University of Leicester

The Fibonacci Project

Strategies to Enhance Mathematics and Science

The Fibonacci Project in Leicester

Disseminating Inquiry-based Science and Mathematics Education in Europe

WITH THE SUPPORT OF
EUROPEAN COMMISION
SEVENTH FRAMEWORK PROGRAMME

The Leicester Fibonacci Project aims to develop a more integrated approach to science and mathematics education for teachers to enhance the scientific and mathematical practice of pupils in the 4-13 age range.

Teachers' sessions within the first year of the project have included

- **Investigation and measuring**
- **Averages and sample size**
- **Active graphing**
- **Looking for patterns**
- **Classifying and exploring the significance of shape**

In the second year the focus on these continues but we are also including: Shape, Area, Perimeter, Volume, Ratio and Proportion.

At all stages the aim is to focus on both mathematics and science concepts and skills.

Participating Schools:

- Beaumont Leys Secondary School
- Catherine Infant School
- Cossington C E Primary School
- Fullhurst Community College
- Medway Community Primary School
- Mellor Community Primary School
- Oakham C E Primary School, Rutland
- Orchard Primary School, Nottingham
- Rushey Mead Sports & Science College
- Sandfield Close Primary School
- St Thomas More Catholic Primary School
- Wolsey House Primary School

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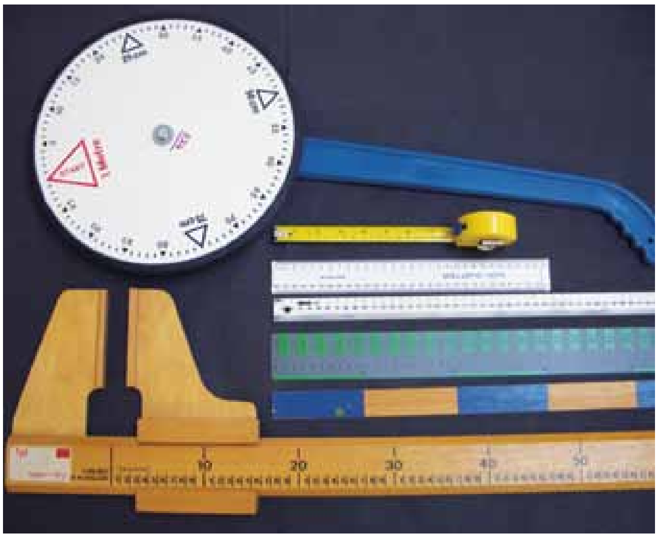


A wide variety of instruments are used in science. These are worthy of close scrutiny and exploration to support children's understanding of the measurements made and results obtained in their investigations as well as their comprehension of the underlying concepts.

Similarities and differences between different types of length measuring devices (eg. rulers and tape measures) provide a useful starting point.

Thinking about scale

Many of the instruments pupils use have scales.

Scale as a number line

Rulers provide a very familiar scale and illustrate both

- choice of scale for example imperial or metric units (inches or cm)
- marking of scales with either each division numbered or main divisions numbered with unmarked sub-divisions

Structured number lines are very commonly used in measuring instruments. The usual structure mirrors the base ten number system. Therefore structured number lines can provide a model of place value.

Variety of scales

Measuring instruments with other kinds of scales are all around us. They don't all use linear scales. Many (eg trundle wheels, clocks, thermometers) use circular scales.

Looking at and comparing scales on different instruments

Pupils' attention may be drawn to the variation in scales by considering particular questions eg What units does it use? What is the beginning and end of the scale? What are the scale intervals? How do you use it? When is this instrument used? What does it measure?

Year 3/4 Looking at scales on measuring devices ▸

The children looked at a collection of measuring devices to see that they often contained more than one type of scale, that the scales did not always start at the end of rulers and that the scales were often marked in different ways. The children then practised using the rulers to make measurements and for reading scales.

Choosing a measuring device

As a wide variety of instruments are available for measuring length or distance eg ruler, tape measure, trundle wheel, pupils will need support to consider the appropriateness of the instrument for the task and the accuracy required when making a particular measurement ie to the nearest m, cm or mm. Pupils might practise by considering the best device for making particular measurements such as the height of their chair or width of the room.

Choosing and using measuring instruments

Year 3/4 Propulsion of cars

Pupils used a type of elastic catapult to safely propel a toy car along the floor. They investigated whether the distance the car travelled was affected by how far they stretched the elastic. The children chose equipment for measuring the distance the elastic band was pulled back and the distance travelled by the car.

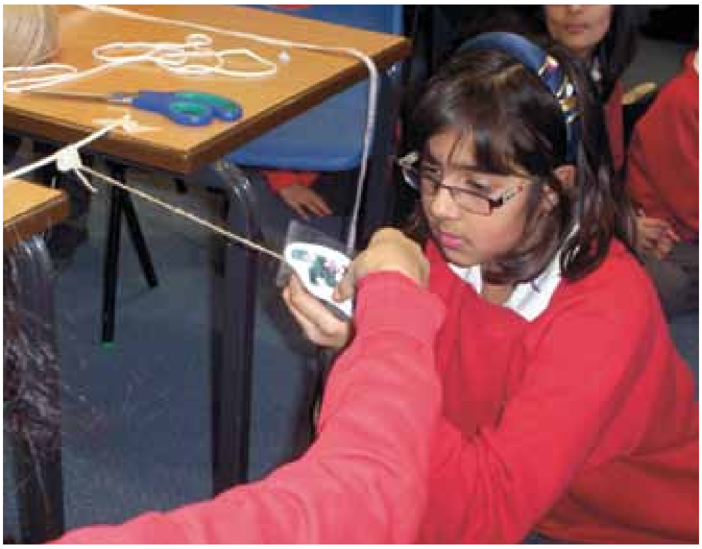
Some chose a metre trundle wheel but experienced difficulties measuring the distance the elastic was moved because it was so small. Others were confused by a tape measure which was marked in mm on one side and cm on the other. Consequently they were inconsistent in their use and unclear about the difference. Another group was perplexed when the car was propelled further than the length of their 1 metre measure.

While they had initially selected inappropriate equipment, they discovered through undertaking the investigation, that they had made a poor decision and were able to review this in the follow-up session.

Supporting children's measuring skills

Year 5 Rope swing ▸

The children were told a story about the elves in Santa's workshop wanting to swing on some ropes. They then explored the effect of the length and the material of the rope, the heaviness of the elves and angle of swing. Each group investigated one factor. The teacher organised groups for the activity according to the children's identified needs and strengths in aspects of measuring. One group of children needed to consolidate measuring lengths and were given the task of altering the length of the rope swing. Others who were more confident varied the angle of swing.



◂ Year 4 Absorbency

The children were looking at absorbency of different paper towels. They dropped a fixed amount of coloured water onto each of the paper towels. They measured the height dropped by the water and the spread of water across each of the paper towels.

Instruments – Measuring Devices

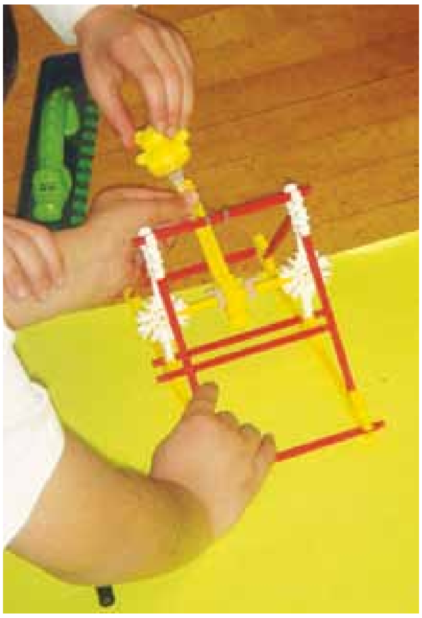
Non-standard measures and comparative language

The history of measurements indicates the need for consistency. Early measures based around physical properties such as hands and feet were not consistent. These formed the basis for developing consistent measurements. This process can be replicated in primary schools as very young children are not ready to use complex scales. In addition, the language of comparison (eg long/ longer/ longest) and their understanding and use of number can be developed.

Year 2 and Foundation Stage   Bouncing balls ▶

The children in Year 2 and Foundation Stage read the 'Mr Bounce' story, sang songs and looked at animations of balls bouncing. Outside they threw a variety of balls making observations and comparisons about bouncing. The children selected 3 balls, made predictions about their bouncing and tested them. They stuck small stickers on teachers to record the height of the bounces using different colour stickers for the different balls. The transfer of stickers to an outline of the teacher drawn on lining paper provided a more lasting record.

The activity encouraged the children to focus on language related to the concept of height such as 'high', 'higher' and 'highest', as well as on observing, measuring, recording measures and representing the measures.



◀ Year 1 and Year 3/4   Catapults

A Year 1 and a Year 3/4 teacher jointly planned activities using catapults as part of topics on Toy Stories (Year 1) and Fantasy Worlds in Literacy (Year 3/4).

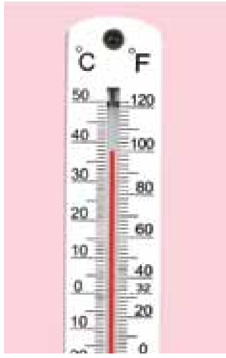
The older children had done some preliminary work on reading scales, using protractors and looking at different types of angle. They had also estimated a metre length on a paper strip and compared their estimates. They were then set a challenge to design a catapult to project a small plastic bear a metre along the ground. Catapults were made at home and then tested to see if they satisfied the criteria. Children were required to select the measuring equipment used to measure the distance the bear was projected. They also tested if the bear went the same distance each time and discussed repeated testing, methods of recording and accurate reporting. Finally the younger children were invited to do the same investigation under the guidance of their older peers. The older children needed to help the younger ones use non-standard measures such as 'footprint' and 'hand shapes'. This enabled both groups to talk about measuring in general.

Reception   Paper planes ▶

Children in the Reception class were very enthusiastic and skilful at making paper planes and flying them. Their teacher encouraged them to see how far different designs would travel. For example, the children observed and compared whether the planes travelled further with or without a paper clip. Year 5 children worked with them to measure the distance travelled by each plane.

Detailed examination of instruments

It is important to ask children to look at instruments they will use in science investigations. This will give them a better appreciation of their results as well as help them choose the correct instrument.



Thermometers

Areas for consideration include:

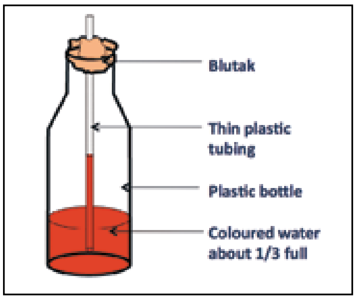
- Why are thermometers needed?
- The scale on the thermometer

  Is it a linear scale? What is the range? Is it marked in 1s, 5s or 10s?

  If there are different scales such as Fahrenheit/ Celsius what are the differences between the two scales? What are the advantages and disadvantages of the two scales?

- Different types of thermometers and their use

  Pupils can look at oven, freezer and medical thermometers to see differences in range of scale and design.



Rain gauges

Rain gauges can be difficult to understand because it is not obvious what is being collected or measured. They also come in a variety of shapes. As with thermometers pupils can:

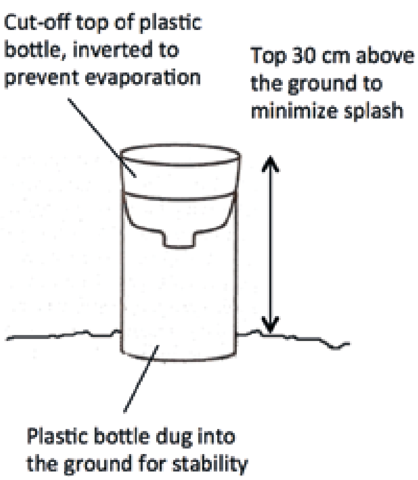
- Look at the scales

  Tapered gauges are very mathematically complicated. Teachers need to think carefully about what rain gauges they will buy and how they will explain it to the children.

- Make a rain gauge

Year 3/4 Designing, making and using a rain gauge ▶

Children in an after-school club made a rain gauge. They designed their rain gauge and then tried to decide what scale to use to measure the rain collected. They carried out some research and found that rain gauges were usually measured in either inches or millimetres. They decided to use inches as they thought these would be easier to read. However they soon realised that they had a problem as there was not enough rain to enable them to make a reading on their scale. Consequently they had to revise their plans.



Measuring wind

Wind measurement involves the concept of speed which is complex as it is underpinned by ideas of both time and distance. It easier for young children to describe the wind in simple terms – fast, faster, slow or by making comparisons by observing differences in how things move around them. They might then use the Beaufort scale which was developed by the Royal Navy in 1805 to provide some standardisation of descriptions of the effect of wind. The numbers in the scale originally described the effect of the wind on the sails of a warship but were then related to movements on land. Severe weather warnings given to the public still use the Beaufort descriptions.

Metres per second
Knots

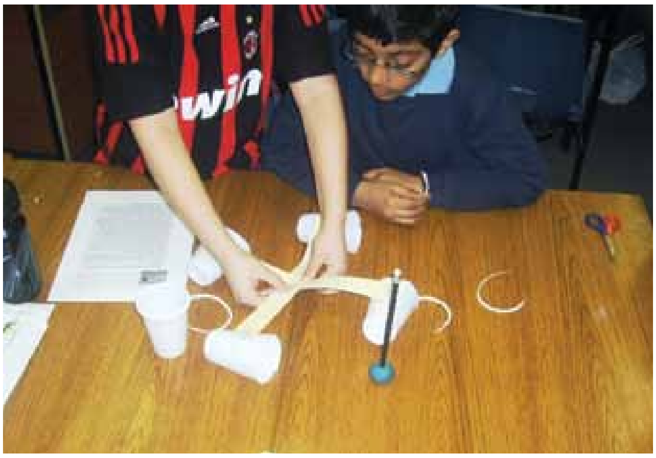
Kilometres per hour
Beaufort scale

Anemometers enable more accurate measurements of speed to be taken. However they also show the Beaufort scale. Many anemometers show 4 different scales: kilometres per hour, metres per second, knots and the Beaufort scale. Therefore it is important pupils have a chance to look carefully at the instrument.

Mixed age groups
Making and testing anemometers ▶

A mixed age lunchtime club and Year 5 and 6 classes made anemometers and tested them outside.

Once the pupils had made their measurements, they counted rotations per minute. Each model anemometer was satisfactory for comparing daily wind speeds. However as the arms of the anemometers varied, it was not possible to compare data from different models. To achieve this the rotations per minute have to be converted to a standard measurement such as metres per second. The first step is to know how far the cup travels in one rotation. The pupils might do this by measuring the circumference or calculating it using π.



Instruments – Measuring Devices

Measuring lung capacity

Through breathing our lungs both deliver oxygen to the blood for circulation throughout the body and remove waste carbon dioxide out of the body. Breathing (or ventilation) plays a vital role in the process of respiration. Respiration is the chemical reaction that allows cells to release energy from food. The reaction requires oxygen from the air, and produces carbon dioxide as a waste product. Different people have different lung capacities. This can be measured.

Pupils can look at existing instruments and then try making their own instruments.

Two easy ways to measure lung capacity involve:

- inflating a balloon and measuring its circumference or diameter; and
- displacement of water and then observing, comparing or measuring the amount of air in the container.

Once the instrument has been developed, pupils can investigate:

- whether there is a variation in lung capacity related to height, hand size or age; and
- the immediate effect of exercise on lung capacity.

Manufactured instruments for measuring lung capacity

▼Year 6 Measuring lung capacity

The children used balloons to measure their lung capacity. They recorded the circumference of their balloons as a measure for comparison. They then investigated whether there was any link between height and lung capacity. They went into the playground, lined up in height order and then inflated their balloons. They were able to see that in most cases taller people appeared to have larger balloons. Next they exercised and re-measured their lung capacity. They were particularly interested in results from two boys one of whose lung capacity had decreased a lot and the other whose balloon size had decreased very little. The first said he did not do very much exercise whereas the second was involved in many sports.

Dealing with Variation

In practice younger children often do one experiment, whereas older children repeat the experiment three times and work out an 'average' of their results. However it is important to help pupils to think more about the reasons for repeating the experiments and the size of sample.

It may not be necessary to have as many as three repeats if the results are clearly accurate and very different. However it is often necessary to have more than three measurements if, for example:

- Method of the experiment is inconsistent as in controlling the flight of a paper dart.
- The quality of the instrument is poor.
- The person taking the measurement cannot be consistent as when trying to see the height of a bouncing ball.

Material	Time for descent (seconds)
Hessian	4 secs
Cotton	9 secs
Muslin	5 secs

Results are clearly very different so need few repetitions

Type of parachute	Drop Times (seconds)	Average Drop Time (seconds)
Plastic	1) 1.80 2) 1.56 3) 1.62	1.66
Cotton	1)1.70 2) 2.00 3) 1.78	1.83
Muslin	1) 1.70 2) 1.56 3) 1.59	1.62

Developing results indicate that further measurements are needed.

Investigating parachutes

This is a common investigation which provides opportunities for discussing these issues with pupils. Points teachers might cover include:

- There is likely to be experimenter error as it is difficult for the timer to react consistently with the person releasing the parachute.
- Pupils need to decide if they should ignore strange samples such as extremely high or low results if these may be due to experimental error.
- Pupils may need to use decimal numbers on the stop watches if they use relatively short drops for reasons of safety. The pupils many not understand the decimal numbers or give greater significance to small differences because they 'look accurate'.
- If there is overlap between repetitions of different samples, this indicates that further sampling is needed.

If the measurement results are too complicated or error is likely to be too great, the teacher might decide that the younger and less able pupils should use a comparison method. This was done with a group of reception-aged children who simultaneously dropped parachutes made of different materials and just watched which landed first.

Investigating gliders

In some investigations results for different variables may overlap, initially masking a pattern, so there is a need to use a large sample.

Teachers and student teachers undertook investigations with gliders to see if the distance between the 'wings' made any difference. They were asked to record differences on the floor, using different colour markers for different distances between the wings. They also recorded their results as measurements. Whilst initial measurements did not appear to show a pattern it was possible to see a pattern on the floor by looking at the markers that recorded the landing point. The teachers could see it was necessary to increase the sample size to get a clear pattern.

This activity was repeated in Year 3/4 and Year 5/6 classes. The pupils were able to recognise they needed extra measurements after an interim review of their experiments.

Distance between wings	8 cm	12 cm	16 cm	20 cm	24 cm	28 cm
	125	144	140	197	207	193
	163	169	163	210	216	195
	163	173	173	214	231	202
	173	175	183	216	239	206
	173	183	188	228	239	228
	179	188	210	233	251	233
		194			259	
		199				
Average	**163**	**178**	**176**	**216**	**235**	

Recorded flight distances (mm) when the distance between the wings was varied

▼Year 5/6 Investigating gliders

The class had explored the flight of the gliders and considered what might affect their flight. This was followed by a focus on the effect of altering the distance between the wings on the distance flown. The teacher encouraged the children to explain how they would attempt to change only one variable and how they might try to ensure their results were as consistent as possible. The children were asked to identify a precise question for their investigation as they had previously found this difficult. They predicted there would be an effect on altering the distance between the wings on the distance flown.

Gliders were flown outside in the playground which provided space but was windy at times. The children were encouraged to be consistent in launching the glider, to note carefully where it had landed and to make accurate measurements of the distance travelled.

A main focus for the teacher was the direct recording of data and discussion of the data with the children as they worked. He was interested in the children's conviction about what a 'good' graph would look like. The children confidently recorded their results on laptops. Some groups worked with single results but most carried out more than one test and worked out a mean. The children looked carefully at their graphs to identify any anomalous readings and perhaps to try these again.

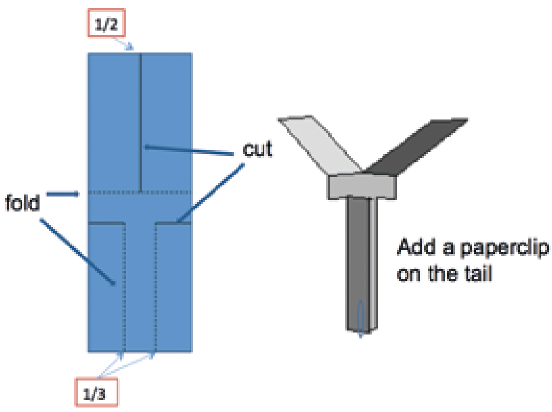
The children looked at emerging patterns but were frustrated when the results did not appear to fit it in with their prediction of a straight line graph. Their results were also somewhat variable. The children identified throwing with different 'strengths' and the wind blowing possible reasons for the variation in results. Some were able to attempt an explanation about why making more than one measurement might be more reliable.

Active Graphing

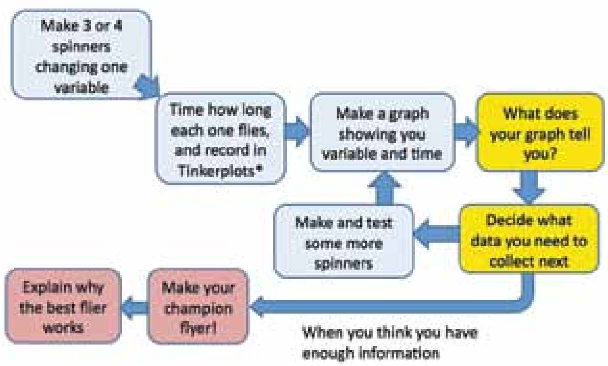
Graphs are frequently the end point or product of an investigation. When using an active graphing approach graphs are seen as an integral part of the investigation or as a starting point for children. In the active graphing approach a graph is produced as soon as two or three pieces of data have been collected, and then used to support decisions about what data to collect next. This moves away from a ‘linear’ approach to investigations to a more ‘open’ or informed approach which may give better reflection of how some scientists work.

This approach was used by the Year 5/6 class investigating gliders on the previous page. The teachers also trialled active graphing with paper spinners and when investigating yeast.

Spinners

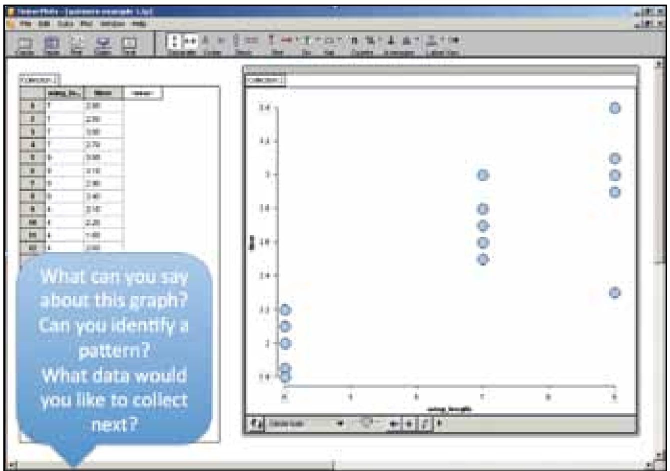


Paper spinners can be easily constructed from a single piece of paper. Teachers were asked to choose one variable that they thought would make a difference to how the spinner flies and to think about how they might explore changing that variable.

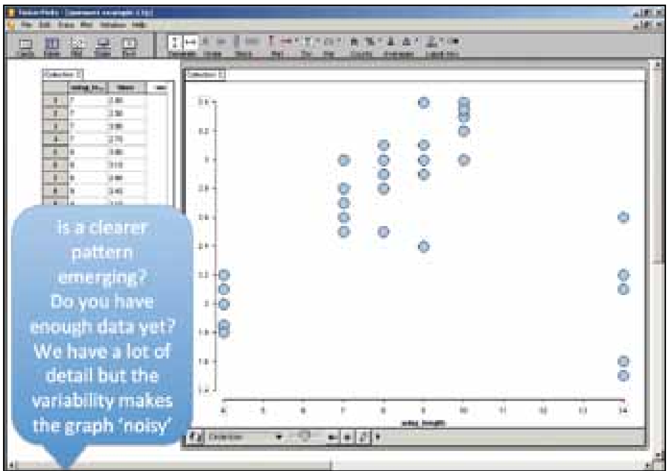


They were additionally challenged to use the information they gained in an investigation to design a champion spinner that has the longest flight time. They followed the approach illustrated.

The teachers used a data handling software (TinkerPlots) which allowed easy graphical representation of all data collected for each set of conditions.



The plot for 3 wing lengths indicated a developing pattern of increasing flight descent time as wing length was increased.

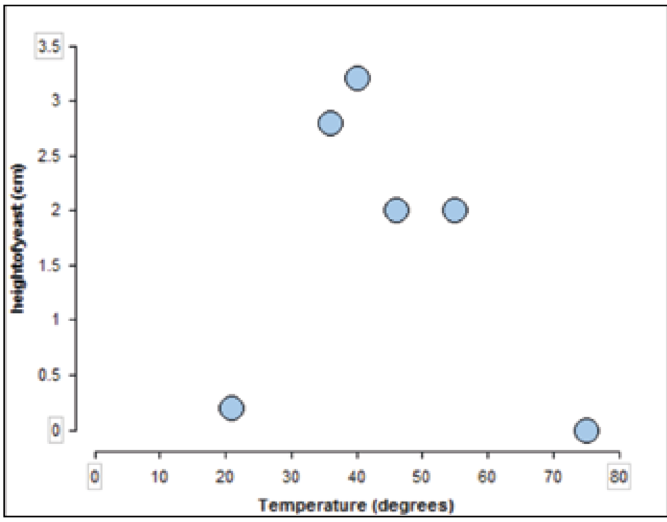


Additional tests using wing lengths both within and beyond those already tested provided information to indicate the ideal wing length for the champion spinner.

Investigating yeast

If there is not enough time to allow a lot of samples, it is possible to provide the learners with some data to start with. Teachers were asked to investigate the effect of sugar or temperature on the growth of yeast. Existing data was presented to the teachers as a starting point.

They were then asked to find out the ideal conditions for growth of yeast.



The highest foam indicates greatest yeast activity. This graph appears to show that temperature is important. One group of teachers thought the ideal temperature was about 40-50°C. They decided to explore this limited temperature range further.

Handling large amounts of data

Graphs provide one way of sorting data. Other methods such as Venn diagrams, Carroll diagrams, branching data bases can be used with children of different ages.

Year 6 Venn, Carroll and branching diagrams ▶

The teachers realised that the children were experiencing difficulties extracting data from different databases and decided they would develop activities for their classes which involved data handling. The children initially used Venn diagrams and branching data bases relating to mathematical shapes. This was followed by a visit to local gardens during which the children were asked to gather data about the numbers and different types of invertebrates that were found in a wooded area. They were provided with a branching data base to help with identification. They were also asked to find particular flowers and to record noticeable characteristics of the flowers.

When they returned to school the children worked in groups to construct Venn diagrams, Carroll diagrams and branching data bases with the information gathered.

Using existing data sets

Data can be collected by children but they can also use existing data sets to stimulate investigation or to extend an investigation. It is useful to consider whether the results from a completed class investigation will be the same as results from another class. This is a way to introduce pupils to the use of large data sets which they might not have time to collect themselves. On-line data sets from other classes in the UK and other countries might be used.

Are boys taller than girls?

When a class lines up with children arranged by age and height will the results be the same as for other classes (of same age, younger or older children)? Teachers were given two sets of data from different schools, different countries and different eras ie data from:

- 136 children born in California in 1928-9 and
- a Year 4 class in the UK collected in 1994

Both data sets contained data about gender, height and age were available in different formats (ie hard copies and in a spreadsheet) so the teachers could choose the format with which they felt most comfortable. They were encouraged to use the data in a variety of ways to explore different interpretations of the question and the different variables (such as age) that might be applied to look for patterns. They were also encouraged to try to explain the patterns.

Classifying and Exploring the Significance of Shape

Classification

Classification is often used to sort scientific phenomena but similar strategies can be useful to sort mathematical phenomena eg shape.

In mathematics it is important to look at the properties of shape as well as identifying and naming shapes. In science shape is important as shapes are significant in both natural and manufactured objects. Mathematics provides a language which is useful for both for science and for mathematics.

Shape in mathematics

Teachers were asked to make shapes from triangles, to sort and classify them, to identify the properties they were using to do so and to explain how they were classifying them.

A variety of four sided figures were then reviewed and represented in a Venn diagram.

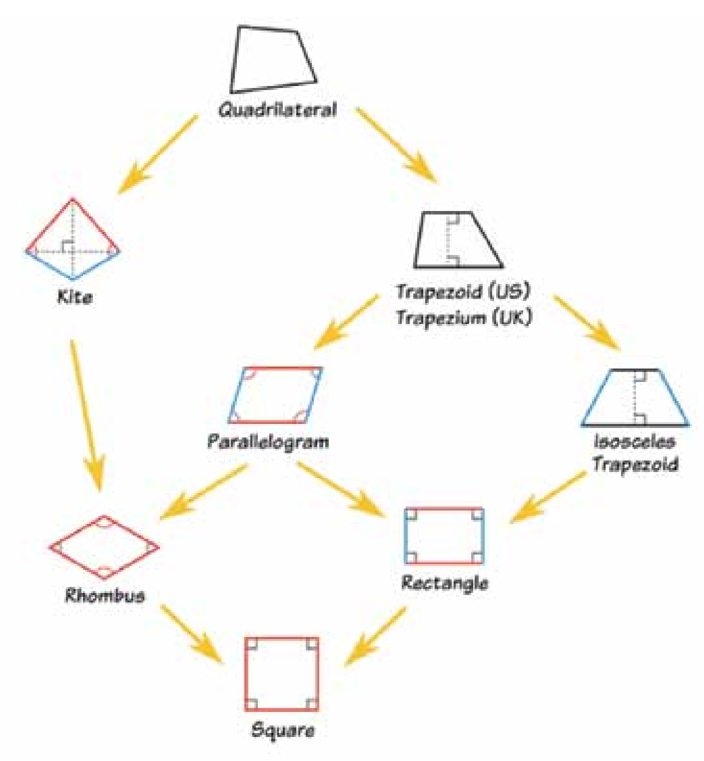
The language of shape

The language of shapes that has been developed in mathematics can support observations, explorations and explanation of work on shapes in science eg observations of natural phenomena and looking at structures such as bridges and supports.

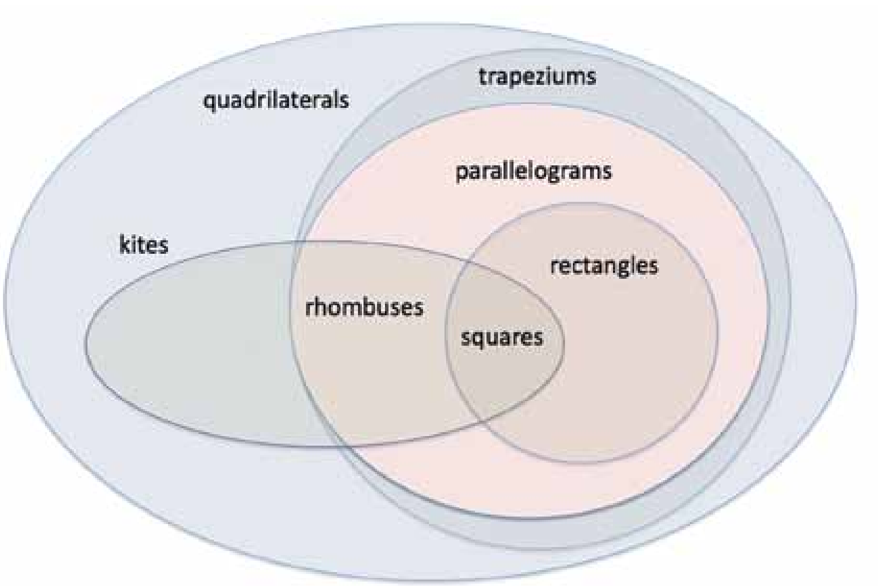
This might be achieved by:

- Identifying the shapes involved in the exploration / investigation
- Explaining how the shapes behaved in this situation
- Thinking about why this shape occurred or was used
- Exploring the possible links between the mathematics language about shape with a scientific explanation

Investigations testing the strength of bridges provided opportunities for teachers to use the language of shapes to explore their scientific significance.



Pierce, Rod. (3 Dec 2011). "Quadrilaterals - Square, Rectangle, Rhombus, Trapezoid, Parallelogram". Math Is Fun. Retrieved 8 Feb 2012 from http://www.mathematicsisfun.com/quadrilaterals.html

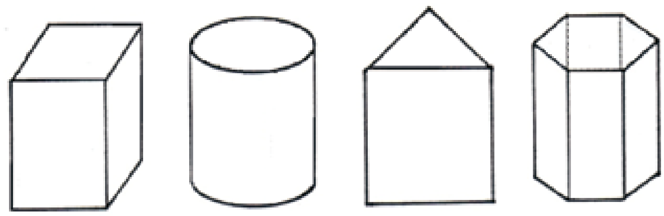


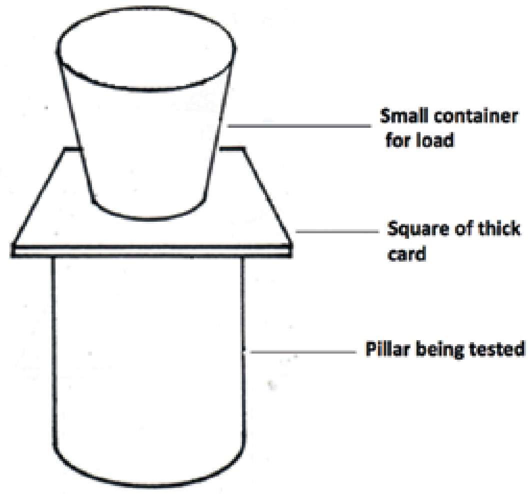
Venn diagram for four sided figures.

Investigating pillars

Finding ways of making a strong bridge using one sheet of A4 paper to span a gap of about 15 cm between two blocks and carry a weight of 100g helped teachers to identify triangles and cylinders for strong shapes. They also investigated shape and height of pillars. Following the results of their investigations, the teachers were helped to understand why cylinder shapes were so good.

A horizontal card will bend (or compress) easily if its opposite sides are pushed together horizontally. Once the card starts to bend it will buckle upward or downwards. If the card is folded at right angles along its length, it can no longer bend easily. A tube provides more strength than flat paper as it resists bending in any direction. Bundles of tubes are even stronger.



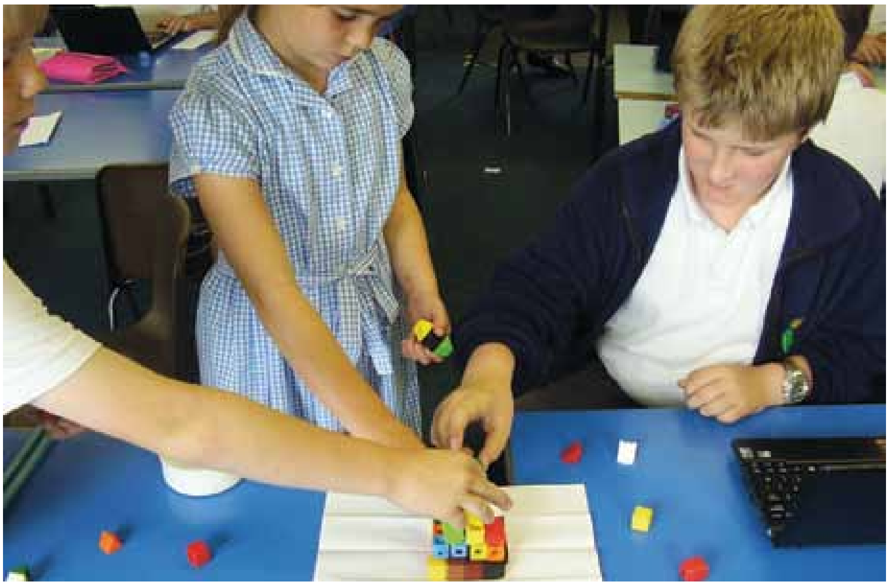


▼Year 3/4 and Year 8 Exploring bridges

Year 3/4 children were set the challenge of designing and testing bridges made from paper. Additionally they looked at different shaped pillars.

Towards the end of a school year in a secondary school a science teacher and a mathematics teacher worked together to develop a short unit of work on shape for their Year 8 pupils.

This was taught by the two teachers in a mix of science and mathematics lessons. They reviewed shapes in both natural and designed structures. The work included the pupils exploring the use of different materials and shape for the bridge pillars.



Future

Area volume ratio and proportion are mathematics concepts used throughout science eg looking at dissolving sugar or volume affecting cooling rates. These are the current focus.

Tina Jarvis, Janet Ainley and Frankie McKeon

School of Education
University of Leicester
21 University Road
Leicester LE1 7RF
UK

t: +44 (0) 116 252 3659
f: +44 (0) 116 252 3653
w: www.fibonacci-project.eu

University of Leicester

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