

THE MATHEMATICAL ACHIEVEMENT OF FOURTH-GRADERS OF TAIWAN IN THE TIMSS 2003 FIELD TEST

Pi-Jen Lin

National Hsin-Chu Teachers College, Taiwan

Abstract

Taiwan's mathematics curriculum has undergone three reforms in the last three decades. The Standard of School Mathematics Curriculum, issued in 1993 and implemented in 1996, has been in effect for six years. There is a heated debate over the content of mathematics curriculum and over whether students still maintain mathematical proficiency. For this reason, student performance in each mathematics strand in the TIMSS 2003 field test was examined. Moreover, the study proposed 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 sampled 1601 students in 50 classes distributed in 25 primary schools. Two curriculum specialists and two teachers inspected each item of the test, to see whether it was covered in the intended curriculum, issued in 1993.

It was found that Taiwanese students performed better in mathematics 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 students in algebra was lower than the international average. This study offers a curriculum analysis as a resource to explain the differences in academic achievement of mathematics topics. In this time of great interest in mathematics education reform, the findings of the field test provided powerful evidence to diminish opponents' attacks on the 1993 version reform. The assessment afforded an important marker of the level of students' achievement in the period of reform. The lack of learning the topics measured in the field test, unfamiliarity with assessment format, the culturally unfamiliar in some context referred to questions were possible factors contributing to Taiwanese students' poor performance in some items.

INTRODUCTION

Three Curriculum Reforms in Taiwan

Taiwan's mathematics curriculum has been 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 first describes 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 concentrated in urban areas and, as a result, the typical class in urban areas has 30-35 students and 25-28 students in suburban areas. 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 elementary schools has been used nationwide. Mathematics is one of the seven courses offered in elementary school. The proportion of mathematics classes per week in grade 1-2, grade 3-4, and grade 5-6 are $\frac{3}{26}$, $\frac{4}{33}$, and $\frac{6}{35}$, respectively. Each class is 40 minutes in length. The school day is from Monday morning to Friday afternoon. Students have no school on Wednesday afternoons, when the teachers attend in-service professional training. A typical school day containing seven classes begins at 7:30 a.m. and runs through to 4:00 p.m. The first hour of each day functions as a morning pre-session time in which students are educated in ethics and assignments are checked. Elementary school teachers generally teach 25 classes per week. Two-thirds of elementary school teachers are responsible for teaching all subject areas to their homeroom class. The other one-third of teachers specializing in courses like art, music, or science, teaches their specialization to different classes throughout the school. Thus, 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 the past three decades was replaced by the newly published textbooks, which must be 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 and away from the teacher-centered approach. Teachers under the 1993 reform version faced a complete paradigm shift; as a result, they were put under enormous pressure to teach the mathematics contents in the time available in the school schedule.

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. This represents one of the largest educational reforms to date. Courses offered in elementary and junior high schools have shifted from subject-oriented to area-oriented. The indicators for measuring student achievement in the new curriculum are of competency-driven, as opposed to the topic-driven as this had been in the traditional version. As a consequence, the mathematics content for the various grade levels is determined by those committees who write textbooks for different publishers. Therefore, certain mathematical concepts might be targeted for in different grade levels depending on the publisher of the textbook. Under the reform teachers are expected to help students link the connections between two mathematical concepts and bridge any gaps that might arise from using one textbook and then changing to another textbook. One new expectation placed on elementary and high school teachers under the reform is that their role changes from an executor to a designer of curriculum. Teachers are expected to play an active role in using curriculum.

Mathematics is one of the seven learning areas in the 2001 curriculum. 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 curriculum was less than that of the 1975 version, and the school week has been reduced to five from six days. Moreover, the mathematics contents recommended in the curriculum is not as great as that of the 1975 and 1993 versions.

The reform of 1993 has been in effect six years. Currently six-grade students use the textbooks of the 1993 curriculum, while the first- to fifth-grade students use the textbook of the 2001 version. There is a furious debate over mathematics in curriculum and the most effective way of teaching mathematics. Indeed, the mathematics education community is confronted with thousands of newspaper articles and websites arguing for or against the constructivist approach. Some involve interviews 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 oppose the reform of 1993 blame it for students' poor computation skill despite the fact that there is no evidence to support this. The influence of the reform on students' mathematics achievement has become an issue of debate between the proponents and opponents. Nevertheless, there was no adequate large-scale data on the reform of 1993 to resolve the debate and to measure students' performance under the curriculum reform. Now, however, we have the data collected from the TIMSS field test administered to fourth grade students who used only the 1993 version from first grade through fourth grade. Thus, the purposes of the study were: 1) to understand how fourth-graders of Taiwan performed in mathematics and 2) to compare the level of fourth-grade mathematics achievement of Taiwan to the 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 in many different countries have analyzed the data from IEA's Third International Mathematics and Science Study (TIMSS) and have produced scholarly work on the contexts that affect students, classroom, and school outcomes. Also,

many doctoral dissertations students studying science and mathematics have analyzed the data collected from the different populations involved in TIMSS. In mathematics, a group of researchers examined how teachers' personal beliefs about how students learn mathematics and their instructional practices relate to the mathematical achievement of eighth graders (Gales, 2000; Gerber, 2000). Results indicate that teachers' beliefs and practices are not related to students' achievement (Gerber, 2000). A second group of researchers sought to determine the relevance to achievement of certain factors including home environment, peer influences, school environment, educational aspirations, attitudes toward mathematics and habits in three countries including the Republic of South Korea, Singapore, and the United States as measured by TIMSS (Chen, 2001). Another group of researchers using the video component 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 follow-up studies of TIMSS made comparative analyses across countries, and as such have little bearing on mathematics education in a particular country. Moreover, there is a little research on TIMSS using the intended curriculum of a country as a resource to interpret students' mathematical achievement in relation to different mathematics strands.

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

TIMSS 2003 is directed and coordinated by the TIMSS International Study Center (ISC), which is located at Boston College, in the United States. The National Research Coordinator (NRC) 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.

Sampling design

Students participating in TIMSS 2003 field test were sampled in two stages. In the first stage, a sample of schools is selected, using an approved random sampling procedure. Taiwan sampled 25 schools at fourth-grade level. 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 numbers 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 include four cognitive domains, knowing facts and procedures, using 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 the 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

<i>Number of items</i> <i>Cognitive</i> <i>Mathematics</i>	<i>Knowing facts and procedures</i>	<i>Using concepts</i>	<i>Solving routine problems</i>	<i>Reasoning</i>	<i>Total (%)</i>
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 of 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 level. The student questionnaire collected data on students' home environment and educational learning activities, as these factors might account for differences in academic achievement. However, the relationship between the affecting factors and mathematics is not the focus of this paper.

A total of 229 items consisting of 104 multiple-choice items and 125 constructed-response items 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 instruments in April and began scoring in May 2002.

Table 1-2: Distribution of the Test Items in Booklets

<i>Booklet number</i>	<i>Format</i>	<i>Multiple-choice</i>	<i>Constructed-response</i>		<i>Number of items</i>
			<i>Short-answer</i>	<i>Extended-response</i>	
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 was not only required to adopt a rigorous approach to data collection activities including visit schools to observe data collection, but also to provide documentary evidence that the test administration complied with prescribed 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 forwarded to the IEA Data Processing Center (DPC) in Hamburg. Upon arrival at the DPC, the data from each country underwent an exhaustive cleaning process designed to identify, document, correct deviation from the international instruments, file structures, and coding schemes. The DPC provided Taiwan with the percentage for each answer to multiple-choice questions and for each diagnostic code for constructed-response questions. The DPC reported the international average of each item, and ranked each country in relation to the international average for each item, as well.

This study proposes 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 involved in each test item to see if it was covered in the intended 1993 curriculum of Taiwan.

RESULTS

Results across content domain in mathematics

The overall average percent correct in mathematics of Taiwan and International average is 52.3% and 47.5%, indicating that 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 the international average, while the performance of Taiwanese students in algebra was lower than international average. The Taiwanese students' average percent correct in mathematics content from high to low were number (59%), geometry (54%), data (52%), algebra (49%), and measurement (48%). The highest correct percent for both Taiwan and International average was in number, while the lowest correct percent was in measurement.

Table 1-3 gives the results for the Taiwanese students' average correct percent for the items covered in the intended curriculum. The Taiwanese average correct percent of in number, geometry, data, algebra, and measurement were 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.

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%	57%	50%	45%	52%	48%	50%	43%	53%	52%
	(60)		(38)		(23)		(14)		(19)	
Total (# of items)	59%	50%	48%	43%	54%	48%	52%	45%	49%	50%
	(85)		(55)		(39)		(17)		(33)	

Inav.: International average

Results across cognitive domains in mathematics

The Taiwanese average correct percent on the items across cognitive domains is presented in Table 1-4. The data of the table reveals that the student performance increased with the increase in the complexity level. The Taiwanese average correct percent in using facts and procedures, using concepts, solving routine problems, and reasoning were 61%, 53%, 51%, and 42%, respectively. The Taiwan mean achievement is higher than the International average for 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 percentages of correct responses for the items covered in the intended curriculum of Taiwan are presented in Table 1-4, by performance expectation. The Taiwan average correct percent compared to the International average at different levels of performance expectation were, 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.

Table 1-4: Taiwan and International students' performance across cognitive domains

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

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. Items 57, 12, 7, and 9 were related to whole numbers, fractions, decimals, and ratio and proportion, respectively. Of the 57 number-related items, 9, 11, and 37 items refer to the meaning of whole numbers, rounding and computation, and solving routine and non-routine problems, respectively. The Taiwan average correct percent in number topics were in decreasing order 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, which is higher than the international average (69%), have apparently mastered straightforward computation and have competency in solving word problems. The items involved four operations that dealt with three-digit numbers and were covered in Taiwan's intended curriculum. The average percent correct of addition, subtraction, multiplication, and division were 90%, 85%, 90%, and 83%, respectively.

Thus, apart from three items, the Taiwan average percent correct for each item related to understanding the meaning of whole numbers was roughly 87%, better than international average. However, the performance of Taiwanese students on the baseball game item (7.3%) was very poor compared to the international average (21%). The poor performance was the result of the question context, which was unfamiliar to Taiwanese students in relation to western countries. Item #32 in booklet 1 used the term "multiple", which was not included in Taiwan's intended curriculum, and therefore less than 50% of the students answered correctly. They misunderstood the phrase "multiples of 8" to mean "a number containing digit 8".

The 12 items on 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 of identifying equivalent fractions until the fifth grade. Taiwanese students understood the meaning of fractions better and performed better on the subtraction and addition of fractions with the same denominators than the international average - 96% answered correctly in these items. However, the average percent correct fell to 43%, when Taiwanese students were required to shade an area for a given fraction in which the number of partitioning was not equal to the denominator. Fourth-grade students had similar difficulty performing the same task with a decimal, on which only 13% of Taiwanese students answered correctly. In contrast, 81% of the students incorrectly represented the decimal 0.3 by shading 3 out of 20 partitions.

Likewise, compared to international average, Taiwanese students did not perform well on the item in which students were asked to choose a fraction such that it is the closest to the unit fraction $\frac{1}{2}$. They incorrectly chose the fraction with the largest denominator as their final answer. The strategy Taiwanese students used to compare fractions with different denominators, 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 55 items, 11 were related to attributes and units and 44 involved the use of tools, techniques, and formulas. Of the 44 latter items, 15 were related to using instruments to measure and estimate, 7 were to calculate area and perimeter, and 22 were to compute measurements in simple problem situations. The Taiwan average correct percent in measurement were in decreasing order, 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 showed 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 difficulty distinguishing 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.

Except for converting from meter to centimeter, fourth-graders of Taiwan are not taught the conversion between two standard units until the fifth grade. As a result, they performed poorly on these items. Besides, these were 13 items involving the use of a cardboard ruler to answer a set of questions related to a map, such as measuring the distance between two towns. The Taiwan mean average correct percent on the 7 items was above 65%, while the correct percent on the 5 of these 7 items was only 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 were related to lines and angles, 14 dealt with 2-and 3-dimension shapes, 3 related to congruence and similarity, 9 dealt with location and spatial relationships, and 7 involved symmetry and transformations. The fourth-graders of Taiwan do not learn the concept of translation, reflection, and rotation until they are sixth-graders. In addition, the concepts of relating a net to a shape, identifying two similar shapes, and recognizing cones and cylinders are not included in Taiwan's intended curriculum at fourth-grade level. The Taiwan average correct percent in geometry were, in decreasing order, 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 parallel and perpendicular to a tiled line, respectively. It seems the orientation of the line was a crucial factor drawing a perpendicular line to the given line, and 54% of Taiwanese students had difficulty with drawing a symmetrical line of a shape. They identified a figure's reflection line when it partitioned the figure equally. Taiwanese students performed better on the task dealing with three successive rotations of 90° (49%) than the tasks on 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 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 performed better on the data representation tasks than the international average. In particular, 67% were able to solve the pie chart problem, even though they did not learn the topic in the fourth grade.

Achievement in algebra

The algebra domain included 33 items on patterns and relationships among quantities, using algebraic symbols to represent mathematical situations, identified as patterns, equations and formulas, and relationships. Sixteen of the items which were not included in Taiwan's intended curriculum, so Taiwanese performance was lower than the international average. The Taiwan average correct percent in algebra items were, in decreasing order patterns, equations and formulas, and relationships.

The mean achievement of Taiwanese students was higher than the International average for "patterns" by 61% vs. 54% and "relationships" by 53% vs. 50%, while the mean achievement of Taiwan students was lower than the international average for "equations and formulas" by 50% vs. 56%.

In terms of patterns, 9 items referred to the numeric and geometric patterns, which were covered in Taiwan's intended curriculum. Students performed better in the items of geometric patterns than those of numeric patterns. For instance, only 22% of the students successfully made a number pattern using the "add 4" rule, while 58% chose the incorrect answer, using the "multiplying 4 rule" as their final answer.

Regarding the concept of relationship, there were 10 items. 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 consistently supported the literature on international comparison studies that report Asian students in general do better in school than other, western countries. Many different factors may account for the differences in academic achievement. The home environment and educational activities largely accounted for the differences in Asian students' versus other students' achievement (Peng and Wright, 1994). Nevertheless, our analysis of the mathematics students are taught in the intended curriculum was valuable because it provided a basis for understanding in which areas the fourth-grade curriculum of Taiwan was ahead and behind those of other countries. Because of the non-experimental nature of 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 traditional concepts and skills measured in greater proportion by the test, while they focused more heavily on a broader area 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 for those areas 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 counter opponents' accusations against the 1993 version of curriculum reform. The assessment afforded an important marker of the level of students' achievement early in the period of reform.

The framework of the international assessment specifications can be used as a reference for examining the extent to which certain mathematics concepts 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 internationally 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 the number domain, fourth-graders did not learn the concepts of multiples of a number, the meaning of equivalent fractions and reducing a fraction to a simple fraction, an integer multiplying a fraction, and proportion. In the 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 the 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-dimensional shapes when shown 2-dimensional views of cones and cylinders, and to perform the geometric transformation. In the data domain, Taiwan's intended curriculum did not cover the topics interpreting pie charts and the change of line graphs. 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 possibly be a contributing factor to Taiwanese students' poor performance 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' poor performance in the problem-solving questions. Some of the sub-questions were mutually dependent; as a consequence, students were less likely to successfully perform the problem-solving questions than other multiple-choice questions. The performance in the free-response items (48%) was lower than that for 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 in some of the questions was not suitable to Taiwan's culture. For instance, bike rental is an uncommon practice, and a ticket price for 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 in these items were not realistic situations for the fourth-graders of Taiwan. This may possibly be the third factor contributing to Taiwanese students' poor performance in some items.

References

- Chen, H. L. (2001). *A cross-national study of factors influencing mathematics achievement for eight-grade students*. Unpublished Dissertation. Boston College.
- Gales, M. J. (2000). *Relationship between constructivist teacher beliefs and instructional practices to students' mathematical achievement: Evidence from TIMSS*. Unpublished Dissertation. Indiana University of Pennsylvania.

- Gerber, S. (2000). *Teachers' orientations and practices: Students' mathematics achievement*. Unpublished Dissertation. State University of New York at Buffalo.
- Kawanaka, T. (2000). *Comparative case studies of mathematics instruction and learning in three high-achieving European Countries (Czech Republic, Switzerland, Netherlands)*. Unpublished Dissertation. University of California, Los Angeles.
- Ministry of Education of Taiwan (1993). *The standards of elementary school mathematics*. Taiwan: Taipei.
- Ministry of Education of Taiwan (2000). *The Nine-year school Curriculum*. Taiwan: Taipei.
- Mullis, I. S, Martin, M.O., Smith, T.A, Garden, R.A, Gregory, K.D, Gonzalez, E.J, Chrostowski, S.J & O'conner, K.M. (2001). *TIMSS Assessment Framework and specification 2003*, International Study Center. Lynch School of Education, Boston College.
- Peng, S. & Wright, D. (1994). Explanation of academic achievement of Asian American students. *Journal of Educational Research*, 87 (6).

ACKNOWLEDGEMENTS

Preparation of this report was supported in part by National Science Council grant NSC92-2511-S-003-001. However, opinions given in this paper represent that of the author and not the funding agency. The author acknowledges the research team for their invaluable contribution to the research project.