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Author(s)	Jane M. Watson, Jonathan B. Moritz and Lionel Pereira-Mendoza
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Interpreting A Graph In A Social Context

Jane M. Watson
Jonathan B. Moritz
Lionel Pereira-Mendoza

Abstract

Drawing and interpreting graphs, and making predictions from graphs, are important skills in the mathematics curriculum. They are also essential components of statistical literacy in today's society. Students need to be able to interpret a graph in an authentic context, and identify any misleading features. Responses to questions about a graph-based advertisement suggest that students have difficulties in tasks such as comprehending the relevance of a graph in the context of a standard interpretation task, and applying calculation skills which have been learned in other contexts to data in graphical representations. In this report data from 37 Primary 6 Singapore students are discussed.

Recent curriculum documents (Curriculum Planning Division, 1995; Australian Educational Council [AEC], 1994) have included data representation as a part of the statistics curriculum relevant to mathematics and the wider school curriculum. The general goals are operationalised within the Curriculum Development Institute of Singapore (CDIS) materials which are used in all primary schools within Singapore. For example, at Primary 3 the *Primary Mathematics Teacher's Guide 3A* (CDIS, 1993) suggests that pupils should undertake activities such as collecting their own data and drawing graphs and collecting graphs from newspapers and magazines. These goals are consistent with those stated in various Australian documents such as *A National Statement on Mathematics for Australian Schools* (AEC, 1991), where statement B5 suggests students should "represent, interpret and report on data in order to answer questions posed by themselves and others," and "[d]iscuss and interpret information presented in graphs and tables found in newspapers, magazines and text materials" (p. 172).

There is limited research involving students' comprehension and interpretation of statistical graphs. With respect to young children's understanding and use of graphs, Pereira-Mendoza and his co-workers have

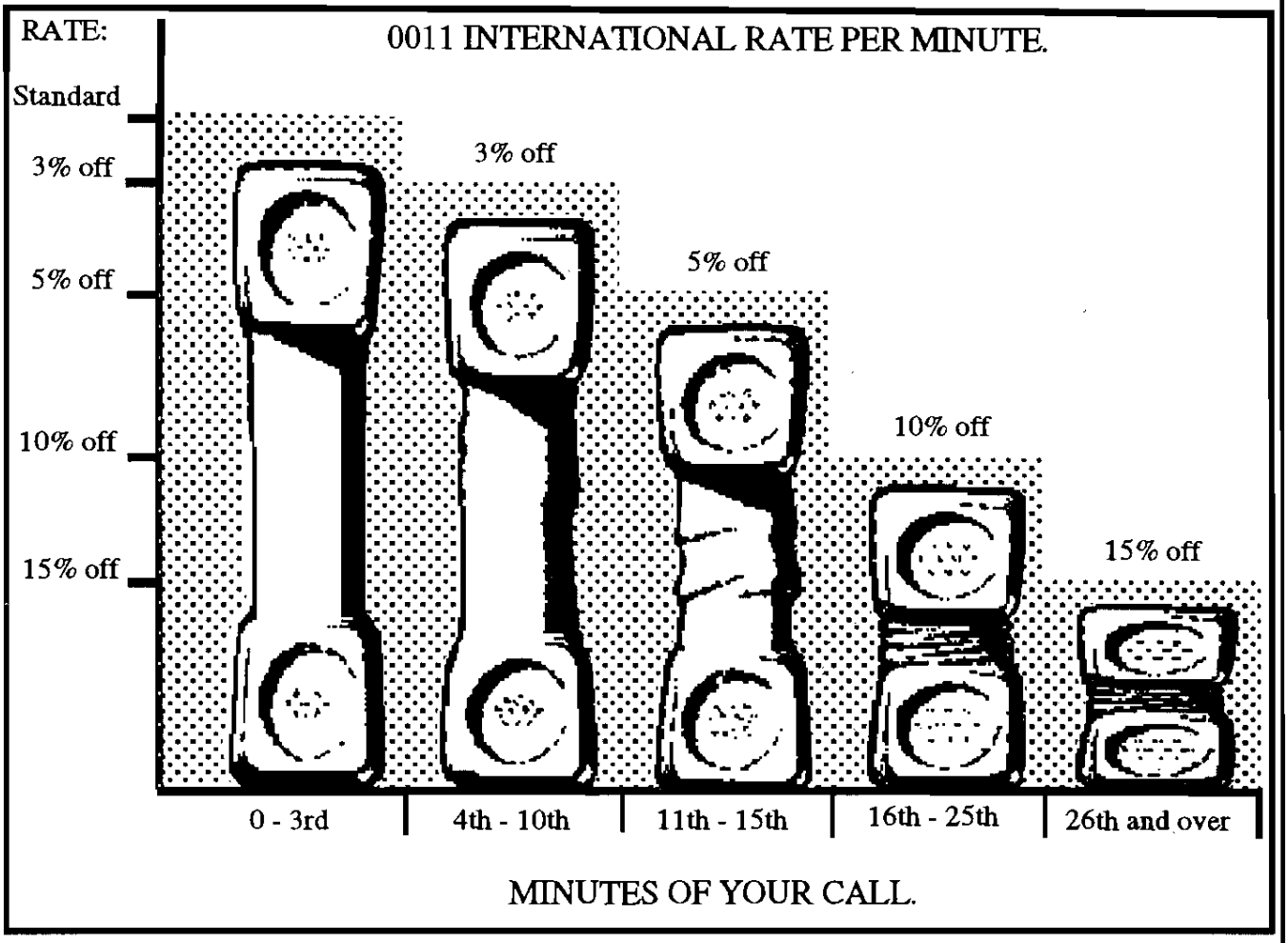
identified a number of areas of difficulty such as interpreting scale, distinguishing missing values from zero value data, misapplication of appropriate knowledge of a topic when predicting, making inappropriate generalisations about patterns in graphs, and an inability to correctly manipulate bar graphs (Pereira-Mendoza & Mellor, 1991; Pereira-Mendoza, Watson & Moritz, 1995; Watson & Pereira-Mendoza, 1996).

Curcio's (1987) research with students in grades 4 and 7 led her to suggest three distinct levels of questions that teachers should ask students when teaching graphing: (1) reading the data, (2) reading between the data, and (3) reading beyond the data. At level (1), students simply repeat information lifted from the graph with no interpretation. At level (2), students are required to integrate information by comparing quantities and applying other mathematical concepts and skills. At level (3), students must employ their background knowledge to go beyond the data (Curcio, 1989, pp. 5-6).

As implied in curriculum documents from both Singapore (Curriculum Planning Division, 1995) and Australia (AEC, 1991), interpreting graphs in context should be included in the experiences provided for students in the data handling part of the mathematics curriculum. It follows further that similar settings should be the basis for the assessment of outcomes from the curriculum. Watson has suggested a three-tiered hierarchy for assessing statistical literacy based on authentic extracts from the media (Watson, 1997; Watson & Moritz, 1997). The hierarchy includes (i) a basic understanding of a concept, (ii) an understanding of that concept in a social context, and (iii) the ability to question a claim improperly made within the context. Students who reach this final level are ready to take an active part in decision-making in social contexts.

The item chosen for this study presents the opportunity to extend the research of Pereira-Mendoza and Curcio in terms of interpreting graphs, as well as test the levels of Watson's hierarchy. The item shown in Figure 1 contains questions based on an advertisement taken from an Australian newspaper. The presentation is unusual in that the scaling used on the y-axis does not correspond to the numerical values. Furthermore, intervals on the x-axis are visually the same but each represents a different time interval. These features make it a complex activity to calculate the cost of a long conversation, and consequently it could be suggested that the advertisement is misleading. Questions concerning the advertisement were developed to investigate how students interpret a graph in a social context.

The longer your overseas call, the cheaper the rate.



(a) Explain the meaning of this graph.

(b) Is there anything unusual about it?

Suppose the standard rate is $1.00 for 1 minute.
You have already talked for 30 minutes.

(c) How much would the next 10 minutes cost?

(d) How much did the first 30 minutes of the phone call cost?

Figure 1: Graphing Item from Media Survey about Chance and Data

Method

The item in Figure 1 was originally used as part of a Media Survey administered to students in Tasmanian government schools (Watson, 1994; Moritz & Watson, 1997). The item was then used as part of a survey in a Primary 6 class in Singapore with 37 students. Since this was an exploratory study, no attempt was made to obtain a representative sample of Singaporean students. It is felt, however, that this small sample provides valuable information for teachers.

Results

Responses of the Singapore students to each part of the question are discussed below with reference to the findings of previous researchers concerning levels of interpretation and common student difficulties. Comparisons with Australian students are based on analysis described in Moritz and Watson (1997).

Part (a) Describing the graph

There were several types of response to the first question about the meaning of the graph. Responses often involved minimal re-wording of the advertisement title, corresponding to Curcio's (1989) literal "reading the data." Students often just lifted the title from the advertisement to explain the meaning.

> *"It means that if you talk on the phone for a longer time the cheaper the rate."*

Other students re-worded the title slightly, sometimes preferring "price" to "rate." In this respect, it is not evident whether these students understood the distinction, since the price continues to increase though at a slower rate.

> *"It means the longer you make an overseas call the cheaper the price."*

A few students appeared to appreciate the increasing cost but not the reduced rate. Although the following response is technically correct, it does not reflect the intended message of the advertisement.

> *"The more minutes you call the more expensive the price goes."*

Some students did a good job of interpreting the message of the advertisement in other words, conveying the correct intention. These responses illustrate Curcio's level (2) of "reading between the data" to interpret meaning, and the second tier of Watson's hierarchy for statistical literacy, being able to understand a graph in a social context.

> *"It shows percentage off the price per minute for minutes that you have called."*
> *"It means that if you call overseas ... the charges for each minute or another is lower if you talk on the phone longer."*

Finally one student conveyed the intention of the company in placing the advertisement, illustrating Curcio's third level of "reading beyond the data" to infer the company's purpose.

> *"The company is promoting their international overseas call and encouraging us to call more often."*

Part (b) Questioning unusual features of the graph

Most students (68%) did not identify anything that they considered unusual about the graph. Two responses considered the graph unusual based on what students think a phone or a graph should look like.

> *"Yes. They used telephone handles in the graph."*
> *"Yes. They use telephones in the shaded graph and makes it get smaller and smaller, it looks unusual because other graphs would usually use line graphs and through this graph, I can see that the person who drew it is very creative."*

Some students picked up on the relationship of the decreased rate not meaning a decreased total cost, and either were misled themselves, or thought this might be misleading to others.

> *"Yes. By right it should be 'The longer your overseas call, the more expensive the rate.' "*
> *"Yes. The longer the call is, the more expensive it is, but it is opposite!"*

One student was able to comment on the unusual nature of the representation with respect to the reversed scale, which appeared to be recognised

as unusual in contrast to standard expectations, almost assuming patterns should appear in graphs, as observed elsewhere by Pereira-Mendoza.

> *"Yes. The amount of time the call is, is not following the percentage off increasing, in another word, it is not increasing in a pattern."*

Another student understood the graph and expressed a belief about the company's discounting policy.

> *"Yes. The discount should increase when the call made is more than 26 minutes."*

It is unknown whether this belief is of commercial origin or related to patterns as with the previous student.

Other responses commented on the non-linear aspect of the scales, acknowledging that this gives a visual misrepresentation which might mislead people.

> *"Yes, there something wrong in the graph. E.g. 15% off should not be so low."*
> *"Yes, the pattern of the minute and the pattern of the percentage reduced is different."*

In the last response, the use of the word "pattern" appears to reflect the unusual use of scaling rather than a pattern in the information provided in the graph. It would appear that these final responses are at the third level of Watson's hierarchy.

These responses reflected the same points made by Australian students. Overall 24% of Singapore students claimed something unusual about the graph related to the pricing or the kind of graph used, while 8% made a claim related to misleading scale. At the Grade 6 level in Australia, 27.4% and 1.4%, respectively made similar claims.

Parts (c) and (d) Applied use of the graph with calculations

These parts of the item are asking students to go beyond the data at Curcio's second and third levels and to use the context and their mathematical skills to find the cost in particular settings. For Part (c), the simplest structural form of response involved using the cues "10 minutes" and "rate of $1/min" from

the question to conclude that the cost is $10. A similar response used the "30 minutes" cue also, resulting in a conclusion of a $40 cost. The key feature of these responses is that there is no evidence that the graph plays any role in the students' reasoning. A significant point to note is that only 8% of Singapore students responded in this fashion while 64% of Australian students took this approach. It appears that, in general, Singaporean students used the graph when drawing conclusions.

Of those students who did employ the graph in their responses, some appeared to take a single cue such as "3% off" or "15% off", but when choosing this latter figure did not go on to calculate the cost for another 10 minutes. About the same percentage of students from Singapore did this as from Australia. The correct answer of $8.50 was achieved by 68% of the Singapore sample, a much better performance than the Australian group, as is seen in Table 1. Non-response or incorrect responses whose derivation could not be ascertained accounted for 19% of Singapore responses.

Table 1 : Percentage of Responses to Part (c) by Response Category

Classification	Singapore Primary 6* (n = 37)	Australia Grade 6 (Moritz & Watson, 1997) (n = 502)
$8.50	68	3
3%/15%...	5	4
$10/$40	8	64
Other	16	14
NR	3	14

Note: NR = No Response
* = Primary 6 and Grade 6 are roughly equivalent

For part (d), summarised in Table 2, 8% of students gave no response while 5% continued a simplistic interpretation ignoring the graph to respond $30. Thirty-two percent used the graph and interpreted the 15% discount as applying to the entire call, achieving an answer of $25.50. For those who interpreted the graph as representing differential discounts over time, there was the added complexity of working out the length of each interval. The correct multistage approach was used by 41% of students but only 14% achieved the answer of $27.79. In contrast to these students, only 2% of Grade 6 students in Australia appreciated the complex approach required for a solution.

Table 2 : Percentage of Responses to Part (d) by Response Category

Classification	Singapore Primary 6* (n = 37)	Australia Grade 6 (Moritz & Watson, 1997) (n = 502)
$27.79	14	0
($27.79)	27	2
$25.50	32	3
$30	5	65
Other	14	16
NR	8	14

Note: NR = No Response
* = Primary 6 and Grade 6 are roughly equivalent

Discussion

This study aimed to investigate the ways that students interpret a graph in the context of a media advertisement and apply calculation skills to data presented in the graph. While the results from the Singapore sample are tentative, due to a small sample size, it would appear that these calculation skills of Primary 6 students from Singapore are superior to comparable students from Australia. While it would appear plausible that wider society plays a role in students' conceptions, it is not possible to say whether the understandings of the students in this study were grounded in experiences from school or from the surrounding environment. The much better performance of Singapore students at the Primary 6 level may be related to higher levels of numeracy skills, in particular in relation to working with percentage, as shown in calculating the discounts and total cost. In Singapore, the concept of percentage is introduced in Primary 5 which includes encouraging students to find examples of percentage in the real world, conversion between fractions and decimals and percentage, and solving word problems (Curriculum Planning Division, 1995). In Australia, these skills correspond to the curriculum for grades 6 to 8 (AEC, 1994, Profile Levels 5 and 6), and so it is hardly surprising that differences are apparent in responses from students at the Grade 6 level.

The presence of responses expressing the expectation that a pattern should appear in the graph supports evidence found in other studies and points to an area where classroom discussion may prove helpful. Teachers should discuss contexts where it is appropriate and inappropriate to expect to find patterns in

graphs. Comparing situations where algebraic relationships are graphed with those where random fluctuations in data values appear may be helpful here.

In terms of the misleading information provided in the graphical representation, it is possible that students who responded $25.50 would claim that the graph does not specifically say that the discount rate applies to each time interval. This could be another point for classroom discussion and debate. Those who responded $27.79 are likely to defend the choice using the language employed in labelling the intervals — the "rd" and "th" imply payment for those minutes at the noted discount. This is very subtle and in some instances it may be necessary to approach the company placing the advertisement to find out its intentions. Whichever the meaning, the graph is not clear and students should be developing questioning attitudes in such situations.

Unusual and sometimes misleading graphical presentations occur periodically in the media and provide excellent opportunities to motivate and challenge students. Teachers could bring examples to the classroom through the year for class discussion. It is also possible for students to be set the task of finding misleading or unusual graphs on their own to bring to class. While such activities can begin as early as Grade 6, it is important to continue them throughout the high school years to reinforce understanding and the importance of developing a questioning stance when making decisions on social issues presented with support from graphical data and claims. As noted by Watson (1997), the same experiences which are used to motivate students can also be used in assessment. This is important if students are to take the aims of the curriculum seriously. Using social contexts at all stages of the teaching-learning-assessing process will assist in providing statistically literate students leaving school.

Acknowledgment

The newspaper advertisement for Telecom which formed the basis for this item appeared in *The Age* (22 July, 1993, p. 11) and *The Mercury* (22 July, 1993, p. 17).

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