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The Findings and Implications from the TIMSS and TIMSS-R Korean data

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I. Introduction

Korean students came 2nd in the fourth grade and 3rd in the eighth grade mathematics tests in TIMSS[1] (Beaton et al, 1996; Mullis et al, 1997), drawing wide attention of researchers on mathematics education in Korea and abroad. The recently released TIMSS-R[2] results (Mullis et al, 2000) showed that Korean students maintained their high position among the 38 participating countries. Analysis of the TIMSS-R Korean data shows that the eighth grade Korean students attained even higher levels of achievement in mathematics than in TIMSS.

The superiority of the Korean students becomes even more remarkable if we consider the unfavorable learning environment that they are subjected to. One of the most unfavorable conditions is the large class size. In Korea, 93% of the classes have more than 40 students in TIMSS data and 88% of the classes have more than 36 students in TIMSS-R. Thus the Korean class size is one of the highest among all the countries that participated in TIMSS and TIMSS-R. The large class size could be one of the stumbling blocks to building an appropriate learning environment, and many teachers complain that they can barely manage such large classes and that it is difficult to help all students learn mathematics properly (Lew & Kim, 2000).

<Table 1> Performance of eighth grade East Asian students in TIMSS and TIMSS-R

TIMSS (eighth grade)			TIMSS-R (eighth grade)		
Ranking	Country	Difference from average across countries	Ranking	Country	Difference from average across countries
1	Singapore	+87 (3.8)	1	Singapore	+80 (5.9)
2	Japan	+59 (1.8)	2	Korea	+63 (2.0)
3	Korea	+59 (2.1)	3	Hong Kong	+58 (4.2)
4	Hong Kong	+47 (5.8)	4	Japan	+55 (1.8)

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1) Third International Mathematics and Science Study

2) Third International Mathematics and Science Study - Repeat

Why are Korean students able to attain such superior performance despite the afore-mentioned unfavorable condition? This paper examines the factors that contribute to the high achievement of the Korean students, and at the same time reports on some of the negative findings and gender differences of the TIMSS-R Korean data which have thus far not been given attention when the high achievements of Korean students were reported.

II. Factors Contributing to the High Achievement

Various reasons have been suggested to account for the high achievements of the students in East Asian countries (including Singapore, Japan and Hong Kong as well as Korea) in international comparative studies of mathematics achievement (Leung, 2000). As far as Korean students are concerned, the following factors seem to be contributing to their success in TIMSS and TIMSS-R.

1. The Korean Number Counting System

Two characteristics of the Korean number counting system may have contributed favorably to Korean students high level of performance in mathematics: the simple pronunciation of numbers and the regularity of the number system. The pronunciations of Korean numbers are simple. Korean numbers up to 10 are all pronounced in one syllable, making it efficient for students when they are handling with numbers. This is not so with Western languages such as English, where the pronunciations of some numbers may be more complicated (e.g. the number seven has two syllables). Incidentally, this characteristic of the Korean number system may be used to explain the superior performance of East Asian students in mathematics in general.

The second characteristic is the regular nature of the Korean number system. In Korean, a consistent rule is applied to all numbers. For example, for numbers between eleven and nineteen, they are all pronounced as "ten followed by a single digit number." There is no irregular numbers such as eleven or twelve in Korean. Similarly, numbers between twenty-one and twenty-nine are expressed as "twenty followed by a single digit number", and so on. In contrast, for numbers between thirteen and nineteen in the English language, they are pronounced as "a single digit number followed by ten". For example, 16 is pronounced as sixteen, with six followed by teen. However, when it comes to numbers between twenty-one and twenty-nine, the pattern is changed to "twenty followed by a number". This seemingly trivial inconsistency may cause problem for children when they learn and handle numbers, especially for young children at the lower grades of primary school. The Korean number system is a simpler and more logical system, easier for students to work with (Park, 2000).

2. Examination and Selection

One of the major factors influencing students high achievement in mathematics in East Asian countries appears to be the national enthusiasm for education, the eagerness for study, and the ethics of hard work. This is definitely the situation with Korea, where there is a strong zeal for education (ERO, 2000).

It is a well-known phenomenon that the focus of primary and secondary education in Korea is on subjects required in the national college entrance examination (known as the College Scholastic Ability Test, CSAT). The CSAT is a highly competitive examination which selects secondary school students for entrance into universities, and mathematics is one of the four areas that are assessed in CSAT. Since it is easier to quantify students individual ability in mathematics than in other subjects, mathematics becomes most effective when it comes to a selection-oriented education environment, and schools tend to place a relatively high importance on the subject of mathematics.

In addition, there are many private institutions or tutoring courses dedicated to preparing students for the subjects of CSAT. Korean students and parents take education very seriously, and these private institutions or tutoring courses, in parallel with regular schooling, become major elements of education in Korea. According to a recent survey administered by the Korean Educational Development Institute (KEDI, 2000), 81.2% of the Korean primary and secondary school students are receiving at least one private lesson beyond school work. While private education courses cover a wide range of subjects, mathematics is the most common, and most secondary school students attend additional mathematics private institutions or receive tutoring outside school hours. This reflects Korean students emphasis on mathematics, and results in Korean students having more exposure to mathematics instruction and practice.

3. Competence of Mathematics Teachers

Recent studies (For example, Ma, 1999) suggest that East Asian teachers have a more profound knowledge of fundamental mathematics than teachers in the US, and this may be a factor contributing to the high achievement of East Asian students. There have not been similar research in Korea which directly study the mathematics competence of Korean teachers, but we can find clues from looking into the system that selects teachers and supports their professional skills and knowledge.

Most students who enter the Department of Mathematics Education at the Colleges of Education are from the upper group in CSAT, and this trend is becoming more evident since the financial crisis in 1997. Moreover, some students enter the Department of Mathematics Education after completing their bachelors degree in other fields.

Furthermore, completing the four-year education at a College of Education does not in itself qualify the graduates for teaching in public schools. The graduates are only awarded a teachers certificate which enables them to be eligible for teaching in private schools, but to qualify to teach in public schools, certificate holders are required to pass a very demanding national examination, the Teachers Employment Test(TET). Thus, most certificate holders choose to take the TET.

The TET consists of three parts, encompassing general educational theory, subject matter knowledge and pedagogical knowledge. It ensures that teachers (in the public sector at least) have a firm grasp of the pre-requisite knowledge before they enter the profession. As pointed out above, the TET is very demanding. For instance, the TET for secondary school mathematics teachers that took place in December 2000 had a passing rate of only one in twenty. The low success rate of the TET has earned it a nickname of "bar exam" of the College of Education.

Nowadays there has been an increased interest in pedagogical content knowledge (PCK). PCK refers to knowledge about, and understanding of the concepts involved in a curriculum topic and the interrelationships between those concepts. PCK is regarded as a single most important factor in deciding a math teachers qualification as it is the mixture of content knowledge about mathematics and general pedagogical knowledge. The following Table 2 shows the characteristics of test items included in TET. Items on math education that take up 21% are used as a device to decide whether applicants have competent pedagogical content knowledge.

In summary, the keen competition for teacher education and the demanding entry test ensure that teachers are selected from a pool of candidates with high scholastic achievement and are constantly updated with professional knowledge. Although we cannot simply conclude from these that Korean mathematics teachers should have profound knowledge in mathematics and are competent in pedagogy, it is reasonable to expect that Korean teachers are more competent in performing their roles than in many other countries where there is an acute shortage of mathematics teachers.

<Table 2> The characteristics of items in TET

Content	Percentage of items	Item type	Relevant Knowledge
Education in general	30%	Multiple choice	General pedagogical knowledge
Mathematics (including probability and statistics), history of mathematics, secondary school mathematics	49%	Essay (Free response)	Subject matter knowledge
Mathematics education	21%	Essay (Free response)	Pedagogical content knowledge

4. The Match between the Korean and the TIMSS curriculum

One important factor that determines achievement is the match between the content of the achievement test and the kind of mathematics that the students have been taught prior to taking the test. Although the match between the TIMSS-R items and the Korean curriculum is not particularly high compared to other countries (Mullis et al, 2000, pp. 176-181), further analysis indicates that 118 out of the 162 mathematics items for Koreas eight graders are already covered in their primary mathematics curriculum (Lee et al, 2000). Since 73% of the test items have previously been covered in their primary school, it is natural for Korean eight graders to excel in TIMSS-R.

In addition, although TIMSS-R included items that are supposed to evaluate students high-level thinking abilities (e.g. investigation and problem-solving, mathematical reasoning and communication according to TIMSS-R classification), the majority of the items are still on or involve simple calculations. Given that these are the very items that resemble the kind of test items that Korean students are used to taking, it is natural that they have worked in favor of Korea students in terms of the TIMSS-R results.

5. Attitudes towards the TIMSS Test

Students performance in a test is obviously affected by their attitudes towards the test, and this applies to testing in TIMSS as well. In many Western countries, in order for students to take the TIMSS tests, the national study centers need to get prior approval from the parents concerned. This voluntary nature of taking the tests may have sent a signal to students that this is an activity that does not count, and hence students may tend not to take the tests seriously. In contrast, Korean students, who are raised in the Confucian culture, are educated to take testing seriously.

Their attitude towards the TIMSS tests may have been influenced by this general serious attitude towards testing and may have contributed positively to their performance. Supervising the TIMSS-R tests in Korea, the author of this paper observed a school principal encouraging his students who were taking the test, saying "You should take pride in taking the test since you are representing your country. Do your best." This anecdotal incident shows that Koreans students may be taking the TIMSS-R tests more seriously than their counter-parts in the West.

III. Negative Aspects of the TIMSS-R Korean Data

Although Korean students attain high achievement in international studies, a closer analysis of the data in TIMSS-R studies reveals a number of problems with mathematics education in Korea.

1. Conservativeness in the Use of Technology

From the TIMSS-R teacher questionnaire, Korea is found to be among the most conservative when it comes to using such technological teaching-aids as calculators or computers. For example, according to Mullis et at(2000), the percentage of Korean students having access to calculators in class (28%) was the lowest among the TIMSS-R countries. A similar tendency is found in Program for International Student Assessment(PISA), an international comparative study organized and managed by OECD. The PISA Mathematics Test administered in 2000 allowed the use of calculators in the test. But the Korea Institute of Curriculum and Evaluation (KICE), the national center which administered the test decided not to let their students use calculators in the test based on the judgment that using calculators may be counter-effective for Korean students who are not used to using calculators. This reflects a stereotyped conception prevalent in many Korean teachers that technology does not have a positive effect on mathematics education compared with the traditional pencil-and-paper approach, although most mathematics teachers would agree that technology is an inevitable tool for every student to use information properly in the information era.

This conservatism does not seem to have affected Korean students achievement in the TIMSS-R test. But as the world is moving towards a knowledge-based society and the use of calculator and computer is becoming more and more prevalent in all walks of life, it is doubtful whether Korean students superiority may be maintained in the future. Korea has decided to join the Trends in Mathematics and Science Study with testing planned for the year 2003. This will provide a measure as to whether Korea will be able to maintain the superiority in performance that they attained in TIMSS-R. If education is a preparation for the future, then the conservatism of Korean teachers and students in their use of modern technology should raise concerns from educators and policy makers.

2. Underachievement in the multi-step word problems with real-world context

Korean students tend to underachieve in the problems of real-world context while excelling in pure mathematic problems not directly relating to real world situation (Mullis et al, 2000). For instance, in a multi-step word problem requiring each products quantity of sales from quantities of two products and their total sales amount, 69% of Korean students gave the right answer, showing a considerable difference from 84% achieved by Singaporean students. Though 69% is significantly higher than the international average 44%, it is noteworthy that the score is lower by more than 10% than that of Singaporean students who came first in the test.

On the other hand, in pure mathematics problems with real-life situation excluded, for instance, one that required to find the length of a corresponding side using the properties of similar triangles, Korean students recorded the highest score. Analysis of mathematics text books used in Korea indicates that the content consists of so many formulae and symbols lacking profound context. This may explain why such a big difference in achievement is found among Korean students according to type of problem.

3. Regional Differences

The TIMSS-R results indicate that there are significant discrepancies in the levels of student achievement between large and small cities in Korea. Analysis of the Korean data shows that the average score[3] among students living in large cities is 77.68, higher by 3.06 than that of students in the province-based small or mid-sized cities whose average is 74.52, and the difference is statistically significant with significance level of 1% (KICE, 1999).

Many inter-related factors may be used to explain the discrepancies in achievement between large and small cities. One obvious factor is the opportunities for private tutoring outside formal schooling. In Korea, as mentioned above, more and more students study outside the regular schools through private tutoring courses since the school education system has been criticized as being stagnant. According to the survey done by KEDI(2000), there is a marked difference in the demand and provision of private tutoring between the large cities and the small cities because of economic and other reasons.

<Table 3> The percentages of students receiving private lessons by region

Region	Percentage of students receiving private lessons
Seoul	91.5%
Large cities except Seoul	82.6%
Mid-sized or small cities	82.3%
Rural areas	60.8%

Given the fact that school education is provided in more or less the same manner regardless of location, the low achievement among students in the province-based small or mid-sized cities may be attributable to relatively lower opportunities which exist for private tutoring in such areas. Such discrepancy in achievement between large and small cities is clearly not desirable, as an important aim of education in a modern society should be the provision of equal educational opportunity for students regardless of their background.

4. Negative Attitudes towards Mathematics

Korean students were found to dislike mathematics and lack the confidence in doing mathematics. The TIMSS-R international

3) TIMSS-R scores presented have been converted by 100 perfect-score scale.1) Third International Mathematics and Science Study

report seems to suggest that the negative attitude of Korean students found in TIMSS has persisted. Among the 38 countries, Korea ranked the lowest in terms of their attitudes towards mathematics (as measured by the TIMSS-R Positive Attitudes Towards Mathematics Index, PATM, Mullis et al, 2000, p. 141). Korean students were also among the lowest in terms of their self-concept in mathematics (Mullis et al, 2000, p. 135).

It may perhaps be wrong to accept the above student questionnaire results at face value and conclude that Korean students have a more negative attitude than their counter-parts in western countries. Korean culture stresses the virtue of humility or modesty, and hence the Korean students have the tendency of underestimating their ability. Traditional teaching in Korea requires teachers to teach students not to be conceited while imbuing a proper level of confidence and modesty into them, and this is certainly the case with Korean teachers, who are known for sparing praise for students. Korean students under such a teaching environment and culture may internalize these values of negative attitudes and result in low confidence.

However successful Korean students are in international comparative studies of achievement, if after going through the school system they end up disliking mathematics and having a low self-concept in mathematics, then mathematics education in Korea cannot claim to be successful.

IV. Gender Differences in the TIMSS-R Korean Data

Korea is found to exhibit the second largest (next to Iran) gender differences among the TIMSS countries, with boys and girls average scores being 588 and 571 respectively. As for TIMSS-R, the average scores for Korean boys and girls are 590 and 585 respectively, and this gender difference is slightly larger than the international average gender difference. Compared with the TIMSS results, TIMSS-R Korean results show that the average score for boys rose by 2 points to 590 from 588 while the average for girls went up by 14 points from 571 to 585. Korea was the only country where the increase among girls is statistically significant.

This section is devoted to search the possible reasons of the diminished gender difference in the TIMSS-R Korean data compare to those of TIMSS. And then some of the extant hypotheses related to gender difference in mathematics learning will be reviewed to check whether those hypotheses are valid in Korea.

1. The possible reasons of the diminished gender difference

One of the factors behind the smaller gender difference in TIMSS-R appears to be that there have been efforts made to that purpose especially among young teachers who recognized that there is a gender difference and tried to rid of it.

According to Belenkey et al(1986), females can be identified as "connected knowers" while male can be called as "separated knowers". Based on the characteristics of those two knowers, it can be said that the teaching methods favorable to separated knowers are emphasizing deductive proof, pursuing absolute truth and certainty, using mainly algorithms, and stressing abstraction and logic under mathematical rigor. On the other hand, the efficient teaching methods for connected knowers need to consider mathematics related with profound real world context, emphasizing conjecture, generalization and induction, and learning actively incorporated with intuition and experience. Jacobs and Becker(1997) suggested feminist pedagogy in the mathematics classroom based on the aforementioned characteristics of learning style of female; using students' own experiences to build knowledge, writing in the mathematics classroom, cooperative learning, and developing a community of learners.

In the mean time, there has been a nationwide movement in Korea called "Open Education Movement" from the mid 1990s. The motors of this movement are mathematics embedded in real world contexts, using a variety of manipulative and valuing concrete experiences, and small group cooperative learning and fostering mathematical communication. Although Open Education Movement is not only intended for female, it is true that girls have had more benefits from the movement. In sum, Open Education Movement in Korea could have indirectly contributed to enhance girls achievement level because the direction of this movement accords with females' learning attributes.

2. Familiarity vs. Novelty

Most of the TIMSS-R items are covered in the Korean curriculum and textbooks. However, some are not directly linked to any content domain in the curriculum or textbooks, or are generally covered across several content domains (These can be called as the items in cross-curricular domain). In fact, 24% of TIMSS-R items (39 out of 162 items in total, 35 out of 118 items in primary level and 4 out of 44 items in junior high level based on mathematics curriculum of Korea) are not directly related to Korean mathematics curriculum and textbooks (Lee et al, 2000). According to the further analysis of the TIMSS-R Korean data, the correct answer rates of male and female for the items in cross-curricular domain in primary level are 67% and 63% respectively, and those in secondary level are 61% and 58%. Thus it can be drawn from the data these rather unfamiliar items are where boys excelled and girls did not, while girls recorded a higher score on the items specifically covered in the curriculum and textbooks. In fact, boys who have tendency to challenge unfamiliar problems are different from girls who tend to react passively when they face with such problems, and to put more effort on reviewing what is taught in class. This explains why girls do better on items covered in class or similar to the content of textbook.

One of the explanations about this result is provided by Hanna's hypothesis. Hanna (1994) hypothesized that girls tend to do well on classroom tests that cover material explicitly taught by the teacher and thus familiar to the students, but boys have tendency to do well on standardized tests, which may present unfamiliar content. The fact that male students were superior in TIMSS-R items which are characterized by novelty, and that female students fared better in TIMSS-R items which represents familiarity can be interpreted as a result that befits Hanna's novelty vs. familiarity hypothesis.

3. Algebra vs. Geometry

One argument that is consistently raised in various studies on gender difference is that boys excel in geometry while girls fare better in algebra (Creswell, et al, 1988). The studies provide "the theory of brain development" in an attempt to explain such difference. For instance, girls are used to analytical thinking controlled by the left brain while boys tend to do well with spatial and synthetic thinking, both controlled by the right part of the brain. True it may be that both algebra and geometry items require several different thinking abilities at the same time, algebra requires analytical thinking most while geometry is more related to spatial and synthetic thinking abilities. Thus, the gender difference may be biologically explained by which part of the brain is more developed. This tendency has been partially confirmed by the TIMSS-R test result.

Algebra is the only one out of five content areas where the international average score among girls is high. On the other hand, Korean students had the biggest gender difference in geometry while the international averages by gender in geometry show a smaller difference than in other areas though boys did actually better than girls.

4. Free Response Item vs. Multiple Choice item

Another noteworthy point with regards to the gender difference is the differences by the type of test items. The following table indicates that Korean boys are more successful with multiple choice items

<Table 4> Average achievements in mathematics content area by gender

	Fractions and number Sense		Measure-ment		Data representation, analysis, and probability		Geometry		Algebra	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
Korea	566	573	567	575	574	579	569	578	585	585
International	484	491	483	491	486	489	485	489	489	485

whereas Korean girls attain relatively better results with free response items.

<Table 5> Achievement in TIMSS-R by item types and gender

Item types / Gender	Multiple choice		Free response	
	Mean	SD	Mean	SD
Girl (N=3048)	77.92	17.92	70.14	32.44
Boy (N=3082)	79.48	17.13	69.97	31.63
Total (N=6130)	78.70	17.45	70.06	32.03

This result is again consistent with the findings of one of the studies on gender difference(Bolger, 1984; Murphy, 1982), which finds that boys are more likely to choose a correct answer than girls because they tend to stick to their first choice whilst girls often change their minds due to high test anxiety. Assuming that there is a higher probability that the first answer a student picks from multiple choices is the correct one, boys tend to perform better in multiple choice items. On the other hand, girls in general have better linguistic abilities and superior writing skills. Therefore, they perform better than boys in free response items.

V. Conclusion

In this paper, it was attempted to identify the factors that contribute to Korean students' high achievement in international comparative studies. Although the factors discussed above have not fully accounted for Korean students high achievement, what has transpired from the discussion is that most of the factors identified have a cultural bearing. They involve cultural conventions as basic as the Korean numbers system, and cultural values such as people's views on education. The latter include the community's high expectation on education, strong aspiration for the teaching profession (which resulted in a highly selected teaching force), a high expectation toward the teacher (which influence the competence of the teachers), and a highly competitive education system (which affects the way students look at testing and has implications on the curriculum).

The success of the Korean students in these international studies, however, should be understood in the context of outcomes other than the test scores. In all education systems around the world, mathematics education always encompasses aims beyond mere academic achievement, and includes a host of attributes such as positive attitudes and equal opportunities of different groups in access to and success in mathematics. The analysis in this paper indicates that the Korean education system falls short in this area. Not only is the teaching conservative, but students in general have rather negative attitudes towards mathematics, and there are substantial inequality within the community in terms of mathematics learning.

On the other hand, we need to approach the TIMSS-R result from a critical perspective taking several factors into account. The fact that Singaporean students came first in both TIMSS and TIMSS-R is more or less related to the proportions of certain content items in the tests. Students in Singapore showed high levels of achievement in most areas but recorded a significantly high score on fraction and number sense problems, defeating the second by a big margin. These items take up 38% of the entire TIMSS-R test items and hence indirectly contributed to Singapore topping the list. Korean students highest score is on data representation, analysis, and probability areas. It is thus probable that Korea might have come first or ranked lower depending on how much the test covered areas where Korean students do well. As seen from the forgoing sentence, ranking itself cannot be an absolute benchmark. Thus more efforts should be directed to finding out what TIMSS-R test indicates in general, than to country ranking itself.

If Korea is to benefit from these international studies, we should seek improvement in our mathematics education through attending to these negative findings instead of merely indulging in celebrating the success of their students in yet another international rat race. The value of international studies of mathematics achievement lies not these rankings, but in providing participating countries a common setting for them to identify factors that affect their students achievement. The international results also provide a contrast so that they can understand their own system better, and an opportunity to learn from other countries. After all, international studies of achievement should not be about "who" is better, but should be about "how" we can provide a better education for our students.

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TIMSS와 TIMSS-R 수학성취도 결과로부터의 시사점

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우리 나라 중학교 2학년 학생들은 제3차 수학·과학 국제비교연구인 TIMSS와 그 반복연구인 TIMSS-R의 수학 검사에서 최상위권의 성취 수준을 보임으로써 국내외 연구자들의 관심의 초점이 되어 왔다. 이 논문은 우선 우리 나라 학생들이 높은 성취 수준을 기록할 수 있는 원인을 ① 체계적인 수 세기 방식, ② 상급학교 진학을 위한 시험의 대비, ③ 수학 교사의 능력, ④ 교육과정과 검사와의 관련성, ⑤ 검사에 대한 태도라는 다섯 가지 측면에서 탐

색하였다. 또한 높은 성취 수준 이면에 드리워진 부정적인 측면을 조망하여 ① 공학적 도구의 이용에 대한 소극성, ② 실생활 관련 문장제에 대한 저조한 성취 수준, ③ 지역에 따른 성취 수준의 차이, ④ 수학에 대한 부정적인 태도의 네 가지로 요약하였다. 또한 TIMSS-R의 수학 성취 수준에 대한 성별 차이를 ① 친숙함/생소함, ② 대수/기하, ③ 자유반응형/선택형이라는 세 가지 측면에서 분석하였다. 마지막으로 국제비교 연구의 결과는 국가별 평균 성취 수준의 양적인 비교에 초점을 두기보다는, 성취도 이면에 깔린 다양한 요소에 대한 복합적인 고려와 깊이있는 분석을 통해 수학교육의 현 상태를 점검하는 하나의 잣대로 이용해야 한다는 점을 지적하였다.