Grappling with graphs: supporting students with graph interpretation

Amanda Clegg and **Karen Collins** examine research about graph interpretation and discuss the implications for the classroom

How many times have we become frustrated when carrying out a graphing activity in lessons? Below, we examine some of the research around graph interpretation and look at how to develop student understanding to improve outcomes. How do teachers and students interpret graphs differently from one another?

Why might students struggle to interpret graphs?

You may be surprised to hear that it takes an expert approximately the same amount of time to interpret a graph as it does to interpret a paragraph of text: around 30 seconds (Carpenter and Shah, 1998). This time is spent thinking about and interpreting the line of best fit, relating it to the labels on the axes, and any other information, such as a key. How might this be different for novices, like our students? How long does it take them to interpret a paragraph of text? Do we provide them with enough time to read and interpret graphs?

Harsh *et al.* (2019) used eye-tracking software to find out how the approach to graph interpretation differs between novices and experts (for the purposes of this article we considered specialist teachers to be experts and students to be novices). Experts analysed the contextual information first, focusing on the labels, units, title and key before looking at the line of best fit. Novices looked for clues in the question stem and then went directly to the line of best fit, ignoring the contextual elements. This might explain why students say '*it goes up*', when asked to describe the trend on a graph. They are not making use of the labels on the axes and other information to inform their descriptions. As teachers we might inadvertently focus the students' minds on the question stem by saying, for example, '*What is the question asking you to do?*' Maybe we need to discuss the graph in detail first, talking through our thinking before tackling the question.

Another reason students find the interpretation of line graphs difficult is because they '*consistently ignore or are unable to interpret the variable plotted on the x-axis*' (Peebles and Ali, 2015: 3). This difficulty can arise because the two ends of the line of best fit form a visual chunk that appears to be 'floating' and detached from the x-axis. It is easier for novices like students to interpret bar charts, since the bars form a visual chunk in physical contact with the x-axis, so the eye is drawn down towards the labels.

So what are the implications of the outcomes of this research for us as teachers? We might assume that students develop graph interpretation skills through exposure to graphs, but evidence suggests this is not the case (Glazer, 2011). So, how can we support students with graph interpretation?

How to use the 'Think Aloud' strategy

One potential method is thinking aloud, an effective strategy for modelling mathematical problem-solving (EEF, 2017, 2018). This approach shows the students your thinking as you solve the problem, demonstrating how an expert would approach the task in hand. It makes our cognitive processes explicit, modelling how to tackle the problem, and providing a method that can be used and applied by students to other similar tasks.

Using this strategy to interpret graphs involves explaining where we are looking on the graph, what it is telling us and how we are using this information to describe a trend and draw a conclusion.

What might this look like in practice?

When interpreting graphs, the main difference between novices and experts is the use they make of contextual elements such as labels and units to make inferences. Our role is therefore to draw students' attention to this information and explain how we use it to interpret the graph.

Let's look at a typical example of a graph relating to the Haber Process (Figure 1).

The first step is to look at the labels on the axes and explain what they are telling us. In this case, the label on the x-axis shows us that the independent variable is pressure measured in atmospheres, with the range going from zero up to 400 atmospheres. The dependent variable on the y-axis is the percentage yield of ammonia, ranging from 0% to 80%. At this point it would be a good idea to explain what the term 'yield' means in this context. Only then would we begin to discuss the trend. In this case there is more than one line to consider, so at this stage we would look at the additional contextual information next to each line.

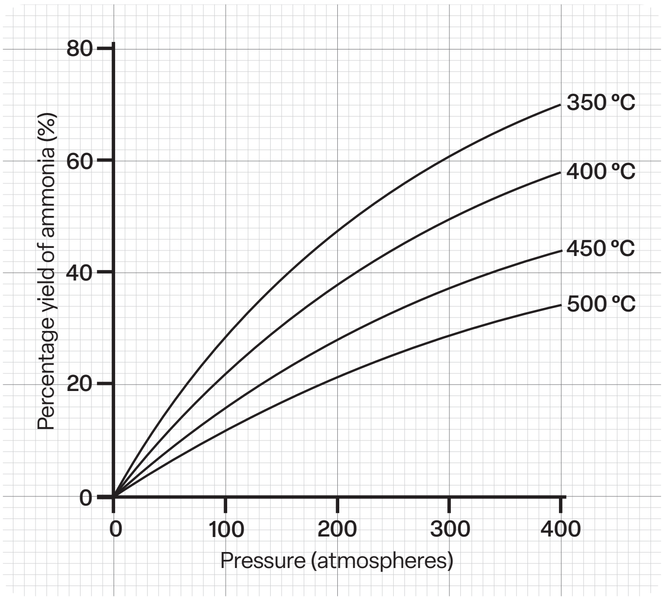

Figure 1 An exemplar graph

There are four trend lines, one for each temperature of 350 °C, 400 °C, 450 °C and 500 °C. This tells us that the experiment was repeated at four different temperatures. We would then go on to describe the trend for each individual line, before discussing how temperature affects the percentage yield of ammonia.

Summary

Think Aloud is a well-documented approach for mathematical problem-solving, which can be used as an effective teaching tool in science. We can make use of this strategy when teaching students to interpret graphs, explaining the thought processes we go through as experts. More information about graph construction and interpretation, including student-focused activities and common misconceptions, can be found in the book *Grappling with Graphs* (Clegg and Collins, 2023).

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GRAPPLING WITH GRAPHS

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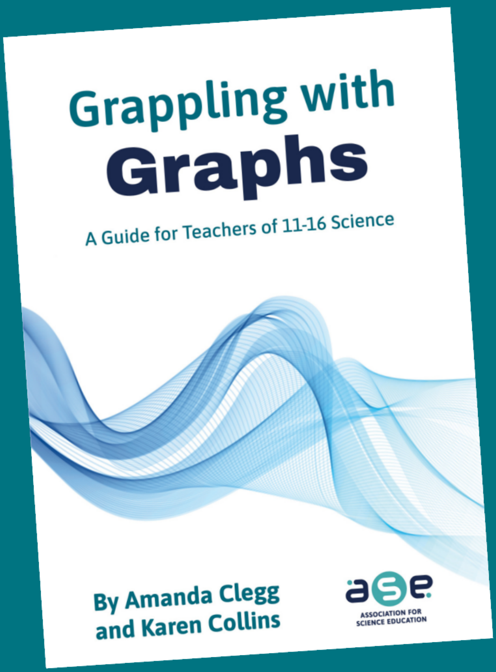

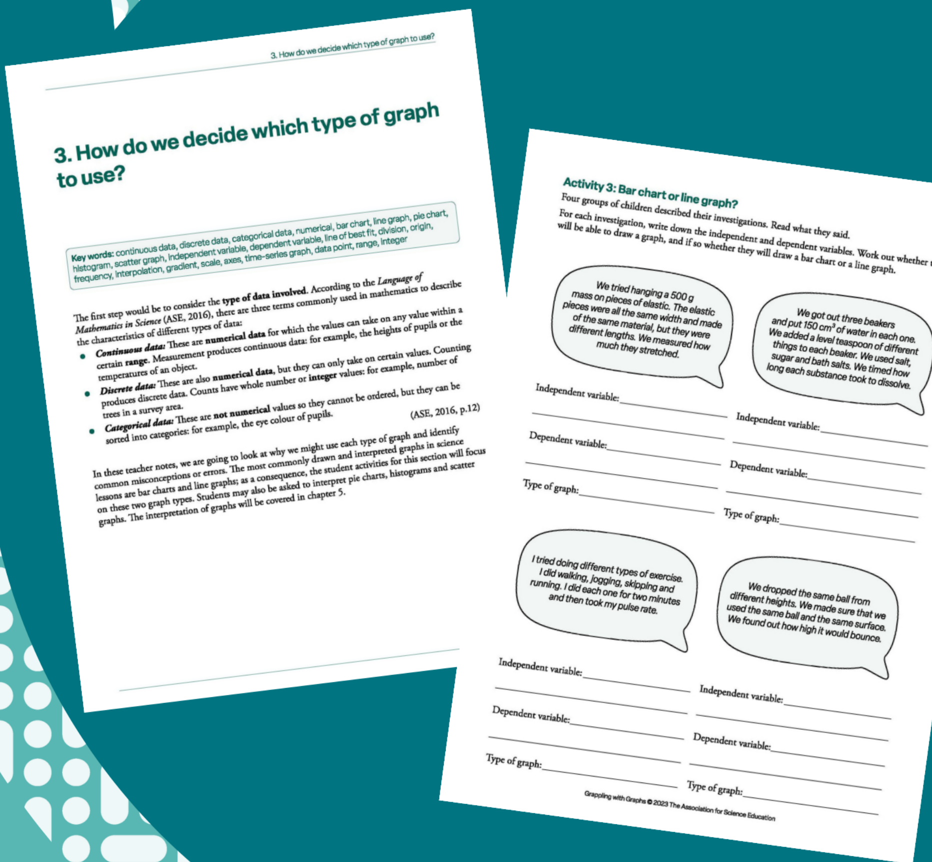

3. How do we decide which type of graph to use?

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Key words: continuous data, discrete data, categorical data, numerical, bar chart, line graph, pie chart, histogram, scatter graph, independent variable, dependent variable, line of best fit, division, origin, frequency, interpolation, gradient, scale, axes, time-series graph, data point, range, integer

The first step would be to consider the **type of data involved**. According to the *Language of Mathematics in Science* (ASE, 2016), there are three terms commonly used in mathematics to describe the characteristics of different types of data:

- ***Continuous data:*** These are **numerical data** for which the values can take on any value within a certain **range**. Measurement produces continuous data: for example, the heights of pupils or the temperatures of an object.
- ***Discrete data:*** These are also **numerical data**, but they can only take on certain values. Counting produces discrete data. Counts have whole number or **integer** values: for example, number of trees in a survey area.
- ***Categorical data:*** These are **not numerical** values so they cannot be ordered, but they can be sorted into categories: for example, the eye colour of pupils.

(ASE, 2016, p.12)

In these teacher notes, we are going to look at why we might use each type of graph and identify common misconceptions or errors. The most commonly drawn and interpreted graphs in science lessons are bar charts and line graphs; as a consequence, the student activities for this section will focus on these two graph types. Students may also be asked to interpret pie charts, histograms and scatter graphs. The interpretation of graphs will be covered in chapter 5.

Activity 3: Bar chart or line graph?

Four groups of children described their investigations. Read what they said.

For each investigation, write down the independent and dependent variables. Work out whether
will be able to draw a graph, and if so whether they will draw a bar chart or a line graph.

We tried hanging a 500 g mass on pieces of elastic. The elastic pieces were all the same width and made of the same material, but they were different lengths. We measured how much they stretched.

Independent variable:

Dependent variable:

Type of graph:

We got out three beakers and put 150 cm^3 of water in each one. We added a level teaspoon of different things to each beaker. We used salt, sugar and bath salts. We timed how long each substance took to dissolve.

Independent variable:

Dependent variable:

Type of graph:

I tried doing different types of exercise. I did walking, jogging, skipping and running. I did each one for two minutes and then took my pulse rate.

Independent variable:

Dependent variable:

Type of graph:

We dropped the same ball from different heights. We made sure that we used the same ball and the same surface. We found out how high it would bounce.

Independent variable:

Dependent variable:

Type of graph:

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The purpose of this book is to provide CPD for teachers and enable them to apply research on graphs into their practice. The book is split into two parts:

Section A contains a summary of the research, common misconceptions, and how to teach both the construction and interpretation of graphs.

Section B contains student-focused activities which have been broken down into key skills.

www.millgatehouse.co.uk/grappling-with-graphs/