Graphics and the National Numeracy Tests

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National numeracy tests herald a new era in Australian school assessment. The sets of sample test items suggest that understanding information graphics (e.g., maps) will be an important component of these tests. However, an analysis of test items reveals limited types of graphics in sample sets, poor quality graphics, atypical use of graphics, and a lack of consistency in the graphics depicting a common shape. These findings indicate the importance of repeating the analysis with the actual tests.

Over the past four years, my colleagues and I have been investigating Australian students' performance on test items that include information graphics (see Diezmann & Lowrie, this symposium; Logan & Greenlees, this symposium; Lowrie, this symposium). Consequently, we argue that a students' ability to comprehend a graphic within a test item will strongly influence his or her ability to successfully complete the item. Thus, our team has a particular interest in the graphics within the inaugural Years 3, 5, 7 and 9 national numeracy tests. In this paper, I present an analysis of the sample items for Years 3, 5, 7 and 9 from the national numeracy tests (MCEETYA, 2007a) to ascertain (a) the role of graphics in these tests, and (b) the quality of the graphics that are included. As a background to this analysis, an overview of graphic comprehension is presented, followed by an outline of the various aspects of graphics and their use.

Understanding Graphics

Perceptual and Cognitive Processes in the Comprehension of Graphics

The comprehension of a graphic involves the interaction between a visual symbol system and perceptual and cognitive processes (Winn, 1994). The symbol system is composed of (a) *visual elements*, such as shapes, that represent objects or ideas and (b) the *spatial relationships* among the elements within the graphic (e.g., one shape inside another). Hence, descriptions of graphical languages (i.e., types of graphics) include reference to both the visual elements used and how the elements are spatially related (see Diezmann & Lowrie, this symposium). For example, a map is comprised of information which is encoded through the spatial location (spatial relationship) of marks (visual element) (Mackinlay, 1999)

In mathematics, the selection of a visual element is typically related to how the creator of a graphic wants the element to be perceived. For example, a <u>steep</u> hill may be represented with a <u>steeply sloped</u> line. An alignment between the referent and its representation has perceptual advantages. Other perceptual elements employed in graphics include position, length, angle, area, volume, density, colour saturation, colour hue, texture, connection, containment, and shape (Cleveland & McGill, 1984). In addition to perpetual processes evoked by visual elements, cognitive processes play an important role in the interpretation of graphics (Winn, 1994): "(These processes) involve the *detection* of symbols, the *discrimination* of one symbol from another and the *configuration* of symbols into patterns" (p. 5) (emphasis added). These processes are then followed by the *identification* of the graphic in relation to the individual's existing knowledge. The processes of detection, discrimination, configuration and identification may be revisited as an individual attempts to comprehend a graphic (Winn, 1994).

A Meta-Taxonomy of Graphics and their Use

There has been considerable research into the use of graphics across various disciplines. However, this research is quite disparate and informed by various theories. As a means to further the "science of diagrams" (p. 47), in Blackwell and Engelhardt's (2002) terms, they have proposed a meta-taxonomy for diagram (aka graphics) research from an extensive review of theories. Their meta-taxonomy has four major aspects: (a) *Signs* (i.e., graphic elements, conventions, level of pictorial abstraction); (b) *Graphic structures* (e.g., a tree diagram, a linear diagram); (c) *Meaning* (i.e., correspondence between a representation and its meaning, such as literal or analogical correspondence; and classifications of information by other theorists, such as graphical languages by Mackinlay (1999); and (d) *Context-related aspects* (i.e., the interaction between the person and the graphic in creating or modifying a diagram, the cognitive processes involved in interpreting a diagram, and the cultural context of the graphic). Each of these aspects needs consideration when a graphic is created as a representation of a mathematical situation.

Graphics and the New National Tests

Sample items from the Years 3, 5, 7, and 9 numeracy tests were analysed according to three questions related to the proportion of graphics on the test, the type of graphics employed, and the quality of these graphics. The limitation of using sample items is acknowledged; however final test items were unavailable at the time of writing and the characteristics of sample items are inclusive of the test items (MCEETYA, 2007b).

What proportion of sample items for the new national tests contained graphics?

A total of 49 sample items (53.3%) contained either information (i.e., structural) (n=46) or context graphics (n=3) (Table 1). Hence, students' ability to distinguish between these graphics and use them appropriately will impact on their performance. For example, in Figure 1 students <u>should use</u> the graphic to determine the number of sausages in calculating the length of the sausage string (Figure 1). In contrast, in Figure 2 students <u>should not use</u> the number of wheelbarrows or the size of the sand piles in the context graphic to calculate the amount of sand that was moved. Discrimination is a key process in comprehending a graphic (Blackwell & Engelhardt, 2002).

What types of information graphics are included in the sets of sample items?

An analysis of the sample items revealed that a variety of graphical languages (Mackinlay, 1999) were presented across the tests with the exception of Connection items (Table 1). In addition, Miscellaneous (47.8%) and Retinal-list items (37.0%) seem more likely than other language items to appear on the national numeracy tests. With the exception of Miscellaneous items, information graphics have unique graphical structures based on the visual elements that are represented and the spatial relationships among these items within the graphic. Hence students' understanding of the structural aspects of graphics will influence their comprehension of these graphics (Blackwell & Engelhardt, 2002).

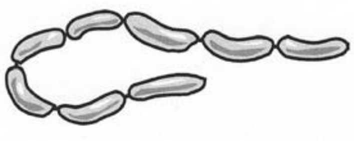

Figure 1. An information graphic (MYCEETYA, 2007b, Sample 2, Item 1)

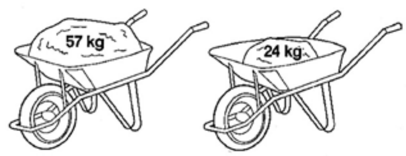

Figure 2. A context graphic (MYCEETYA, 2007b, Sample 1, Item 3)

Table 1

Proportions of Sample Items that Contain Graphics by Year and Type.

Year	Total Items	Graphics Items	Context Graphics	Information Graphics: *Graphical Languages* *MI*	*RL*	*MA*	*AX*	*OP*	*CO*
3	16	75%(n=12)	1	8	1	2	0	0	0
5	14	64.3% (n=9)	1	4	2	1	1	0	0
7	13	53.9% (n=7)	0	2	4	0	1	0	0
7[C]	12	41.7% (n=5)	0	2	3	0	0	0	0
9	16	50% (n=8)	1	4	2	0	0	1	0
9[C]	21	38.1% (n=8)	0	2	5	0	0	1	0
Total	92	53.3% (N=49)	3	22	17	3	2	2	0

Key: *MI=Miscellaneous; RL=Retinal List; MA=Map; AX= Axis; OP= Opposed Position; CO=Connection* [C] indicates the calculator component of the test in Year 7 or 9.

Do the sample items indicate high quality representation of graphics?

There are three concerns with the quality of the graphics in the sample items. The first concern is the *artistic quality of the graphics*. It would be inexcusable to misspell a word or use mismatched fonts in a numeracy test yet poor quality drawings are included. For example, the drawing of pots in a tray (Figure 3) shows lines inappropriately going through the pots and also the right side of the tray, which affects depth perception. The second concern is the *lack of consistency* in showing how a common three-dimensional shape should be represented graphically. In a Year 3 item, the students are expected to identify a *cylinder* based on its visual characteristics (Figure 5), yet in a Year 5 item a *cylinder* is inappropriately represented with two dimensions (Figure 6). This 3D-2D mismatch has implications for the identification of cylinders and the need to attend to graphical conventions (Blackwell & Engelhardt, 2002). The third concern is the use of *atypical graphics*. For example, a grid is not commonly used to identify large sections of a country (Figure 4). More typically used are states and territories or regions with similar characteristics (e.g., geographic terrain). Thus, there is a lack of attention to the cultural context in which graphics are typically used (Blackwell & Engelhardt, 2002). In each of these examples, there is potential for the quality of the graphics to impact negatively on the students' perceptual or cognitive processes employed in comprehending graphics, which is not ideal in assessment tasks.

Figure 3. A poor quality graphic (MYCEETYA, 2007b)

Figure 4. An atypical graphic (MYCEETYA, 2007b)

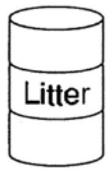

Figure 5. A 3D cylinder (MYCEETYA, 2007b)

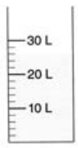

Figure 6. A 2D "cylinder" (MYCEETYA, 2007c)

Concluding Comments

The analysis of sample items in the national numeracy tests has revealed that graphics are likely to play a major role in student' performance on the actual tests. What is <u>within</u> the control of the students (supported by their teachers) is their knowledge of context and information graphics and how to interpret these. What is *beyond* the control of the students is the perceptual or cognitive processing errors and comprehension errors that may result from poor quality graphics. Thus, if the national tests are to have credibility as a performance measure, all graphics need to be of high quality, which is not the case with some of the sample items. In fairness, I will suspend my judgement of the national numeracy test until the tests are available for similar graphical analysis. However, the findings from this study indicate the importance of scrutinising the national tests to provide informed comment on the interpretation of student outcomes from the national tests.

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