Andy Markwick *and* **Kris Clark** *highlight practical examples to offer a rationale for the application of mathematics in science and explore their intrinsic relationship*

Figure 1 Leaves uniting maths and science for learners

Science + Maths = a better understanding of science!

Science and mathematics share a common purpose: to explore, understand and explain the pure beauty of our universe and how it works. They also have a natural relationship that has catalysed some of the most significant changes in society. It could be argued that mathematics has enabled scientists to better describe and quantify observations of natural phenomena and that without such insights our scientific understanding would have been extremely limited and almost sterile. In this sense, mathematics is an integral part of the scientific process. However, ideas in mathematics have also resulted from a desire to explain natural phenomena. For example, calculus was independently created in the 17th century by Sir Isaac Newton to explain motion and by Gottfried Leibniz to explain incremental changes. Certainly, science and mathematics can engage and excite our most inquisitive and curious children as they ask questions about their world.

The importance of using mathematics in science has been recognised by the UK government and resulted in a statutory increase of mathematical content at GCSE (DfE, 2013a). Both primary science and mathematics curricula have been significantly transformed (DfE, 2013b). Far greater emphasis is now placed upon children 'working scientifically', where scientific skills progress from the purely qualitative (e.g. observations) in key stage 1 (ages 5–7) towards more rigorous and quantitative uses of data (e.g. using data to find causal relationships) in key stage 2 (ages 7–11). The mathematics curriculum has been streamlined and now has three key areas of focus: fluency, reasoning and problem-solving (DfE, 2013b: 99). Its prime aim is for children to understand the content of the curriculum at a deep level so that knowledge and skills can be transferred and applied.

Using mathematics in science enquiry can enhance children's understanding of science and also provide opportunities for children to apply their mathematical knowledge to 'real' contexts. Assessing science and mathematics outside normal contexts provides more robust measures of a child's understanding of both subjects. A well-constructed marriage between science and mathematics

Key words: ■ Nature of science

Box 1 Example 1: Reception/key stage 1 (ages 4–7)

Anthony and Antonia go sailing

The lesson begins with a story about two ants that need to cross a stream at the bottom of their garden. They enlist the help of children (your class) to test which type of leaf might be best to use as a boat for crossing the stream (see Box 1A).

Figure 2 Children use blocks to test the carrying power of their leaves

Possible learning outcomes

Children will:

- use a key to identify different leaves and the trees they come from;
- plan an investigation to test each type of leaf as the best boat;
- measure number using blocks (addition of 2s, 5s and 10s);
- calculate numbers of ants from equivalence formulae (1 block = 2 ants, 5 ants, 10 ants, etc.);
- draw a conclusion based upon their data.

Method

1 Children select a leaf to investigate. A selection of leaves might be provided for children or they could collect their leaves themselves.

2 Using a key, children name the leaf and the tree it comes from. They might also be asked to describe the leaf (colour, shape, size).

3 The leaf is placed in a tray of water to see if it floats. Blocks are carefully added and counted until the leaf sinks (Figure 2). The total number of blocks is counted and recorded in a table (Figure 3).

4 Children repeat this test with other leaves of their choice.

5 Once the experiment is complete, children are introduced to the equivalence tables. They are asked to calculate the numbers of ants that each leaf could carry if each block was equal to 2 ants, 5 ants or 10 ants and so on.

Very able children might be asked to determine the mass of each block using a balance and be given the mass of an ant (approximately 0.001 g). From this they could calculate the total number of ants each leaf could carry (Figure 3B).

This investigation helps children to develop their understanding of how scientists use experiments to answer questions. Children develop scientific and core language skills through discussion with each other and employ their mathematical knowledge of addition and multiplication to solve a 'real' problem.

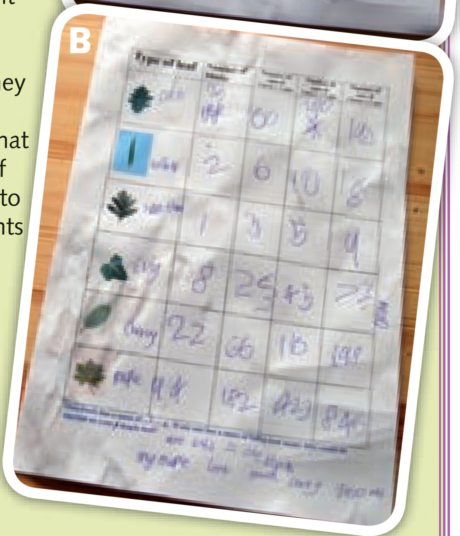


Figure 3 Completed tables demonstrating how children can apply mathematics to their data: (A) from a reception year child; (B) from a year 2 child

Box 1A Story to introduce Example 1

Antony and Antonia go sailing

I woke up early one morning to a faint 'tap, tap' at my back door.

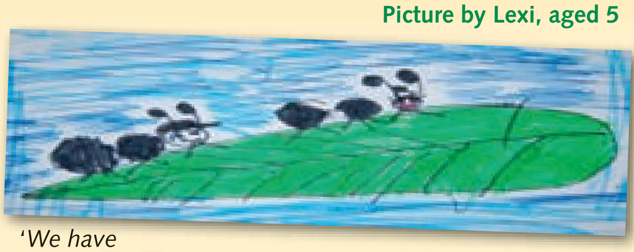
'*Wait a minute*', I called out, '*I need to comb my teeth and brush my hair first. I was half asleep you know!*'

I opened the door to two of my smallest friends, Antony and Antonia, two ants that lived at the bottom of my garden.

'*How are you both on this beautiful day?*' I asked.

'*We are both very well, thank you for asking. How are you?*' said Antonia.

'*Apart from having toothpaste in my hair and hair in my teeth, I'm fine*', I said.



Picture by Lexi, aged 5

'*We have a favour to ask you*', said Antony.

'*Of course,*' I said, '*what favour would that be?*'

'*Well, said Antony, there is a small stream at the bottom of our garden and we want to be able to cross it to see our friends Antoinette and Antario, but we certainly couldn't swim that far!*'

'*Do you know any scientists that could investigate how we might cross the river safely?*' asked Antonia.

could provide opportunities for children to demonstrate their deeper understanding through application of their knowledge and skills.

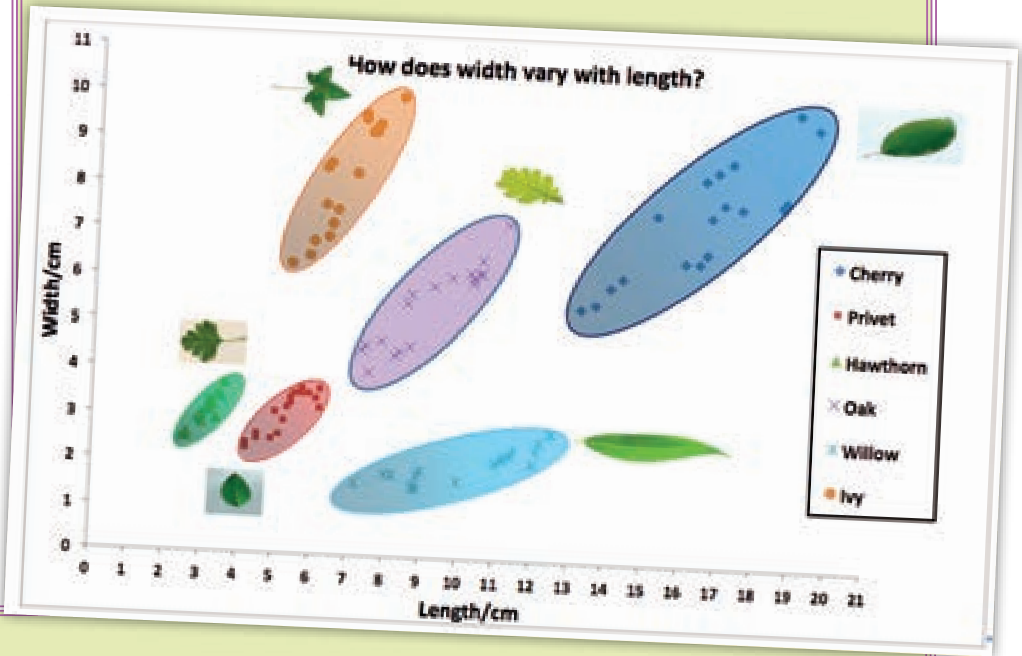
The examples in Boxes 1 and 2 are taken from tried-and-tested lessons across the primary age range.

Applying mathematical concepts

An essential concept that needs to be secure at early key stage 1 is that of place value and grasping the base-10 system. Children require varied and repeated experiences of counting objects across the 10s boundary and regrouping 'ten 1s' to represent 'one 10'. Carefully counting out blocks on to leaves and recording their findings allows children to apply this skill with increasing fluency. Applying their mathematical knowledge in this way is a novel way to add conceptual challenge.

By handling objects such as blocks, children's understanding of scientific concepts can be reinforced. Children will intuitively understand that it is the increase in mass that eventually causes the leaf to sink and, because this mass is modelled by the number of blocks, it is definable and quantifiable. What's more, children can practise their mathematical and scientific language to accurately describe their results; for example, the best leaf to carry the ants is the one that can carry most blocks, the next best leaf is … because … and so on. This reinforcement of mathematical

Figure 4 A plot of leaf length against width for a range of different leaf types



Box 2 Example 2: Upper key stage 2 (ages 9–11)

Classifying leaves

This lesson starts by introducing a range of different leaves to children. Can children name them? Can they suggest how they might classify them? Children should be familiar with grouping using leaf characteristics such as colour, shape, size and so on. Ask children to look carefully at two different leaves, for example willow and ivy. Apart from their general shape and colour, can children describe other differences between these leaves? How can these differences be measured? This should draw their attention to the dimensions of each leaf. For example, measuring leaf length, width, surface area, mass and so on. Suggest that they measure the length and width of six leaves of each type (to obtain a good range of data for each type of leaf).

Possible method

Provide children with a selection of six different leaf types (e.g. oak, maple, willow, hawthorn, ivy, rose, cherry, rowan berry, sycamore, chestnut, etc.).

1 Choose a type of leaf to begin with. Measure its maximum length and maximum width.

2 Record these data in a table.

3 Repeat these measurements with five more leaves of the same type.

4 Record these data.

5 Repeat steps 1 to 4 with a different type of leaf.

6 Continue with different types of leaf until at least five have been measured.

7 Plot the data for each leaf type separately (use a different symbol or colour).

Plots should show that for different leaves there are distinct ranges of measurements. Ask children how their graph might be used to classify an unknown leaf. Figure 4 shows a plot obtained from data collected by year 5 (age 9–10) children.

With nature comes variation. As each and every leaf is different it is important for children to appreciate exactly how much variation there actually is. Children could apply their statistical knowledge to begin defining properties for each leaf. For example, what range do the dimensions of each leaf fall into? What length and width defines an average willow leaf?

Although plotting scatter graphs may not be defined in the primary mathematics curriculum, there is overlap with coordinates and line graphs. The data can be represented in an appropriate way for children to make statistical inferences.

In year 6 (age 10–11), children learn about how shapes can be similar (i.e. differ in size but not in shape). This activity could reinforce how to create similar shapes based on a scale factor or calculate a scale factor if dimensions are known. Although in nature there is variation, children will notice that there is a governing rule that prevents variation from being too great from one type of leaf to another. This is important, because without these differences classification would not be possible. The activity might also be used to promote the use of common correlation using mathematical and scientific language, such as: *for every … cm in length, there is … cm in width.*

understanding increases conceptual flexibility and so improves confidence to use mathematics and this aids scientific thinking and understanding.

The usefulness of using blocks is the flexibility of their representation. Blocks allow children to unitise in different ways. Instead of simply unitising with a one-to-one correspondence (one block represents one ant), children will be ready to accept a one-to-many correspondence because the mass of an ant is intuitively much less than one block. Children can then apply counting in 2s, 5s and 10s to calculate the actual number of ants, depending on information provided. In order to reason multiplicatively, children need to be able to unitise (Fosnot and Dolk, 2001) and so practical activities are extremely useful for children to develop these skills.

Application of new knowledge

The Example 1 investigation shows that the larger the surface area of the leaf, the greater the number of ants it can carry across the stream. To provide children with an opportunity to apply this new knowledge, each child can be given a 10 cm x 15 cm sheet of aluminium foil (baking foil) and asked to design a boat that will carry the most ants. Children will not only need to design and build their boat, but also test it and reach a conclusion from their results.

Conclusion

The two examples show how mathematics and science can be successfully combined to create challenging and experiential learning for all children. By using mathematics in science learning, children's depth of scientific understanding can be greatly improved and such activities provide opportunities to apply mathematical knowledge within 'real' problem-solving contexts.

The National Centre for Excellence in the Teaching of Mathematics (NCETM) defines mastery as: deep and sustainable learning; the ability to build on something that has already been learned sufficiently; and the ability to reason about a concept and make connections. The above examples demonstrate that scientific activities, which rely on mathematics to reach scientific conclusions, provide excellent opportunities for children to demonstrate mastery through deeper learning and understanding in both subject areas.

References

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