The heat is on! Using a stylised graph to engender understanding

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When working within a meaningful context quite young students are capable of working with sophisticated data. Year 3 students investigate thermal insulation and the transfer of heat in a STEM inquiry, developing skills in measuring temperature by conducting a statistical investigation, and using a stylised graph to interpret their data.

Graphing opportunities in the primary classroom focus on the application of conventional graphical representations, such as column graphs. The *Australian Curriculum: Mathematics* (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2016), however, provides the opportunity for various graph types to be used to display and interpret data. In Year 1, there are no particular graphical representations mentioned and students are given the freedom to display data in drawings and describe the displays. This becomes more prescribed in Years 2 and 3, when students create picture graphs and column graphs. In Years 4, 5 and 6, students are extended to construct suitable data displays, and evaluate the effectiveness and usefulness of different data displays. The graphical representations suggested are picture graphs, column graphs, and dot plots. There is, however, the potential to introduce other graphical representations that engender understanding of data and draw out the stories data have to tell. This article describes the application of an unconventional, stylised graph that has the potential to exploit students' understanding of column graphs to interpret a graphical representation that displays time series data.

Graphical representations are visual imagery used to convey information, stimulate ideas, and communicate messages. This involves "transnumeration," which includes the translation of raw data into graphical representations. At the classroom level this involves telling stories from the data (Chick, Pfannkuch, & Watson, 2005). Pfannkuch and Wild (2004) suggest that transnumeration engenders understanding and captures the characteristics of real situations. As such, the effectiveness of the visual representations depends heavily on people's ability to understand the imagery used and the conventions applied when graphing and interpreting data.

Another factor that influences the interpretation of graphs is the context of the data. An understanding of the context and the nature of the variables of interest may be gained from personal experiences of the context, from information about the data, or from the components embedded in the graphical representations (Fitzallen & Watson, 2011; Kosslyn, 1989; Roth, Pozzer-Ardenghi, & Han, 2005). Collectively, the components of graphs are resources that provide a link between the two-dimensional representations and the real world measurement and data collection situations.

English (2013) advocates that young students be given the opportunity to demonstrate creativity when representing data visually without being encumbered by pressure to produce conventional graph types. Indeed, she provides excellent examples of the various ways in which Year 1 students use unconventional graph types to display data. Mulligan (2015) reports similar results but also adds that young students are able to structure data more formally after instruction. Although it is important to give students the opportunity to be creative and express their understanding of data collection activities in ways that are specifically meaningful for each individual, there are circumstances where it is important that the same graphical representation is used by all so that data can be compared and combined. This was the case for an activity, The Heat Is On!, completed by Year 3 students investigating the transfer of heat and the influence of insulation.

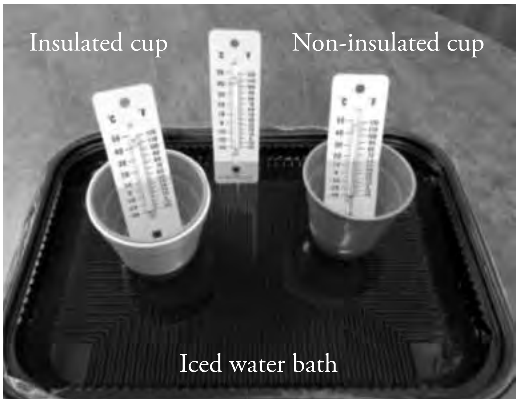

Figure 1. Equipment used for the investigation.

Figure 2. Year 3 students taking temperature readings for The Heat is On!

The Heat is On!

The Year 3 student investigation entitled, The Heat is On!, was designed to support students to explore thermal insulation and the transfer of heat, reinforce notions of variation specifically related to heat loss over time, and develop students' skills in using instruments to measure temperature by conducting a complete statistical investigation. The questions posed for the students were:

- "How does temperature vary when something gets hotter or colder?" and
- "What is the effect of different materials on how the temperature varies?"

Connections to the curriculum (ACARA, 2016) were identified across three learning areas:

- ***The Australian Curriculum: Science***
  Heat can be produced in many ways and can move from one object to another (ACSSU049).
- ***The Australian Curriculum: Design and Technologies***
  Investigate the suitability of materials, systems, components, tools and equipment for a range of purposes (ACTDEK013).
- ***The Australian Curriculum: Mathematics***
  Construct suitable data displays from given or collected data (ACMSP096).

The students worked in groups of three to read and record the temperature of the water in two plastic cups, one insulated with a polystyrene cup (see Figure 1), over a period of 30 minutes (Figure 2). The cups contained the same volume of water at the same starting temperature (≈40˚C), and the temperature was recorded at 5-minute intervals. After the first 10 minutes, iced water was added to the tray in which the cups were sitting, and the temperature of the iced water was also measured at each subsequent five-minute interval. Students recorded the temperatures in a table (Figure 3) and then translated the data to their Thermometer Worksheet (Figure 4).

Time	Temperature˚ C		
	Insulated cup	Non-insulated cup	Iced water
Start			....
5 minutes			....
10 minutes (Add iced water)			
15 minutes			
20 minutes			
25 minutes			

Figure 3. Data collection table used in The Heat is On!

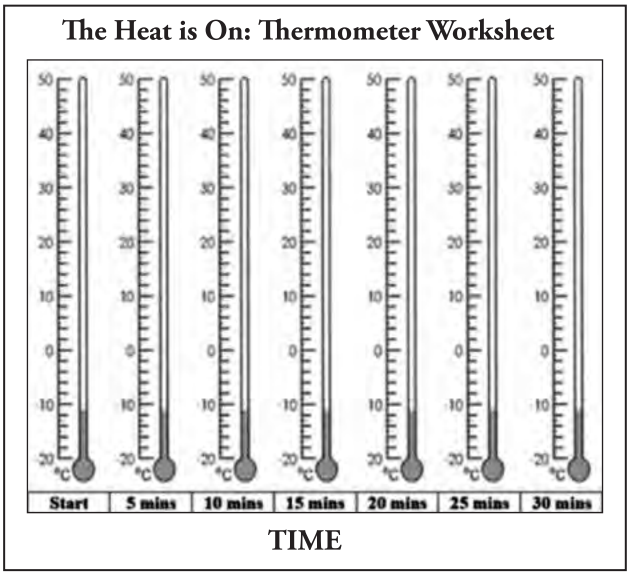

Figure 4. Stylised graphical representation for The Heat is On!

Supporting transnumeration

The stylised thermometer graph was developed to support the students because their graphing experiences had been based on recording tallies in tables and drawing picture graphs and frequency column graphs. They had not met two-dimensional representations of the type needed for The Heat is On! activity. Conventional graphs include the basic-level components that communicate information clearly and concisely. The components include the 'background', the 'framework', the 'specifier', and the 'labels' (Kosslyn, 1989), as shown in Figure 5. Kosslyn's graph conventions are expressed in the stylised thermometer graph as follows:

- **Background:** Collection of thermometer images.
- **Outer Framework:** Horizontal axis with 5-minute intervals forming the scale.
- **Inner Framework**: The scale on the thermometers ranging from –20 to 50 degrees Celsius.
- **Specifiers:** The lines representing the temperatures of the water in the three containers, recorded for the duration of the activity.
- **Labels:** Time and the degrees Celsius symbols provide vital information about what is being measured.

Given the historically acknowledged difficulty some students have comprehending graphical representations (e.g., Fitzallen, 2016; Shah, Mayer, & Hegarty, 1999), the aim was to make explicit the connection between the context of the data collection opportunity and the transnumeration of the data in a visual form. Student understanding was further enhanced by first using a table to record the temperature at each time interval (Figure 3). The students then translated the data from the table to the stylised graph (Figure 6). They used coloured pens to differentiate the three temperature readings—red for the insulated cup, blue for the non-insulated cup, and black for the iced water bath—to construct a graph. An example of a completed graph is in Figure 7.

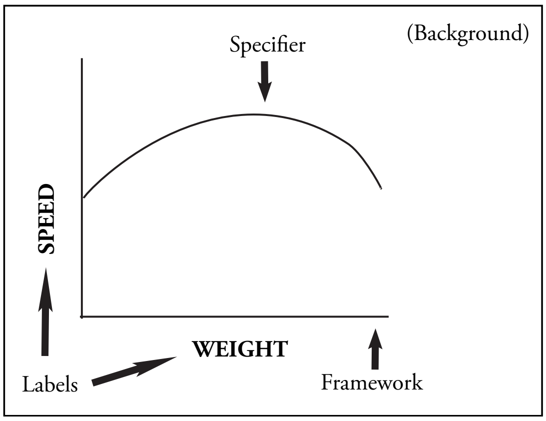

Figure 5. The basic-level constituent parts of a graph (Reproduced from Kosslyn, 1989, p. 188).

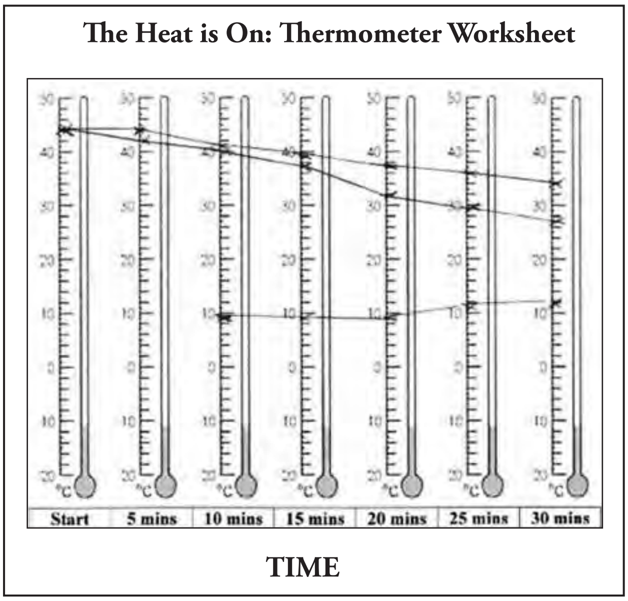

Figure 7. A student's completed graph (top line, insulated cup; middle line, non-insulated cup; bottom line, iced water bath).

Figure 6. Year 3 students translating data from the table to the thermometer graph.

Student descriptions and interpretations

The search for meaning from graphical representations can come from two perspectives, local and global (Guthrie, Weber, & Kimmerly, 1993). Both perspectives were evident in the students' comments when describing and interpreting the graphs constructed. When asked to determine which cup had the greatest change in temperature of the water, some students described the changes from a global perspective, "I looked on the graph," and "The line on the graph for the non-insulated cup went down further and quicker." Another student mentioned all three lines. She said, "The lines are showing how the graph does it, it goes down, so because it is showing that that one goes up [water bath] and it is showing these ones goes down [insulated and non-insulated cups]." This response shows that the student identified the global trends in the data across the time of measurement (with the background and the specifiers) and was able to compare those trends.

Other students interpreted the thermometer graphs differently. They described their graphs from a local perspective (Guthrie et al., 1993). These students were able to use the specific details of the graphs to respond from a local perspective. They made comments such as, "On the graph non-insulated starts at 53°C and ends at 22°C," and "… the non-insulated cup reached from 44°C to 27°C. The other one went from 44°C to 34°C" (using the Background and the Inner Framework). Also evident was the students' use of the local perspective with the Outer Framework and Labels of the graph to describe what occurred. For example, a student commented that the labels showed "how many minutes you need to wait for the next [temperature reading]." These comments demonstrate that the thermometer images in the graph assisted in conserving the context of the investigation and allowed students to use specific details about the data to answer questions and tell a story from the data. At this grade level, however, they tended not to combine the global and local perspectives but to take one perspective or the other.

Concluding thoughts

The interpretation of quantitative data in graphical form is dependent on the characteristics of the graph itself. In their experiments with undergraduate students, Shah and colleagues (1999) demonstrated that the way in which data are displayed affected the students' ability to interpret the data effectively. By replotting the data in an alternative graphical form—transnumeration—the students were guided through the "cognitive processing of the graphs" (p. 694). This is not to say that one graph form is better than another. The appropriateness of a graphical representation is dependent on the task itself and how the user desires to tell its story.

In the current activity, the stylised thermometer graph was deemed appropriate as it enabled the students to connect the context of the data collection opportunity and the visual representation of the data in a meaningful way. The stylised thermometer graph provided a cognitive bridge between the act of measuring the temperature and the process of modelling the data in the graphical representation, which they then used to make decisions.

Research has shown that primary school students may be knowledgeable about the techniques for constructing graphs without fully understanding the underlying rationale for, or purpose of, constructing particular graphs (Parmar & Signer, 2005). In The Heat is On! activity, the background image of the thermometers provided a visual link to the purpose of the graph. The students were able to make the connections among the data in the graph, the temperature in the cups, and the temperature of the water bath at each time interval. The graph supported the transnumeration of the data from which the students identified trends and used the components of the graphs to tell the story about the way in which the heat was transferred and the influence of the insulation. The *Australian Curriculum: Mathematics* (ACARA, 2016) does not suggest the investigation and description of bivariate numerical data where the independent variable is time, until Year 10. The authors suggest that primary school students may also be able to draw conclusions and make meaningful interpretations from data of this form when given graphical representations that are designed specifically to engender understanding by making explicit links to the context of the data.

Acknowledgments

This article is based on research funded by an ARC Discovery Project, Modelling with Data: Enhancing STEM in the Primary Curriculum [DP 15010012]. The authors acknowledge other project colleagues, Lyn English and Jo Macri, and Bruce Duncan who helped with the implementation of the activity. They also express their particular thanks to the teachers and school community that made this study possible.

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