Introduction

The 21st century has placed increasing demand on individuals’ proficiency with a wide array of visual representations, that is graphics (Harris, 1996). Hence, proficiency with visual tasks needs to be embedded across the curriculum (National Academies, 2006). In mathematics, various graphics (e.g., maps, charts, number lines, graphs) are used as means of communication of mathematical ideas and also as tools for thinking about these ideas. Thus, to be numerate in contemporary society, all individuals need to make sense of the graphical aspects of mathematics. Although an understanding of representations is critical for numeracy (Pugalee, 1999), proficiency with graphics in mathematics is often overlooked. The purpose of this paper is to highlight the six key types of graphics used in mathematics and to provide some suggestions for developing students’ ability to interpret each of these types of graphics. As a background to the discussion on types of graphics, two roles of graphics are first discussed. The ability to create graphics has been described elsewhere (Diezmann, 2002).
The roles of graphics in mathematics: Context and information

In mathematics, students need to appreciate whether the intent of a graphic is to contextualise the task or to present information. A contextual graphic (see Figure 1) represents objects, people or locations for illustrative purposes. These graphics contain no mathematical information pertinent to the task and can often mislead students. In contrast, an information graphic (see Figure 2) represents mathematical information in a visual–spatial form. In information graphics, students need to be able to access the embedded information in order to solve the task (Diezmann & Lowrie, 2008).

Information graphics, such as a calendar, are intended to communicate mathematical information but many students are unable to access fully the information embedded in these graphics. Teachers can support the development of students’ knowledge by providing them with opportunities to learn about the various elements that make up information graphics.

Six types of graphics

There are many thousands of graphics which Mackinlay (1999) argued can be categorised into six types of graphical languages. These languages are: Axis, Opposed Position, Retinal List, Map, Connection and Miscellaneous. Like text-based languages, graphical languages have unique characteristics. An overview and example of each graphical language follows, together with recommendations for developing an understanding of each language in the classroom.

1. Axis graphics show information through the placement of a single point on a line. The following Axis item (Figure 3) focuses on this single point by asking students to identify the position of 17 on the number line. Although D is the correct response, some students selected B, reasoning that D is 19, C is 18 and therefore B would be 17. These students have counted back correctly in order. However, counting back by ones is not an appropriate strategy for this task because the marks on the number line are not evenly distributed and the distance between each mark is not “one unit.” To help students understand the proportional aspect of the placement of the points on a number line, have them plot the local landmarks along a main road near your school. Encourage the students to consider the distances between the landmarks to establish that they are not evenly spaced.
2. Opposed position graphics include line charts, bar charts and plot charts. The opposed position item in Figure 4 requires students to calculate the difference between an athlete’s highest and lowest pulse rates. However, in order to make this comparison, students need to be able to identify the high and low points on the graphic. To encourage students to pay attention to the visual elements of the graphics, discuss the nature and movement of the line. Students need to look beyond the plotted points and understand what the line is representing. Encourage students to discuss the rise and fall (and the flatness) of the line before considering information on the x- and y-axes.

Figure 4. An opposed-position item (Educational Testing Centre, 1999, p. 8).

3. Connection graphics, such as in Figure 5, use tree and network-type diagrams to show information. These diagrams have broad everyday applicability, for example representing subway lines or sporting draws and results. However, one error that students typically make on such items is to base their response on everyday experiences rather than on what the graphic actually shows. In this item, students should follow the pathway from bottom to top (hum-soft-low-sound) in order to identify the characteristics that have been represented about this “hum,” rather than base their responses on their knowledge of sound. Facilitate the students’ interpretation of these types of graphics by encouraging them to follow the pathways from top to bottom or bottom to top, depending upon the nature of the task. An authentic scenario for the top to bottom approach is the construction of a family tree.

![Figure 5. A connection item (Educational Testing Centre, 2001, p. 3).](image)

4. Retinal list graphics use colour, shape, size, saturation, texture and orientation to represent information. In Figure 6, orientation has been used to show a change in perspective of an item. However, this item also requires students to understand how the term “flip” is used in association with a change in orientation in two-dimensional space. The outcomes of a flip in two-dimensional (2D) and three-dimensional (3D) space are different. In 2D space, the outcome of a flip is a mirror reversal, but in 3D space after a flip (i.e., travelling through 360°) an object or person returns to their initial orientation.

Which of the following describes a ‘hum’?

- SIREN
- THUNDER
- HUM
- GLASS
- CLINK
- LOUD
- SOFT
Thus, students who are familiar with the concept of flip in 3D space may fail to recognise the result of a flip in 2D space. To develop students’ knowledge of flips, provide opportunities for students to use concrete materials such as mirrors, shapes and tangrams to rotate, reflect and translate objects (Bobis, Mulligan & Lowrie, 2008). Also encourage students to use appropriate terminology as they describe these manipulations.

5. Map graphics include road maps, topographic maps and grids. In Figure 7, location is defined by (1) the grid and also by (2) the bike track. A successful response requires students to use both types of information to identify a solution. To foster students’ knowledge of maps, use the school environment to create maps (e.g., a treasure hunt). In pairs or small groups students can hide an object (treasure) and draw a map to describe its position within the classroom or playground. Other groups are then given the map and asked to find the treasure. For more information about maps see Lowrie and Logan (2007).

6. Miscellaneous graphics are those graphics that are not included in the other five types of graphics. They include some everyday graphics such as a calendar as in Figure 8. Although this appears to be a simple item, some students confuse the rows and columns and incorrectly move along a row rather than a column when counting weeks. Students sometimes make a similar error on the 100 board, incorrectly moving along a row instead of a column when counting in tens. To broaden students’ knowledge of calendars, use them in discussing everyday situations. For example, identify special events (birthday, school fete, concert) on a calendar and calculate how long until these events. Appropriate terminology, such as “in a week,” “in a fortnight,” “three weeks from …” can be used to describe upcoming events.
Concluding comments

The importance of graphics cannot be underestimated in our visually-oriented, technological world. Students need opportunities to develop their understandings about graphics in various mathematical situations. In sum, there are three important ways to develop understandings about graphics. Students need to:
1. be able to identify whether the intent of the graphic is to provide a context or present mathematical information;
2. develop adequate knowledge about the various types of graphic; and
3. have opportunities to experience visually diverse examples of the same type of information graphic. Perceptual variability strengthens understanding (Dienes, 1964).

As teachers, we need explicitly to address the structure and nature of the different types of information graphics. Although such teaching should not be considered in isolation, the unique features of each of these types of graphics needs to be well understood by students to enable them to access and use mathematics that is presented visually.

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References


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