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Title	TIMSS: The strengths and weaknesses of Singapore's lower secondary pupils' performance in mathematics
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Source	<i>ERA Conference, Singapore, 23-25 November 1998</i>
Organised by	Educational Research Association of Singapore (ERAS)

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## **TIMSS – The strengths and weaknesses of Singapore’s lower secondary pupils’ performance in Mathematics**

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### **ABSTRACT**

It has been reported widely that Singapore came top in Mathematics for the Third International Mathematics and Science Study (TIMSS). In this paper the authors examine the performance of Singapore’s lower secondary pupils on some of the mathematics items used in the study. The data shed light on the strengths and weaknesses of these pupils. The implications of the findings for secondary mathematics teachers will also be discussed.

### **INTRODUCTION**

The Third International Mathematics and Science Study (TIMSS) was conducted by the International Association for the Evaluation of Educational Achievement (IEA) in 45 countries between the end of 1994 and the first half of 1995. In Singapore, testing was done towards the end of the school year in 1994. The aims of the study were to investigate student achievement, curricular implementation, instructional processes, classroom context and alternative assessment forms in both Science and Mathematics (Research & Testing Division, 1996).

TIMSS focussed on students in three populations: Population 1 – Primary 3 and Primary 4 pupils in Singapore; Population 2 – Secondary 1 and Secondary 2 pupils in Singapore and Population 3 – Students in the last year of Secondary education. Singapore participated at Populations 1 and 2 only.

This paper examines the performance of Singapore’s Population 2 (i.e. lower secondary pupils) on some of the mathematics items in the study. These items belong to the set of released items that are freely available internationally at the following website: <http://wwwcsteep.bc.edu/timss>.

### **THE STUDY**

#### *THE SAMPLE*

A total of 8650 pupils participated in the study. There were 3744 secondary One (1916 girls and 1828 boys) pupils and 4906 secondary Two (2433 girls and 2473 boys) pupils.

#### *THE TESTS*

The TIMSS tests contained 151 mathematics items and 135 science items. The mathematics items represented six content categories and four performance expectations. The items were of three types: multiple-choice, short answer and extended response. The tests were assembled in eight booklets, with each pupil taking one booklet. Every booklet had both mathematics and science items. Testing time was 90 minutes for lower secondary pupils. Of the 151 mathematics items used in the study, 102 have been published (IEA:TIMSS, 1997). The unreleased 49 items were of multiple-choice type. The 102 released items were distributed by content category as follows: Fractions and Number Sense (37%), Algebra (18%), Measurement (12%), Geometry (17%), Data Representation, Analysis and Probability (12%) and Proportionality (6%). The 102 released items were distributed by performance expectation as follows: Knowing (16%), Performing Routine Procedures (30%), Using Complex Procedures (19%) and Solving Problems (38%).

## RESULTS

### OVERALL PERFORMANCE

Singapore's performance in mathematics content areas in contrast to the International benchmarks (Research & Testing Division, 1996) were as follows:

Content Area	Singapore's Average % correct	International Average % correct
<b>Secondary Two</b>		
Fractions & Number Sense	84	58
Geometry	76	56
Algebra	76	52
Data rep. analysis & probability	79	62
Measurement	77	51
Proportionality	75	45
<i>Mathematics Overall</i>	79	55
<b>Secondary One</b>		
Fractions & Number Sense	79	53
Geometry	69	49
Algebra	68	44
Data rep. analysis & probability	72	57
Measurement	70	45
Proportionality	71	40
<i>Mathematics Overall</i>	73	49

### PERFORMANCE ON SELECTED ITEMS WITHIN EACH MATHEMATICS CONTENT CATEGORY

In the analysis of results, the test items were classified by their international difficulty indexes, which were determined by the proportions of students (at the international level) who answered the items correctly. The difficulty indexes of the items ranged between 326 and 815. The higher the value of the difficulty index, the more difficult the item appeared to be. For a better depiction of how well Singapore's lower secondary pupils had done in the test, this section focuses generally on items which Singapore's pupils found easy, difficult and items for which there was a large difference in percent correct between Secondary One and Secondary Two pupils.

- FRACTIONS AND NUMBER SENSE**

Pupils found *item N11* very easy. This item required students to demonstrate their understanding of rounded values and was answered correctly by 96% of the secondary 1 and 98% of the secondary 2 pupils. The corresponding international average percent correct was 79 for grade 7 and 83 for grade 8. The difficulty index of this item was 392.

#### *Item N11 (Solving Problems)*

A newspaper reported that about 18 200 trees had been planted in the park. The number was rounded to the nearest hundred. Which of these could have been the actual number of trees planted?

- A. 18 043      \*B. 18 189      C. 18 289      D. 18 328

Pupils found *item Q6* difficult. This item required students to work an approximate value based on their knowledge of the number of weeks in a year. Only 51% of the secondary 1 and 54% of

the secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 35 for grade 7 and 40 for grade 8. The difficulty index of this item was 610.

**Item Q6 (Performing Routine Procedures)**

The Smith family uses about 6000 L of water per week. Approximately how many litres of water do they use per year?

- A. 30 000   B. 240 000   \*C. 300 000   D. 2 400 000   E. 3 000 000

*Item O4* had the largest difference in average percent correct between the secondary 1 and secondary 2 pupils. This item required students to round off a number to the nearest hundredth. 68% of the secondary 1 but only 56% of the secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 43 for grade 7 and 46 for grade 8. The difficulty index of this item was 587.

**Item O4 (Performing Routine Procedures)**

Which of these is 89.0638 rounded to the nearest hundredth?

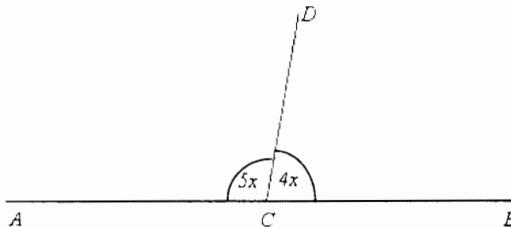
- A. 100   B. 90   C. 89.1   \*D. 89.06   E. 89.064

• GEOMETRY

Pupils found *item M7* easy. This item required students to find  $x$  using their knowledge that sum of angles on a straight line equals two right angles. 84% of secondary 1 and 91% of secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 68 for grade 7 and 72 for grade 8. The difficulty index of this item was 457.

**Item M7 (Solving Problems)**

In this figure AB is a straight line.



What is the measure, in degrees, of angle BCD?

- A. 20   B. 40   C. 50   \*D. 80   E. 100

Pupils found *item 18* difficult. This item required students to determine a point which lay on a straight line passing through two given points. 47% of secondary 1 and 58% of secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 38 for grade 7 and 41 for grade 8. The difficulty index of this item was 597.

**Item 18 (Solving Problems)**

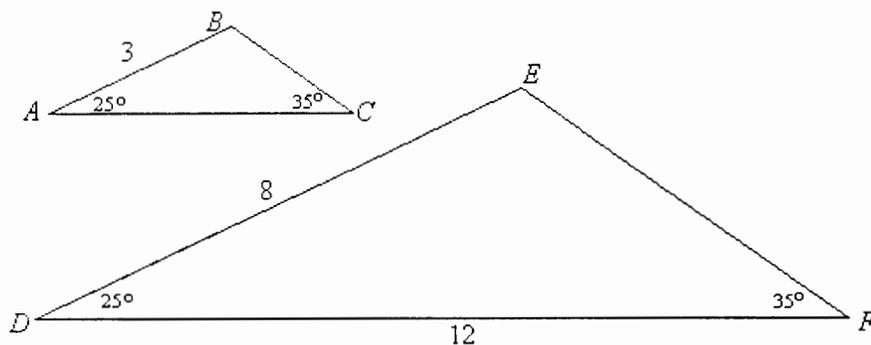
A straight line on a graph passes through the points (3,2) and (4,4). Which of these points also lies on the line?

- A. (1,1)    B. (2,4)    \*C. (5,6)    D. (6,3)    E. (6,5)

*Item P9* had the largest difference in average percent correct between the secondary 1 and secondary 2 pupils. This item required students to use the property of similar triangles to find the length of an unknown side. 49% of the secondary 1 and 64% of the secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 35 for grade 7 and 39 for grade 8. The difficulty index of this item was 617.

**Item P9 (Performing Routine Procedures)**

Triangles ABC and DEF are similar triangles.



What is the length of side AC?

- A. 2    B. 4    \*C. 4.5    D. 5.5    E. 32

- ALGEBRA

Pupils found *item O7* easy. This item required students to solve a linear algebraic equation in which the unknown was only on one side of the equation. 90% of secondary 1 and 96% of secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 63 for grade 7 and 73 for grade 8. The difficulty index of this item was 474.

**Item O7 (Performing Routine Procedures)**

If  $3(x + 5) = 30$ , then  $x =$

- A. 2    \*B. 5    C. 10    D. 95

Pupils found *item L11* difficult. This item required students to solve a problem given a condition that a rubber ball rebounds to half the height it drops. 33% of secondary 1 and 40% of secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 31 for grade 7 and 34 for grade 8. The difficulty index of this item was 640.

**Item L11 (Solving Problems)**

A rubber ball rebounds to half the height it drops. If the ball is dropped from a rooftop 18 m above the ground, what is the total distance travelled by the time it hits the ground the third time?  
**A.** 31.5 m    **B.** 40.5 m    **\*C.** 45 m    **D.** 63 m

*Item L16* had the largest difference in average percent correct between the secondary 1 and secondary 2 pupils. This item required students to solve a linear algebraic equation in which the unknown was present on both sides of the equation. 59% of the secondary 1 and 76% of the secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 29 for grade 7 and 46 for grade 8. The difficulty index of this item was 615.

**Item L16 (Performing Routine Procedures)**

Find  $x$  if  $10x - 15 = 5x + 20$

Answer: \_\_\_\_\_

- DATA REPRESENTATION, ANALYSIS AND PROBABILITY

Pupils found *item J13* easy. This item required students to complete a pictograph given the data and scale. 92% of secondary 1 and 94% of secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 79 for grade 7 and 81 for grade 8. The difficulty index of this item was 394.

**Item J13 (Using Complex Procedures)**

The table shows the number of students in the 7<sup>th</sup> and 8<sup>th</sup> grades in a given school.

Grade	Number of students
7	60
8	55

Complete the Grade 8 row in the pictograph below to represent the number of students in each grade.

One ☺ represents 10 students

Grade 7	☺ ☺ ☺ ☺ ☺ ☺
Grade 8	

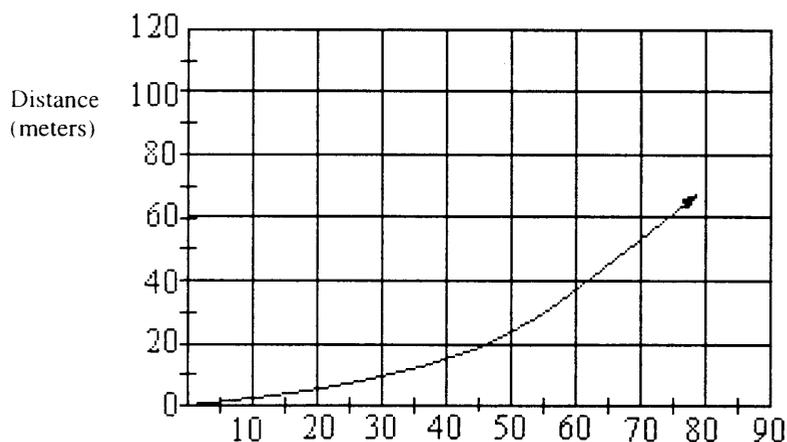
Pupils found *item R8* difficult. This item required students to extrapolate information from a given graphical representation. 44% of secondary 1 and 48% of secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 44 for grade 7 and 49 for grade 8. The difficulty index of this item was 565.

*Item O1* had the largest difference in average percent correct between the secondary 1 and secondary 2 pupils. This item is based on the same graphical representation as that of item R8 and required students to read off the value along the x-axis which corresponded to the given value along the y-axis. 56% of the secondary 1 and 66% of the secondary 2 pupils answered this item

correctly. The corresponding international average percent correct was 52 for grade 7 and 59 for grade 8. The difficulty index of this item was 535.

**Items R8 and O1**

The graph shows the distance travelled before coming to a stop after the brakes are applied for a typical car travelling at different speeds.



**Item R8 (Solving Problems)**

A car is travelling 80 km per hour. About how far will the car travel after the brakes are applied?

- A. 60 m    \*B. 70 m    C. 85 m    D. 100 m

**Item O1 (Solving Problems)**

A car travelling on a highway stopped 30 m after the brakes were applied. About how fast was the car travelling?

- A. 48 km per hour    \*B. 55 km per hour    C. 70 km per hour    D. 160 km per hour

• MEASUREMENT

Pupils found part (a) of *item S2* easy. This part required students to find the area of one square, given the area of a figure made up of 5 such squares. 92% of secondary 1 and 95% of secondary 2 pupils answered this part correctly. The corresponding international average percent correct was 53 for grade 7 and 61 for grade 8. The difficulty index of this part was 498.

Part (b) of the *same item* had the largest difference in average percent correct between secondary 1 and secondary 2 pupils. This part required students to find the length of the side of one square. 72% of the secondary 1 and 88% of the secondary 2 pupils answered this part correctly. The corresponding international average percent correct was 19 for grade 7 and 30 for grade 8. The difficulty index of this part was 665.

Pupils found part c of *item S2* relatively difficult. This part required students to find the perimeter of the figure formed by the 5 squares. 58% of secondary 1 and 65% of secondary 2 pupils answered this part correctly. The corresponding international average percent correct was 17 for grade 7 and 24 for grade 8. The difficulty index of this part was 680.

**Item S2 (Solving Problems)**

The figure consists of 5 squares of equal size. The area of the whole figure is 405 square centimetres.

**Part a**

Find the area of one square.

Answer \_\_\_\_\_ square centimetres

**Part b**

Find the length of the side of one square.

Answer \_\_\_\_\_ centimetres

**Part c**

Find the perimeter of the whole figure in centimetres.

Answer \_\_\_\_\_ centimetres

- PROPORTIONALITY

Pupils found *item V3* easy. This item required students to find the ratio of a part to the whole given the parts that made the whole. 89% of secondary 1 and 94% of secondary 2 pupils answered this item correctly. The corresponding international average percent correct was 37 for grade 7 and 42 for grade 8. The difficulty index of this item was 603.

**Item V3 (Performing Routine Procedures)**

To mix a certain colour of paint, Alana combines 5 litres of red paint, 2 litres of blue paint, and 2 litres of yellow paint. What is the ratio of red paint to the total amount of paint?

- A.  $\frac{5}{2}$       B.  $\frac{9}{4}$       C.  $\frac{5}{4}$       \* D.  $\frac{5}{9}$

Pupils found *item T2* difficult. Part (b) of this item also had the largest difference in average percent correct between the secondary 1 and secondary 2 pupils. This item required students to solve a problem using the concept of proportionality. 36% of secondary 1 and 43% of secondary 2 pupils answered part (a) of this item correctly. The corresponding international average percent correct was 16 for grade 7 and 23 for grade 8. The difficulty index of part (a) was 699.

14% of secondary 1 and 19% of secondary 2 pupils answered part (b) of this item correctly. The corresponding international average percent correct was 6 for grade 7 and 8 for grade 8. The difficulty index of part (b) was 815.

**Item T2 (Solving Problems)**

Two boxes of square-shaped cardboard pieces are available to make a larger pattern. There are 4 small squares in each piece.

All pieces in Box 1 look like



All pieces in Box 2 look like



In the required pattern, for every piece from Box 2 there are 2 pieces from Box 1.

**Part a**

If 60 pieces from Box 2 are used in the required pattern, how many pieces will be needed altogether?

Answer \_\_\_\_\_

**Part b**

What fraction of the small squares in the required pattern will be black?

Answer \_\_\_\_\_

**FINDINGS****OVERALL**

Singapore's overall performance in mathematics was commendable compared to the international cohort at Secondary 1 and Secondary 2 levels. For all the six content areas (Fractions & Number Sense; Geometry; Algebra; Data representation, analysis and probability; Measurement; and proportionality) the Singapore cohort performed significantly better than their international peers. For all the six content areas too, Secondary 2 pupils performed better than Secondary 1 pupils.

**SECONDARY 1 VERSUS SECONDARY 2**

For the content categories: Measurement; and Proportionality the Secondary 2 pupils outperformed the secondary 1 pupils on all items. For the content categories: Fractions & Number Sense; Geometry; Algebra; and Data representation, analysis and probability, the Secondary 1 pupils outperformed the Secondary 2 pupils on four, three, one and one items/item respectively. For all these items with the exception of one (i.e. item O4) the difference in average percent correct was in the range of 1 to 3 and therefore rather insignificant. For item O4 which is shown in this paper the difference was 12% and rather disturbing.

**SINGAPORE STUDENTS VERSUS THE INTERNATIONAL COHORT**

Secondary 1 pupils outperformed or performed as well as the international cohort at grade 7 on all items in the content categories: Fractions & Number Sense; Geometry; Algebra; Measurement; and Proportionality. There were two items [L10 (81% vs 85%); P17(74% vs 80%)] in the content category: Data representation, analysis and probability for which the international cohort at grade 7 outperformed the Secondary 1 pupils.

Secondary 2 pupils outperformed the international cohort at grade 8 on all items in the content categories: Fractions & Number Sense; Geometry; Algebra; and Proportionality. There were one item [L12 (73% vs 75%)] in the content category: Measurement and two items [P17 (80% vs 83%); R8 (48% vs 49%)] in the content category: Data representation, analysis and probability for which the international cohort at grade 8 outperformed the Secondary 2 pupils.

## DISCUSSION

Generally, pupils found items based on content knowledge (Curriculum Planning Division, 1990) that they had already covered in their school curriculum easy. Furthermore most of these items were of a routine nature, given the practice pupils go through in their mathematics lessons.

Pupils had difficulty with items that included content that is not an integral part of the local school curriculum at their respective levels, where the language or terminology was unfamiliar e.g. words like *paces* (item L12) and *weeks* to denote time (item Q6) and where the context was unfamiliar e.g. information given in tabular form (item L10) or diagrammatic form (items P17 & R8).

Item O4 is an interesting one. The performance of Secondary 1 pupils was far better than that of Secondary 2 pupils on this item. Since the response to the item was only in a written format and there was no interviewing, it may be speculated that Secondary 1 pupils' formal exposure to approximations of the type "hundredths" may have been more recent and as such they may have recalled the required knowledge more easily.

## IMPLICATIONS

Performance of students on items that are not an integral part of their curriculum or which include specific words that may not be familiar to them, have no direct pedagogical implications. However, this performance suggests that for most pupils the school mathematics appears to be the only mathematics that they learn or are comfortable using when doing mathematics tests.

Our students appear to perform well on computations and direct application of the knowledge they acquire in the mathematics class. For further progress we need to refine what we have been doing so far. Greater emphasis needs to be placed on conceptual understanding and transfer of learning to enhance our pupils' performance on non-familiar tasks. Our mathematics classes of tomorrow must be hubs of "mathematical thinking" or "thinking mathematically". At the same time we must ensure that our pupils put in enough practice and maintain their proficiency in mathematical skills.

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