demonstrate the high quality of data collection procedures, Taiwan not only required to adopt a rigor approach to data collection activities including visit schools to observe data collection, but also to provide documentary evidence such as recording the compliance of the test administration with prescribed in the standard international data collection procedures.

Scoring

In constructed-response questions, students were required to write their responses. The success of assessments containing constructed-response questions depends on the degree to which student responses were scored reliably. This was accomplished through the provision of explicit scoring guides and extensive training in their use, and continuous monitoring of the quality of the work. Besides, TIMSS 2003 provided training packets for selecting questions, and practicing scoring to achieve a consistent level. TIMSS 2003 field test developed a two-digit coding scheme to diagnose students' various answers to the constructed-response items. The first digit registered the degree of correctness while the second digit was used to code the type of correct and incorrect answer given. The ultimate aim of this scheme was to provide a rich database for research on students' cognitive processes, problem-solving strategies, and common misconceptions.

Data processing

To ensure the availability of comparable, high-quality data for analysis, TIMSS undertook a set of rigorous quality control steps to create the international database. TIMSS prepared manuals and software for countries to use in recording their data on computer files so that the information would be in a standard international format before being forward to the IEA Data Processing Center (DPC) in Hamburg. Upon arrival at the DPC, the data from

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each country underwent an exhaustive cleaning process designed to identify, document, correct deviation from the international instruments, file structures, and coding schemes. DPC provided Taiwan with the percentage of each choice of answers for multiple-choice questions and of each diagnosis code for constructed-response questions. The DPC reported international average of each item and Taiwan was ranked by the international average for each item, as well.

The study tended to use the intended curriculum of Taiwan as one of the sources to explain differences in achievement. Thus, two curriculum specialists and two elementary school teachers of Taiwan examined each mathematics topic involving in each test item if it was covered in the intended curriculum of Taiwan, issued in 1993.

Results of the TIMSS 2003 Field Test

Results across content domain in mathematics

The overall average percent correct in mathematics of Taiwan and International average is 52.3% and 47.5%. Taiwanese students performed better when compared to the International average. As can be seen from Table 1-3, the average performance of Taiwanese students in number, measurement, geometry, and data was higher than international average, while the performance of Taiwanese students in algebra was lower than international average. The average percent correct of Taiwanese students in mathematics content from high to low was number (59%), geometry (54%), data (52%), algebra (49%), and measurement (48%). The highest correct percent of Taiwan and International average was found in number, while the lowest correct percent was in measurement.

Table 1-3 gives the results for the average correct percent of Taiwanese students performing in the items covered in the intended curriculum. The average correct percent of Taiwanese students in number, geometry, data, algebra, and measurement was 65%, 50%, 52%, 50%, and 53%, respectively. Of the items covered in the intended curriculum, Taiwanese students performed better in each of the five content areas than the international average.

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Table 1-3：Taiwan and International students' performance across content domains

Correct answer (%) / Content / Taiwan	Number		Measurement		Geometry		Data		Algebra	
	Taiwan	Inav	Taiwan	Inav	Taiwan	Inav	Taiwan	Inav	Taiwan	Inav
Covered in intended curriculum (# of items)	65% (60)	57%	50% (38)	45%	52% (23)	48%	50% (14)	43%	53% (19)	52%
Total (# of items)	59% (85)	50%	48% (55)	43%	54% (39)	48%	52% (17)	45%	49% (33)	50%

Inav: International average

Results across cognitive domains in mathematics

The average correct percent Taiwanese students performing on the items across cognitive domains is presented in Table 1-4. The data of the table reveals that average correct percent of the students increased with the increase in the complexity level of the performance expectation. The average correct percent of Taiwanese students in using facts and procedures, using concepts, solving routine problems, and reasoning was 61%, 53%, 51%, and 42%, respectively. The mean achievement of Taiwanese is higher than the International average at the performance levels of using facts and procedures by 61% vs. 54%, using concepts by 53% vs. 50%, solving routine problems by 51% vs. 46%, reasoning by 42 vs. 39%.

The percentage of the correct responses of the students for the items covered in the intended curriculum of Taiwan is presented in Table 1-4, by performance expectation. The average correct percent for Taiwanese and International students at different levels of performance expectation was respectively: using facts and procedures 65% and 56%, using concepts 61% and 56%, solving routine problems 54% and 50%, and reasoning 43% and 39%. Of the items involving different levels of performance expectation covered in the intended curriculum, Taiwanese students performed better in each of the levels than the international average.

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Table1-4：Taiwan and International students' performance across cognitive domains

Correct \ Content answer (%) Taiwan	Using facts and procedures		Using concepts		Solving routine problems		Reasoning	
	Taiwan	Inav	Taiwan	Inav	Taiwan	Inav	Taiwan	Inav
Covered in intended curriculum (items)	65% (48)	56%	61% (22)	56%	54% (57)	50%	43% (27)	39%
Total (# of items)	61% (60)	54%	53% (41)	50%	51% (86)	46%	42% (42)	38%

Inav: International average

Results of students' achievement by the items covered in the intended curriculum

Achievement in whole number

The number content domain contains eight-five items that assessed performance on understanding of counting and numbers, ordering and comparing numbers, and applying numbers and operations to solve problems. Of the items, 57, 12, 7, and 9 items were related to whole numbers, fractions, decimals, and ration and proportion, respectively. Of the 57 items included 9, 11, and 37 items are related to the meaning of whole numbers, rounding and computation, and solving routine and non-routine problems, respectively. The average correct percent of Taiwanese students achieved in number topics was decreasing by computation (79%), understanding the concepts of number (55%), solving routine and non-routine problems (49%), and ratio and proportion (44%). The data reveals that about 79% Taiwanese students higher than the international average (69%) have apparently mastered straightforward computation and have a competency of solving word problems. The items involved in four operations were dealt with three-digit numbers and were covered in Taiwan's intended curriculum. The average percent correct of addition, subtraction, multiplication, and division was 90%, 85%, 90%, and 83%, respectively.

The finding was that excepting 3 items, the average percent correct of each item Taiwanese students performing in understanding the meaning of whole numbers was roughly 87% and was better than international average. However, the performance of Taiwanese students in baseball game item (7.3%) was highly poor than international average (21%). The poor performance was resulted from unpopular context to Taiwanese students, when compared to western countries. An item in booklet 1 #32 involving "multiple", which was not included in Taiwan's intended curriculum, less than 50% of the students answered correctly. They misunderstood the "multiples of 8" misunderstood it as "a number containing digit 8".

The 12 items of fractions and decimals were designed to assess meaning, representation, comparing unit fractions or fractions with the same denominators, equivalent fractions, and operations of fractions and decimals. The fourth graders of Taiwan did not learn the concept

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of identifying equivalent fractions until at the fifth grade. Taiwanese students understood better the meaning of fraction and performed better on the subtraction and addition of fractions with the same denominators than the international average. 96% of the students answered correctly in these items. However, the average percent correct was decreased into 43%, when Taiwanese students preformed in shading an area for a given fraction in which the number of partitioning was not equal to the denominator of the fraction. The difficulty fourth-grade students had with solving such a problem was consistent with performing in representing a decimal. Only 13% of the Taiwanese students participating in the field test answered correctly. On the contrary, 81% of the students represented incorrectly a decimal 0.3 by shading 3 out of 20 partitions.

Likewise, Taiwanese students were not achieved well in the item in which students were asked to choose a fraction such that it is the closest to the unit fraction 1/2, when compared to the international average. They chose incorrectly the fraction with the largest number of the denominator as their final answer. The strategy Taiwanese students used to compare fractions with unlikely denominator was the same as that of comparing whole numbers, before they learned the concept in the school.

Achievement in measurement

The measurement domain contains fifty-five items that assessed performance on understanding measurable attributes and demonstrating familiarity with the unit and processes using in measuring various attributes. While working on certain measurement items, students were permitted to use paper rulers or cardboard manipulatives in the form of geometric shapes. Of the items, 11 items were related to attributes and units and 44 involved the use of tools, techniques, and formulas. Of the 44 items, 15 items were related to using instruments to measure and estimate, 7 items were to calculate area and perimeter, and 22 items were to compute measurements in simple problem situations. The average correct percent of Taiwanese students achieved in measurement was decreasing by understanding attributes and units (63%), computing measurements in simple problem situations (45%), using instruments to measure and estimate (44%), and calculating area and perimeter (41%). Moreover, calculating area and perimeter was the lowest correct percent in the measurement domain for Taiwan's students, the same as the international average (29%).

All 7 items of calculating area and perimeter were covered in Taiwan's intended curriculum, but more than 50% of Taiwanese students had the difficulty with making the distinctions between area and perimeter. For instance, 56% students misused the perimeter as area divided by 4 to solve the problem in which students were asked to find the perimeter of a given figure.

Exception of converting from meter to centimeter, fourth-graders of Taiwan have not been taught the conversion between two standard units until at the fifth grade. As a result,

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they were achieved in these items poorly. Besides, 13 items involving the use of cardboard ruler to answer a set of questions related to map, such as measuring the distance between two towns. The mean of average correct percent of Taiwanese students performed in the 7 items was more than 65%, which the correct percent Taiwanese students performed in the 5 items was decreasing to 34%.

Achievement in geometry

The 39 items in geometry included analyzing the properties and characteristics of a variety of geometric figures. These figures included lines, angles, and 2-dimension and 3-dimension shapes. Of the items, 6 items were related to lines and angles, 14 items dealt with 2-and 3-dimensioal shapes, 3 items related to congruence and similarity, 9 items dealt with location and spatial relationships, and 7 items involved in symmetry and transformations. The fourth-graders of Taiwan did not learn the concept of translation, reflection, and rotation until they are sixth-graders. In addition, the content of relating a net to a shape, identifying two similar shapes, and recognizing cones and cylinders were not included in Taiwan's intended curriculum at fourth grade level. The average correct percent Taiwanese students achieved in geometry was decreasing by lines and angles, congruence and similarity (67%), location and spatial relationships (54%), to identify the shapes with symmetry and transformation (50%), and to classify 2-dimension and 3-dimension shapes according to their properties (46%).

We found that 32 % and 64% of the fourth-graders were able to draw a line to parallel and perpendicular to a tiled line, respectively. It seems the orientation of the line was a crucial factor for students to draw a perpendicular line to the given line. 54% of Taiwanese students had a difficulty with drawing a symmetry line of a shape. They identified a reflection line of a figure as the line when it is able to partition the figure equally. Taiwanese students performing on the task dealing with three successive rotations of 90^0 (49%) were better than the tasks with the combination of translation, reflection, and symmetry (16%).

Achievement in data

In the data domain, 17 items measured the concepts of data representation, analysis, and probability. The items were designed to organize data that have been collected by others, display data in tables, graphs, charts, and plots. Of the items, only one item was related to data collection and organization, 8 items were involved in data representation, 8 items were related to data interpretation. Pie charts and histograms were not covered in Taiwan's intended curriculum for fourth graders, while the other graphs such as line graph and bar graph were presented in the intended curriculum. We discovered that fourth-graders had higher achievement in organizing and displaying data than interpreting data. The average correct percent for Taiwan and International students was respectively: displaying data 67% and 56%, interpreting data 36% and 32%. The data reveals that Taiwanese students performing on the

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data representation tasks were better than the international average. In particular, 67% of the students were able to solve the pie chart problem; even they did not learn the topic in the fourth grade.

Achievement in algebra

The algebra domain including patterns and relationships among quantities, using algebraic symbols to represent mathematical situations was measured through 33 items. It was identified as patterns, equations and formulas, and relationships. Students performing on 16 of the items, which were not included in Taiwan's intended curriculum, were poor than the international average. The average correct percent Taiwanese students achieved in algebra was decreasing by patterns, equations and formulas, and relationships. The mean achievement of Taiwanese was higher than the International average at the performance of "patterns" by 61% vs. 54% and "relationships" by 53% vs. 50%, while the mean achievement of Taiwan was lower than the international average at the performance of "equations and formulas" by 50% vs. 56%.

In terms of patterns, 9 items referred to the numeric and geometric patterns have been covered in Taiwan's intended curriculum. Students achieving in the items of geometric patterns were better than those of numeric patterns. For instance, only 22% of the students preformed successfully on making a number pattern using the "add 4" rule, while there were 58% chose incorrectly with the rule "multiplying 4" as their final answer.

Regarding the concept of relationship, there were 10 items to measure it. Relationships included 6 items for generating pairs of numbers following a given rule, 3 items for writing a rule for a relationship given some pairs of numbers satisfying the relationship, and 1 item for graphing pairs of numbers following a given rule. Within these four categories, fourth-graders of Taiwan had the most difficulty in solving the problems that asked students to write a rule for a given relationship of pairs of numbers.

Conclusion

The major finding of the study was that the overall achievement of Taiwan in the field test was better than the international average. This study supported consistently the literature of international comparison studies that report Asian students in general do well in school than other western countries. Many contribute factors may be possible to account for the differences in academic achievement. The differences in home environments and educational activities largely accounted for the differences in students' achievement between Asian and other countries students (Peng and Wright, 1994). Nevertheless, the analysis of mathematics students expected to learn in the intended curriculum investigated in the study was valuable because it provided the bases of understanding where fourth-grade students of Taiwan learned ahead and learn behind other countries curricula. Because of the non-experimental nature of

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survey data, no definitive causal effects can be inferred from the study. However, the result of the field test suggested that fourth-graders were not forgetting the traditionally held concepts and skills measured in greater proportion by the test while they focused their more heavily on a broader vies of mathematics. At the same time, we note that there is still distance to cover in assisting students to move from their present levels of performance to higher levels on those involving problem solving. Moreover, in this time of great interest in mathematics education reform, findings of the field test provided the most powerful empirical data to diminish opponents' furious blames against the 1993 version of curriculum reform. The assessment afforded an important marker of the state of students' achievement early in the period of reform.

The framework of the international assessment specifications can be as a reference for examining the extent to which mathematics contents should be covered in Taiwan's future fourth-grade curriculum. The primary school mathematics curriculum of Taiwan is undergoing development as part of revising the Curriculum 2003. Although the analysis of Taiwan's intended curriculum revealed several similarities with curricula internationally, the evidence is overwhelming that Taiwanese students lacked 21% basic knowledge expected at international intended curriculum at the fourth grade level and furthermore cannot communicate their answers in the language of the field test. There were 3%, 4%, 7%, 1%, and 6% in number, measurement, geometry, data, and algebra. In number domain, fourth-graders did not learn the concepts of multiples of a number, the meaning of equivalent fractions and reduced a fraction to a simple fraction, an integer multiplying a fraction, and proportion. In measurement domain, Taiwan's intended curriculum at fourth grade level did not cover the topics of converting between kilograms and grams and using proportion to measure the distance between two locations on the map. In geometry domain, fourth-graders of Taiwan did not learn to recognize pentagons and hexagons, to identify similar figures, to recognize relationships between 2- and 3-dimenstional shapes when shown 2-dimentsioal views of cones and cylinders, and to operated the geometric transformation. In data domain, Taiwan' intended curriculum did not cover the topics including interpreting pie chart and the change of line graph. In algebra, fourth-graders of Taiwan have not been taught to find missing terms of numeric patterns and to select a rule for a relationship given some pairs of numbers. Clearly, the lack of learning the topics measured in the field test may possible be a contributing factor to Taiwanese students performing poorly in some items.

Taiwanese students struggled with complex problem-solving questions that were presented in the consecutive sub-questions. Fourth-graders seldom engaged the problem-solving questions including mathematics games such as number and geometry tiles and reversal numbers in classroom. The unfamiliarity of the assessment format is likely to be another factor contributing to Taiwanese students performing poorly in the problem-solving questions. Some of the sub-questions were dependent mutually; as a consequence, students

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had more possibility to perform unsuccessfully in the problem-solving questions than other multiple-choice questions. The performance in the free-response items (48%) was much more than that of multiple-choice questions (62%) and it appears that many students depended on guessing the correct option and thereby achieving a higher score than by writing a correct answer to open-ended questions. Thus, the field test can serve as a source of assessment tasks that can be used or adapted for use in national assessment or teachers' classrooms.

In addition, the context referred to some of the questions was not suitable to Taiwan's cultures. For instance, bike rental is not a popular market and a ticket price of a fair for a child and an adult in Taiwan is not as cheap as the price referred to in the field test items. The contexts involving in these items were not realistic situations for the fourth-graders of Taiwan. This may possible be the third factor contributing to Taiwanese students performing poorly in some items.

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