Singapore Students’ Performance on Australian and Singapore Assessment Items

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This study describes Singapore students’ (N=607) performance on a recently developed Mathematics Processing Instrument (MPI). The MPI comprised tasks sourced from Australia’s NAPLAN and Singapore’s PSLE. In addition, the MPI had a corresponding question which encouraged students to describe how they solved the respective tasks. In particular, the investigation considers two tasks the cohort found difficult to solve—a relatively complex task from the Singaporean item bank and a novel task from the Australian tasks.

Introduction

The digital age has profoundly transformed the world around us. Tech-savvy citizens not only possess cognitive and emotional capacities, they engage with (and demand) a digital capacity which is used to navigate and make sense of the landscape of new online media (Kerr, 2011; Ong, 2011). Since online media consists of a myriad of spatial information in the form of diagrams, graphics and non-graphics, expectations for our capacity to represent, manipulate and decode information has increased and is still increasing (Lowrie & Diezmann, 2007). Interpreting and decoding spatial information has not only been recognised as essential in everyday life, this ability has become increasingly important in education contexts (Åberg-Bengtsson, 1999; Lowrie & Diezmann, 2011). In the Singapore primary mathematics classrooms, students, at an early age, are already required to make sense of spatial information in various learning contexts including graphic and non-graphic information in textbooks, the representation of information and the reinforcement of mathematics concepts (via digital and electronic forms).

The ability to make sense of spatial information is an important skill in concept acquisition (Ahsen, 1981, 1989) and aids in the process of problem solving (see Presmeg, 2008). Problem solving plays a key role in the Singapore primary mathematics curriculum (Ministry of Education, Curriculum Planning and Development Division, 2007). In particular, students are given both graphic and non-graphic problems to solve in the mathematics classrooms. Understanding the spatial information and relationships among the elements in the problem is an essential component in problem solving. It is obvious that spatial information can be found in graphic items. Spatial information can too be found in non-graphic items, that is, spatial relationships exist between the elements in the problem. In order to begin solving the problem, students are required to not only understand the relationship among elements in the problem, they also need to be able to interpret how these elements are related to each other spatially. It is important to note that processing information in non-graphic items is high as graphics are not provided in the problem to show the relationships among elements in the problem.

In J. Dindyal, L. P. Cheng & S. F. Ng (Eds.), Mathematics education: Expanding horizons (Proceedings of the 35th annual conference of the Mathematics Education Research Group of Australasia). Singapore: MERGA.
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The (Re)presentation and Assessment of Mathematics

At a time when citizens require new forms of numeracy of function effectively in society, changes to assessment practices are occurring in mathematics classrooms. New levels of accountability are being placed on school systems (Lowrie & Diezmann, 2009), with national assessments of students' mathematics performance commonplace. Students performance, even at a primary school level, is reported to describe and rank the performance of individual schools (e.g., in Australia) or to select and apportion students for the transition to high school (e.g., Singapore). Not only do such national assessments have a different intent, the way in which mathematics concepts are presented and represented are quite different.

Indeed, both Australia and Singapore have national assessments for primary-age going students—NAPLAN (National Assessment Program – Literacy and Numeracy) in Australia and PSLE (Primary School Leaving Examination) in Singapore. The National Assessment Program – Literacy and Numeracy (NAPLAN) is one of the assessments under Australia's National Assessment Program which measures and determines whether or not Years 3 (age 8-9), 5 (age 10-11), 7 (age 12-13), and 9 (age 14-15) Australian students are meeting important educational outcomes. The NAPLAN tests "skills that are essential for every child to progress through school and life, such as reading, writing, spelling and numeracy" (Australian Curriculum, Assessment and Reporting Authority, 2011, n.p.). It was implemented nationwide in Australia since 2008 and undertaken annually in the second full week in the month of May.

The primary national assessment in Singapore takes the form of a high-stake examination, the Primary School Leaving Examination (PSLE). It was implemented in 1960 with the primary purpose of the examination to allocate placement for students into secondary school based on the score achieved (Tan, Chow, & Goh, 2008). The PSLE is undertaken by Primary 6 Singaporean students (age 11.5-12) at the end of their final year of primary school education. A student can sit for the PSLE as an approved Singapore institution candidate or as a private candidate. The PSLE is conducted in Singapore annually, usually from mid-August to early October.

This investigation is part of a larger cross-cultural study which focuses on students' interpretation of assessment tasks in numeracy and mathematics learning. The study draws attention to cross-cultural dimensions of students' learning by analysing students' mathematics assessment performance and sense-making in high performing but culturally different contexts—Australia and Singapore. Specifically, the larger project aims to: (a) compare the performance of Australian and Singaporean students on tasks sourced from each country's respective national assessment instruments; (b) identify the approaches and strategies students from different cultures employ to solve mathematics tasks; and (c) draw conclusions about the influence cultural and pedagogical practices have on students' approaches to solving these tasks.

To the best of our knowledge, no studies have simultaneously (1) compared the performance and (2) analysed the mathematics processes of students from different countries on mathematics items drawn from the respective countries. To date, most cross-cultural studies of students' performance are drawn from internationally generic instruments (e.g., Third International Maths and Science Study [TIMSS]). Such studies do not consider the different ways mathematics is present and represent within country—we argue this is important in an age where spatial and graphic-rich representations are increasingly used to display information.

Research Design and Methods

The focus of this paper is to report Singapore students' performance on tasks sourced from Australia's NAPLAN and Singapore's PSLE. This paper does not compare results of the Singapore students' performance with their Australian counterparts. Hence only information for the Singapore sample will be discussed in this paper.

The Participants

607 Grade 6 students (aged 11-12) from 5 Singapore schools (three government and two government-aided) took part in this study. There were 320 boys and 287 girls in the sample.

The Test Instrument

Students' ability to decode mathematics tasks were investigated using a *Mathematics Processing Instrument* (MPI) developed and designed by the research team. The instrument comprised 24 items sourced from both the Australia's National Assessment program Literacy and Numeracy (NAPLAN) and Singapore's Primary School Leaving Examination (PSLE), of which there were: (a) 6 graphic items from Australia's National Assessment Program Literacy and Numeracy (NAPLAN), (b) 6 non-graphic items from Australia's National Assessment Program Literacy and Numeracy (NAPLAN), (c) 6 graphic items from past-years Singapore's Primary School Leaving (PSLE) Examination, and (d) 6 non-graphic items from past-years Singapore's Primary School Leaving (PSLE) Examination.

The analysis in this study focuses on two items, namely the Postcard Problem (see Figure 1) and the Plum Problem (see Figure 2). Both items are non-graphic items where there is only text. In order to solve these items, students need to make sense of the spatial information embedded in the text. The Postcard Problem was sourced from Singapore's Primary School Leaving Examination (PSLE) and the Plum Problem was sourced from Australia's National Assessment program Literacy and Numeracy (NAPLAN).

> Gilbert and Hazel have some postcards. After Gilbert gives 18 postcards to Hazel, he has 20 postcards more than her. How many more postcards than Hazel does Gilbert have at first?

Figure 1. A non-graphic Singapore item.

> Peta has some plums to give to her friends.
> If she gives each friend 4 plums, she will have 6 plums left over.
> She cannot give each friend 5 plums because she would need 4 more plums.
> How many plums does Peta have?

Figure 2. A non-graphic Australian item.

The Test Procedure

Two research staff from the research team attended specified schools in Singapore during their morning classes. The classroom teachers were asked to help administer the Mathematics Processing Instrument along with the research staff. The administration of the Instrument was in two parts. Firstly, students answered the 24 mathematics items as a pencil and paper test. The duration of the paper-and-pencil test was 1 hour. After a short break, students then filled out the processing instrument. A common set of instructions (for both parts) were read to the students in each school.

Analysis of Data

The conceptual underpinnings for data analyses were drawn from the work of Presmeg (1986a; 1986b). Presmeg (1986a) defined a visual method as one that contains a visual image—either in the mind's eye or a diagram—which is an essential component of the solution. A non-visual method, on the other hand, does not rely on a visual image. Presmeg also differentiated the different types of visual imagery in her study. For the purpose of our coding of data, we classify visual imagery as either (1) in the mind's eye; or (2) diagrams or pictures (usually drawn on paper).

The data in the study were coded according to two criteria; (a) whether the answer was correct or incorrect, and (b) type of method of solution used. The type of method solution used was coded using the coding scheme shown in Table 1. The coding scheme incorporates Presmeg (1986b)'s definitions of visual imagery and also includes another method identified; namely, kinaesthetic imagery. Table 1 outlines the coding spectrum.

Table 1
Coding Spectrum

Coding	Method of Solution used
0	Use of a non-visual method
1	Use of a visual method – diagram on paper (pictorial)
2	Use of a visual method – concrete imagery (imagery)
3	Use of a visual method – kinaesthetic imagery (gesture)

A coding of '0' was assigned to students who used a non-visual method. A non-visual method is one that does not have a visual image as an essential part of the method of solution. A coding of '1' was given to method of solution that showed use of a visual method where a diagram drawn on paper plays an essential role in the solution. A coding of '2' was given when the student used concrete imagery as a method of solution, that is, using "picture in the mind". A coding of '3' was assigned to method of solution that involved kinaesthetic imagery.

Results and Discussion

This section discusses two items that were performed poorly by the Singaporean students; namely, the Postcard Problem and the Plum Problem. Both problems are non-graphic items. The overall percentage correct for these two items was 36.7%, and 39.7% respectively.

The Postcard Problem

The Postcard Problem is an item from the Singapore past-years Primary School Leaving Examination (PSLE). Table 2 shows the performance of students in this item and the percentage of the various solution methods used by the students.

Table 2
Correct and Incorrect Responses by Approach for The Postcard Problem

Coding	Incorrect Response	Correct Response	Total
0	188 (35.8%)	67 (12.8%)	255 (48.6%)
1	115 (21.9%)	154 (29.3%)	269 (51.2%)
2	1 (0.2%)	0 (0%)	1 (0.2%)
3	-	-	-
Total	304 (57.9%)	221 (42.1%)	525 (100%)

Note: 82 students did not answer the second part of the Mathematical Processing Instrument (MPI). Hence, the percentages in Table 2 were computed over the base of 525 students who answered both parts of the MPI.

Only 42.1% of the students were successful in answering the Postcard problem. The majority of the students who gave an incorrect answer chose a nonvisual method of solution (35.8%). Of the students who were successful, 12.8% chose a nonvisual method, while 29.3% chose a visual method (diagram on paper). It is interesting to note that only 1 student worked out a “picture in the head” and she was unsuccessful in answering the item. This suggests that the item could be too complex for students to visualize and hold any imagery in their minds.

Ho (2009, 2010) found that drawing diagrams for non-graphic tasks helped students see the task visually, specifically, how the elements in the task relate to each other. Ho also found that diagrams aid in the transformation of the task into mathematical forms, that is, mathematical forms may be obtained from the diagram to solve the task. In this study, 115 students (21.9%) who drew a diagram to solve the item were unsuccessful in solving the item. Figure 3 shows two common incorrect bar-model diagrams drawn by the students in the study. Bar-model drawings are problem-solving tools commonly taught in the Singapore classrooms to help students visualize and solve problems (see Fong, 1998 and Yeap, 2010). Bar models represent mathematical quantities (known and unknown) and their relationships given in a problem (Ministry of Education, Curriculum Planning and Development Division, 2009).

This finding points to an important implication that the use of a visual method is necessary but not sufficient for successful problem solving. Although studies on Singapore students have found that the bar-modelling approach is especially helpful for the weaker students, who would otherwise be unsuccessful in solving complex problems like the Postcard Problem (Goh, 2009; Poh, 2007), it is important to take note that the diagram needs to be correctly drawn in order to reflect the correct relationships among the mathematical quantities so as to obtain the correct mathematical forms from them.

Gilbert and Hazel have some postcards. After Gilbert gives 18 postcards to Hazel, he has 20 postcards more than her. How many more postcards than Hazel does Gilbert have at first?	Gilbert and Hazel have some postcards.After Gilbert gives 18 postcards to Hazel, he has 20 postcards more than her. How many more postcards than Hazel does Gilbert have at first?

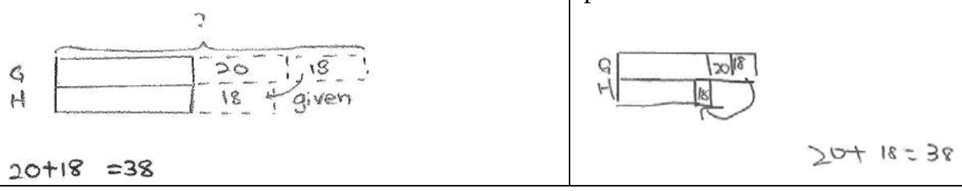


Figure 3. Ashley’s (left) and Brenda’s (right) solutions for the Postcard Problem.

The Plum Problem

The Plum Problem is an item from Australia's National Assessment Program Literacy and Numeracy (NAPLAN). Table 3 shows the performance of students in this item and the percentage of the various solution methods used by the students. Note that the use of kinaesthetic imagery is not a possible solution method for this item. Also note that 154 students did not answer the second part of the Mathematical Processing Instrument (MPI). Hence, the percentages in Table 3 were computed over the base of 453 students who answered both parts of the MPI.

Around three-fifths of the students were not successful in answering the item. Almost half of the students chose a nonvisual solution method and got the answer wrong. This suggests that students should consider using visual methods when a task is unfamiliar to them. The only visual method used by the students for this item was through drawing diagrams on paper. This suggested that the item could be too complex for them to use concrete imagery to solve the task.

Table 3
Correct and Incorrect Responses by Approach for The Plum Problem

Coding	Incorrect Response	Correct Response	Total
0	220 (48.6%)	134 (29.6%)	354 (78.1%)
1	49 (10.8%)	50 (11.0%)	99 (21.9%)
2	0 (0%)	0 (0%)	0 (0%)
3	-	-	-
Total	269 (59.4%)	184 (40.6%)	453 (100%)

Note: 154 students did not answer the second part of the Mathematical Processing Instrument (MPI). Hence, the percentages in Table 2 were computed over the base of 453 students who answered both parts of the MPI.

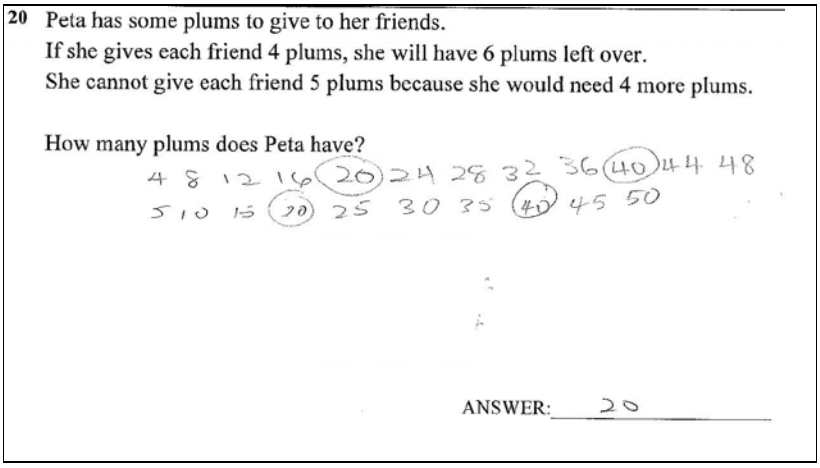
The Plum Problem is an unfamiliar task to Singapore students. Singapore students are more familiar with the following task, which is structurally differently from the Plum Problem:

When a number is divided by 3, the remainder is 2.

When the same number is divided by 4, the remainder is also 2.

Find the number.

Kaur (2009) noted that although Singapore students are performing well in international tests such as the Third International Maths and Science Study (TIMSS), they "do not perform well on content that is not an integral part of the local school curriculum" (p. 463). In addition, Singapore students also have "difficulty with items that require them to comprehend concepts or apply knowledge in non-familiar contexts" (p. 463). This is evident in Cedric's solution method (see Figure 4). Cedric used exactly the same method he learnt in school (see Figure 4) to solve the Plum Problem, probably not realising that a different approach of solution method is required.


20 Peta has some plums to give to her friends.
If she gives each friend 4 plums, she will have 6 plums left over.
She cannot give each friend 5 plums because she would need 4 more plums.

How many plums does Peta have?

4 8 12 16 20 24 28 32 36 40 44 48
5 10 15 20 25 30 35 40 45 50

ANSWER: 20

Figure 4. Cedric's solution to Item 20.

Conclusion and Implications

The investigation described the mathematics performance and processing approaches of Grade 6 Singapore students solving mathematics tasks drawn from Singaporean and Australian national assessment instruments. The study particularly focused on items (one from Singapore and one from Australia) that students had most difficulty in solving. For both items, the Singapore students predominately used a non-visual response in their processing approach. Although there has been an extensive body of literature (since the seminal work of Krutetskii, 1976) that suggests that non-visual methods are the most efficient, visual methods are certainly appropriate (and recommended) when the problem solver is faced with complex or novel tasks (Ho, 2009; Lowrie & Kay, 2007; Pirie & Kieran, 1992).

Since The Post Card Problem (a complex Singaporean item) and The Plum Problem (a novel Australian item) were items the students found difficult to solve we would have expected most of the students to use visual methods (see Lowrie & Kay, 2007; Presmeg, 1986a). However, non-visual methods were utilised in 48% (Post Card problem) and 78% (Plum Problem) of cases. Ho (2009, 2010) found that students' use of a visual method in their problem solving was influenced by two factors: (1) the novelty of the problem, and (2) students' perception of their teacher's problem-solving preference. In the current investigation, it was noteworthy that the Australian item was predominately solved using non-visual methods—which may reinforce Ho's second point.

Several implications emerge from the study. From a theoretical perspective, we encourage researchers to consider the relationship between task correctness and the methods or approaches used by students to solve tasks. We argue that the Mathematics Processing Instrument provides an opportunity for such analyses whilst also considering the social-cultural influences embedded within task development. From a classroom perspective, we encourage teachers to provide students with opportunities to develop powerful visual representations when engaged in sense making—especially when confronted with tasks that are complex or novel. Moreover, it is critical for teachers to "value" such approaches and not rely on developing analytic procedures.

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