The Japanese Perspective on TIMSS

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Abstract: The International Association for the Evaluation of Educational Achievement (IEA) undertook three international mathematics studies: the first, FIMS, in 1976 , the second, SIMS, in 1980, and the third, TIMSS, in 1995. 13-year-old Japanese students were included in these studies. The purpose of this paper is to discuss the level of mathematics achievement and attitudes toward mathematics among Japanese students and the situation of mathematics education in Japan, based on the results of TIMSS and previous studies.

From our analysis of results, we can indicate the following points: Although achievement in the fundamental techniques of calculation can be viewed in general as satisfactory, the attainment levels cannot be regarded as acceptable for problems which require a high degree of thinking and comprehension. And from the consequence of international comparison about interest and attitude, it became evident that a smaller fraction of Japanese students have a favorable opinion than in other countries.

Kurzreferat: *TIMSS – aus japanischer Perspektive.* Die IEA (International Association for the Evaluation of Educational Achievement) führte drei internationale Studien zur Mathematik aus: die erste, FIMS, 1976, die zweite, SIMS, 1980, und die dritte, TIMSS, 1995. Die Studien bezogen auch 13jährige japanische Schüler mit ein. Ziel dieses Beitrags ist es, das Niveau mathematischer Leistung und Einstellungen zur Mathematik japanischer Schüler sowie die Situation des Mathematikunterrichts in Japan auf der Basis von TIMSS und den vorhergehenden Studien zu diskutieren.

Unsere Analyse der Ergebnisse ergibt folgendes: Obwohl die Leistung in grundlegenden Rechenfertigkeiten im allgemeinen als zufriedenstellend angesehen werden kann, ist das Leistungsniveau bei Aufgaben, die einen hohen Grad an Denkfähigkeit und Verständnis erfordern, nicht akzeptabel. Und was Interesse und Einstellungen im internationalen Vergleich betrifft, so wurde offensichtlich, dass von japanischen Schülern ein kleinerer Teil als in anderen Ländern eine positive Einstellung besitzt.

ZDM-Classification: D13

1. Introduction

In 1995, the Third International Mathematics and Science Study (TIMSS) was conducted in 41 countries/systems including Japan. This study was carried out by the International Association for the Evaluation of Educational Achievement (IEA) in cooperation with all participating countries/systems.

The first major IEA study was concerned with mathematics achievement. The data from this survey were collected in 1964 in 12 countries including Japan. This study will be called the First International Mathematics Study (FIMS). It made public for the first time the high level of achievement in mathematics of Japanese students throughout the world. And also, the Second International Mathematics Study (SIMS) was carried out by IEA in cooperation with each of more than 20 participating countries/systems including Japan in 1980–81.

The purpose of this paper is to discuss the level of mathematics achievement and attitudes toward mathematics, and its tendency among Japanese students and in mathematics education in Japan, based on the results of TIMSS and others. Our data records come out from these international and national reports: Husen 1967, Travers & Westbury 1989, Robitaille & Garden 1989, Beaton et al. 1996 a, b, NIER 1996.

2. Mathematics curriculum and achievement

2.1 Curriculum analysis

TIMSS in Japan was carried out among 10-year-old and 13-year-old students. Another envisaged sample of students in the final year of secondary school in Japan was not carried out because of the lack of data and the difficulty of sampling students in the 3rd grade of upper secondary schools (12th grade). In Japan, we regard students in the third and fourth grades of elementary school (aged 10 years) and in the 1st and 2nd grades of lower secondary schools (7th and 8th grades) aged 13 years, and in each case we studied approximately 150 classes/schools and 5,000 students respectively in 1995.

At this study we intended not to simply compare achievements among participating countries/systems, but to study each nation's mathematics curriculum and teaching methods and then to investigate the relation between them and students' attainments. When we compare the results of Japan with those of other countries, we must consider differences of curriculum between them. One of the indexes we can use to see the learning condition is the results of Test-Curriculum Matching Analysis (TCMA). To gather data about the extent to which the TIMSS tests were relevant to the curriculum of the participating countries, TIMSS asked the NRC (national research coordinator) of each country to report whether or not each item was in the country's intended curriculum at each of the grades being tested.

At the eighth grade, for example, half of the countries indicated that items representing 90% or more of the score points (145 out of total 162 items) were appropriate, with a total average of 87%. And also, at the fourth grade, two-thirds of the countries indicated that items representing three-quarters or more of the score points (85 out of total 113 items) were appropriate, with a total average of 79%. When students have many learning opportunities in mathematics, they will be able to get better results.

Table 1 indicates percentages of TCMA and results of students' achievements scores for grades 3, 4, 7 and 8 students in Japan and international average.

Table 1: Test-curriculum matching analysis and mathematics achievement for TIMSS

	Japan		International	
Grade	TCMA	Score (*a*)	TCMA	Score
3th grade	74%	538 (3)	57%	470
4th grade	89%	597 (3)	79%	529
7th grade	90%	571 (3)	73%	484
8th grade	94%	605 (3)	87%	513

(Note) TCMA: results of test-curriculum matching analysis
Score: Average score of students' achievement at each grade
a: ranking among the participating countries/systems
Source: IEA Third International Mathematics Study (TIMSS), 1994-95

In comparison with the international average in Table 1, students in Japan have both high average scores concerning the results of TCMA and high achievement scores in all grades.

Next, Table 2 indicates percentages of opportunities to learn and students' achievements for both Japanese and international data among the 13-year-old in SIMS. Here "*O*pportunity *to* *L*earn" (OTL) means ratings by teachers of whether the content needed to respond to each item on the mathematics test had been taught to their students that year, in previous years, or not at all.

Table 2: Opportunity to learn and mathematics achievement for SIMS

	Japan		International	
Grade	OTL (%)	Score (*a*)	OTL (%)	Score
Arithmetic	85	60 (1)	80	51
Algebra	83	60 (1)	73	43
Geometry	51	58 (1)	52	41
Statistics	76	71 (1)	57	55
Measurement	95	69 (1)	80	51
Total	77	62 (1)	69	47

(Note) OTL: "Opportunity to Learn" rated by teachers
Score: Average percentage of students' correct responses by contents areas
a: ranking among the participating countries/systems
Source: Second International Mathematics Study (SIMS), 1980-81

According to the international data in Table 2, there are good learning opportunities in arithmetic, algebra and measurement but not in geometry, probability and statistics. Further, in algebra, the more opportunities a country gives to students, the better will be the students' achievements, but in geometry there seems to be no relation between opportunity to learn and achievements, as reported. It seems that all countries/systems are confused about the contents and teaching method in geometry. In Japan, except for geometry, there are good opportunities to learn in all domains, and in each domain Japanese students got the best scores of 20 countries/systems.

These are the results of a comparison based on the "Implemented Curriculum", i.e. the actual learning activities in each school. We can also take another way to compare by the *Course of Study* (national curriculum guidelines for all subjects at all educational levels) and textbooks, etc.

The SIMS study applied the rates of opportunity to learn to the former, and the rates of appropriateness of items to the latter, which was determined in advance by what percentage of specialists in each country/system judged each item as effective concerning their curriculum. In a comparison on the "Intended Curriculum", we find that most elements of the mathematics curriculum are introduced half a year or even one year earlier in elementary and lower secondary schools in Japan than in other developed countries like the U.S., England and France.

In most countries curricula are reviewed in the next school year, but in Japan few schools use the spiral method and in general their curriculum is taught intensively and efficiently within one school year, so they can introduce various elements of the curriculum earlier than others.

2.2 Students' achievement in mathematics

We can consider each nation's educational level by comparing the "Attained Curriculum" indicated by students' achievements and changes of their attitude towards mathematics. The international report showed the mean achievements of each country by the grade levels. We tried to arrange them by top ten countries for TIMSS in Table 3.

Table 3: Mathematics achievement by each grade for TIMSS

rank	G3 M (se)	G4 M (se)	G7 M (se)	G8 M (se)
1	KOR 561(2.3)+	SIN 625(2.1)+	SIN 601(6.3)+	SIN 643(4.9)+
2	SIN 552(4.8)+	KOR 611(2.1)+	KOR 577(2.5)*	KOR 607(2.4)+
3	JPN 538(1.5)	JPN 597(2.1)	JPN 571(1.9)	JPN 605(1.9)
4	HKO 524(3.0)-	HKO 587(4.3)*	HKO 564(7.8)*	HKO 588(6.5)*
5	CZC 497(3.3)-	NET 577(3.4)-	BFL 558(3.5)-	BFL 565(6.5)-
6	NET 493(2.7)-	CZC 567(3.3)-	CZC 523(4.9)-	CZC 564(4.9)-
7	SLO 488(2.9)-	OST 559(3.1)-	NET 516(4.1)-	SLV 547(3.3)-
8	OST 487(5.3)-	SLO 552(3.4)-	BUL 514(7.5)-	SWI 545(2.8)-
9	AUS 483(4.0)-	IRE 550(3.4)-	OST 509(3.0)-	NET 541(3.7)-
10	USA 480(3.4)-	HUN 548(3.7)-	SLV 508(3.4)-	SLO 541(3.2)-

(Note) G 3 = Grade 3, G4 = Grade 4, G 7 = Grade 7, G 8 = Grade 8
M: mathematics score,
(se): standard errors are presented in parentheses,
KOR= Korea, SIN= Singapore, JPN= Japan, HKO= Hong Kong, CZC= Czech Republic, NET= Netherlands, BFL= Belgium(FL), SLO= Slovenia, OST= Austria, SLV= Slovak Republic, BUL= Bulgaria, SWI= Switzerland, AUS= Australia, IRE= Ireland, HUN= Hungary, USA= United States
+ : Significantly higher than Japanese score,
* : No significant difference from Japanese score,
- : Significantly lower than Japanese score
Source: Third International Mathematics Study (TIMSS), 1994–95

Table 3 presents the mean achievement for the top ten countries at the third, fourth, seventh and eighth grades. Singapore and Korea were the top-performing countries at both the third and fourth grades. Japan was second level and also performed very well. Hong Kong was not significantly different from the Japanese score at the fourth grade. Other countries scored significantly lower than Japan. Singapore was the top country at both the seventh and eighth grades, and Singapore and Korea had a significantly higher mean achievement than other countries at the eighth grade. Japan and Hong Kong also performed very well and got second place.

3. Changes in mathematics achievement from 1964 to 1995: FIMS, SIMS and TIMSS in Japan

In the 30 years since the 1960s, after the First International Mathematics Study (FIMS) had been performed, great reforms of mathematics education took place in many countries. In the first decade of this period, a modernization movement of mathematics education (New Math Movement) developed in each country and was implemented in the second decade. In the last decade, teaching methods using various technologies were introduced in the mathematics classroom. It was very interesting to study the results. In the SIMS international report of 1989 (Travers/Westbury 1989), the problems caused by a rapidly increasing number of students entering upper secondary schools, the changes of the mathematics curriculum in each country and the comparisons of results in each contents are presented in detail.

We have a great interest in changes in the mathematics achievement from FIMS and SIMS to TIMSS. We therefore examined the 9 key items included in each achievement test for 13 year-old students in all three studies. These key items are divided into 5 non-verbal (computational) problems and 4 verbal problems by the criteria of the FIMS. Japanese students' achievements are presented in Table 4.

Table 4: Mathematics achievement in FIMS, SIMS and TIMSS: 13-year-old pupils in Japan

Area	No	FIMS	SIMS	TIMSS	T-S	T-F
Overall	9	64.4	63.4	65.6	2.2	1.2
Non-verbal	5	62.5	65.9	69.3	3.4	6.8
Verbal	4	66.8	60.8	60.9	0.1	-5.9

(Note) No: number of key items from FIMS to TIMSS

According to the achievement scores of anchor items from the first study to the third, the total scores (overall) are nearly the same for all three studies but there are some difference by items. For example, while the results of simple calculation (non-verbal) improved by 3 $\sim$ 7% from the first study, the results of verbal items which requires reading ability, judgment and mathematical thinking decreased by 6% from the first study in 1964. Figure 1 shows more evident facts.

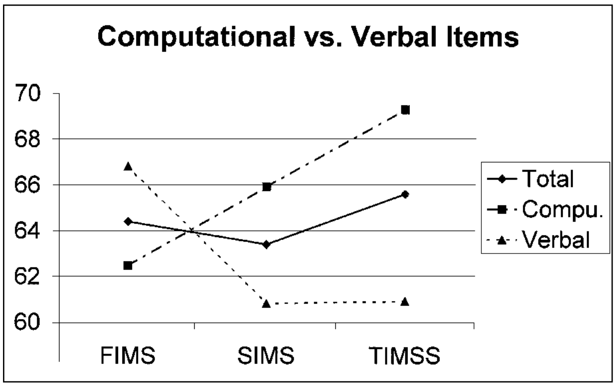

Fig. 1: Change in mathematical achievement from FIMS to TIMSS

As is shown in the graph in Figure 1, the total score is not nearly changed in each study. The computational score increased rapidly, but on the other hand the verbal score decreased in the stage of SIMS and TIMSS as compared to FIMS.

Next, we would like to show a comparison of the average number of correct answers to some common problems for 13-year-old students in each study in Japan.

Example 1 (item A07 in TIMSS)
If P=LW and if P=12 and L=3, then W is equal to
A 3/4 B 3 *C 4 D 12 E 36

Correct Answers: FIMS = 77% SIMS = 82% TIMSS = 84%

Example 2 (F07)
A runner ran 3,000 meters in exactly 8 minutes.
What was his average speed in meters per second?
A 3.75 *B 6.25 C 16.0 D 37.5 E 362.5

Correct Answers: FIMS = 51% SIMS = 38% TIMSS = 41%

Example 1 is a computational problem, and items like this tend to have a higher score than in the previous study. On the other hand, example 2 is a verbal problem, and items like this have a tendency to have a lower score than in the previous study. For problems such as simple calculation, Japanese students got very good scores but for a word problem which requires the power of thought like example 2 they did not rate as high as expected.

Though Japanese students' achievements were high in this international comparison, it can be said that there will be a big problem for school education in the future, because their good results reflect only their computational skills while the results of questions requiring thinking and application power had declined.

Why did this change occur? After the first study, there was a world-wide reform in mathematics education. That is to say, the 1960s and '70s were the decades of a movement of so-called "Modernization of Mathematics Education" (New Math Movement) and in this period some new concepts like "Set" were introduced already in lower grades. And this raised a problem in the USA and elsewhere, i.e. a decline of computational ability because too much emphasis was placed on teaching these concepts, and in fact this was proved in the IEA's study.

However, the achievement of Japan was just the opposite of this. It can be thought that the teaching of mathematical thinking is neglected while students are crammed with knowledge and technique to pass the hard entrance examinations.

4. Interest in mathematics

In these studies, students were expected to answer mathematics tests and also a questionnaire about their interest in mathematics.

Figure 2 shows the results of a students' questionnaire to "which of the following two subjects did you like best?"

A: Japanese language,
B: Social studies,
C1: Mathematics (number, algebra),
C2: Mathematics (geometry),
D1: Science (physics, chemistry),
D2: Science (biology, earth science),
E: Music,
F: Fine arts,
G: Health and physical education,
H: Industrial arts and homemaking,
I: English.

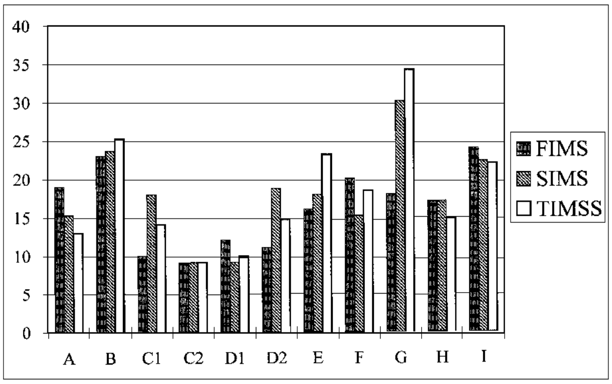

Fig. 2: Most interest subjects

During these studies, responses of C2 (geometry) are the lowest. The percentages are respectively 9.0%, 9.1% and 9.1%. and the values of the sum of C1 (algebra) and C2 have changed respectively to 19.0%, 27.1% and 22.2%. Many educators and teachers in Japan think that the number of students who dislike mathematics has increased amazingly in recent years. However, Figure 2 does not indicate this for mathematics. The Japanese language tends to be liked less by students, but fine arts and health and physical education have gone up.

Table 5 provides students' responses to the question about how much they like or dislike mathematics in relation to their average mathematics achievement in TIMSS.

Table 5: How much do they like mathematics (TIMSS: Eighth grade)

	Dislike a lot		Dislike		Like		Like a lot	
Country	%	MA	%	MA	%	MA	%	MA
Japan	11	550 (4.1)	36	585 (2.6)	43	625 (2.3)	10	649 (4.1)
Australia	12	480 (5.2)	24	523 (4.8)	51	541 (4.1)	13	563 (5.0)
Belgium (FL)	11	520 (7.3)	21	558 (4.9)	49	566 (6.7)	18	602)(6.2)
England	5	473 (8.5)	15	499 (6.5)	56	507 (3.2)	24	518 (4.6)
France	12	506 (5.7)	22	524 (4.6)	51	544 (3.3)	17	566 (5.5)
Germany	23	481 (4.8)	20	508 (6.8)	31	525 (5.0)	24	522 (5.7)
Israel	10	513 (9.8)	24	523 (8.2)	46	522 (5.5)	21	536 (8.5)
Netherlands	13	494 (17.1)	30	535 (7.5)	50	554 (6.2)	8	567 (9.2)
Scotland	7	458 (6.4)	19	493 (5.3)	57	498 (6.0)	17	529 (9.8)
Sweden	11	479 (4.9)	29	510 (3.2)	48	526 (3.3)	13	547 (5.1)
United States	12	463 (5.2)	17	492 (5.2)	47	504 (4.8)	23	519 (6.1)

(Note) %: Percent of students, MA: Mean Achievement,
( ): Standard errors appear in parentheses
Source: IEA International Mathematics Study (FIMS, SIMS and TIMSS)

From Table 5, the significant differences in average achievement by each category in Japan, Sweden and Australia are:

Dislike a lot < Dislike < Like < Like a lot

In England, Israel and the Netherlands, the significant differences in average achievement by each category are:

Dislike a lot = Dislike = Like = Like a lot

In Scotland, the United States and Germany, the significant differences in average achievement in each category are:

Dislike a lot < Dislike = Like = Like a lot

According to the relative consequences of the above countries, many students in England, Scotland and the United States had a favorable opinion of mathematics, and reversely many students in Japan, Germany and the Netherlands felt dislike in mathematics. Other questionnaires suggest the same, i.e. that the proportion of negative responses is larger than in other countries. I am very anxious about that.

5. Concluding remarks

From the data and analysis, several generalizations can be made, particularly as they may bear on policy formulation for future goals. These are as follows:

5.1 Although achievement in the fundamental techniques of calculation can be viewed in general as satisfactory, the attainment levels cannot be regarded as acceptable for problems which require a high degree of thinking and comprehension.

5.2 Specifically, the achievement declined as compared with the previous study for such problems as "ratio" and "proportion", which are taught in the upper grades of elementary school, and for verbal problems.

5.3 It might be hypothesized that the introduction of the New Mathematics in the mid-l960's lowered the calculation ability of students in every country. In the case of Japan, however, the opposite seems to be true: calculation ability improved in general, though the achievement levels in problems requiring a high degree of thinking and comprehension (which is stressed in the New Mathematics) was not as high as in the previous year.

5.4 And from the consequence of an international comparison about interest and attitude, it became evident that a smaller proportion of students has a favorable opinion than in other countries.

5.5 As was recently found in the case of entrance examinations in Japan, the improvement in calculation ability in this study may be regarded as due partly to "cramming" at some place other than public school (like Juku – an informal outside school). In order, however, to assure higher scholastic achievement, it is necessary to develop new methods of teaching this subject in the public school setting under conditions which do not put as much pressure on the students.

In revising the courses of study, the Ministry of Education of Japan took account of anticipated changes in our society and the resulting changes in the life and attitudes of students. It intended to provide students with a sound foundation for their lifelong learning. The basic aim of the revision of the courses of study is to ensure, keeping the 21st century in view, the development of students with open minds who will be capable of coping with the changes in our society such as internationalization in different sectors and the spread of international media.

6. References

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Vorschau auf Analysethemen der nächsten Hefte

Für die Analysen der Jahrgänge 32 (2000) bis 33 (2001) sind folgende Themen geplant:
- Computergestütztes Lösen offener Probleme im Mathematikunterricht
- Mathematikdidaktische Forschung im Primarbereich
- Mathematik an Hochschulen lehren und lernen
- Analysis an Hochschulen
- Mathematik in der Ingenieurausbildung
- Theoretische Betrachtungen zu Schulbuchanalysen.

Vorschläge für Beiträge zu o.g. Themen erbitten wir an die Schriftleitung.

Outlook on Future Topics

The following subjects are intended for the analysis sections of Vol. 32 (2000) to Vol. 33 (2001):
- Computer-aided solution of open problems in mathematics teaching
- Research in primary mathematics education
- Teaching and learning mathematics at university level
- Calculus at universities
- Mathematics and engineering education
- Concepts and issues in textbook analyses.

Suggestions for contributions to these subjects are welcome and should be addressed to the editor.