WORKING SCIENTIFICALLY

Developing children's skills in Comparative Tests

Enquiries that are comparative tests have many similar features to fair tests in that one variable is changed, another variable is measured, and any other variables are controlled. The difference is that in a comparative test the variable that is changed is discrete rather than continuous, so children are comparing different cases/situations.

Children regularly ask questions that lead to a comparative test, and these types of enquiries provide lots of opportunities to measure and collect data.

Big questions

Here are some examples of 'big questions' that pupils can explore through comparative tests in KS1 and KS2. There is at least one for every area of the curriculum, so it is easy to plan opportunities for children to revisit this type of enquiry and develop their skills.

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Which type of compost grows the tallest sunflower?	Do cress seeds grow quicker inside or outside?	Which conditions help seeds germinate faster?	How does the average temperature of the pond water change in each season?	Which seed shape takes the longest time to fall?	Which is the most common invertebrate on our school playing field?
Which tree has the biggest leaves?	Do amphibians have more in common with reptiles or fish?	How does the skull circumference of a girl compare with that of a boy?	In our class, are omnivores taller than vegetarians?	Who grows the fastest, girls or boys?	Which type of exercise has the greatest effect on our heart rate?
Is our sense of smell better when we can't see?	Do bananas make us run faster?	Which soil absorbs the most water?	Does seawater evaporate quicker than fresh water?	Which type of sugar dissolves the fastest?	What is the most common eye colour in our class?
In which season does it rain the most?	Is there the same level of light in the evergreen wood compared with the deciduous wood?	Which pair of sunglasses will be best at protecting our eyes?	Which material is best to use for muffling sound in ear defenders?	How does the length of daylight hours change in each season?	Which material is most reflective?
Which materials are the most flexible?	Which shapes make the strongest paper bridge?	Which magnet is strongest?	Are two ears better than one?	Which shoe is the most slippery?	Which make of battery lasts the longest?
Which materials are the most absorbent?	Which material would be best for the roof of the little pig's house?	Which surface is best to stop you slipping?	Which metal is the best conductor of electricity?	Which shape parachute takes the longest to fall?	Which type of fruit makes the best fruity battery?

Working Scientifically Skills

Comparative tests tend to involve some sort of data collection; KS1 children may use tally charts to record their observations but, as children move through KS2 they should be using an increasingly wide range of equipment to make measurements. They should learn what it means to measure accurately and check for reliability.
Children will learn to independently plan how to record and analyse the data, using tables, pictograms, and bar charts to compare the measurements they make. Children can then use the bar charts to draw conclusions about what they have found out to be the answer to their 'big question'
To promote higher order thinking, children should be challenged to evaluate the procedure they used and the quality of their data, suggesting ways they could improve their test.

Reporting Learning

Comparative tests are a good opportunity for children to focus on writing different aspects of a lab report in a more formal reporting style, organising their writing with subtitles, and, as they move into upper KS2, learning to use the passive voice in their writing. On occasion, children can practice describing the method they planned to collect their data; it is important to note that it is not essential to write a full report but, rather, focus on a key area of reporting in which you would like children to develop their skills. An excellent way to test how well children have described their method is to group them in pairs and ask them to directly follow their partner's written instructions (with no other information). The observing partner will be able to note which important steps and details they have missed in their reporting, and therefore improve their instructions.

In KS1 books you would generally expect to see a tally chart, pictogram, or block chart when reporting a comparative test, but older children in KS2 should be learning to independently draw a bar chart. The aim should be that by the time those children are in Year 6, they will be able to use their table of data to plan the best scale for the axes on their chart, and select sensible labels for the axes and a meaningful title for their bar chart with no support. Children should then use their data to support them in writing a conclusion and evaluation to complete their lab report.

Additional Information

A great example of a comparative test from history that you can share with your pupils is James Lind's controlled experiment aboard two ships (the first ever clinical trial). He gathered two identical populations and provided one with citrus fruit and not the other. This led to the scientific understanding on how to prevent scurvy.

Developing children's skills in Fair Tests

Like comparative tests, fair test enquiries are an opportunity for children to explore cause and effect relationships in science. Children find the answers to 'big questions' in fair test enquiries by planning tests to collect data through changing, measuring and controlling variables. Fair tests involve making systematic changes and analysing data to identify how one variable influences another. Due to the increased challenge in this type of enquiry they are introduced in KS2.

Big questions

Here are some examples of 'big questions' that pupils can explore through fair tests in KS2. There is almost one for every area of the curriculum so it is easy to plan opportunities for children to revisit this type of enquiry regularly and develop their skills.

Year 3	Year 4	Year 5	Year 6
How does the length of the carnation stem affect how long it takes for the food colouring to dye the petals?	Does the amount of light affect how many woodlice move around?	How does the level of salt affect how quickly brine shrimp hatch?	How does the temperature affect how much gas is produced by yeast?
How does the angle that your elbow/knee is bent affect the circumference of your upper arm/thigh?	How does the mass of a block of ice affect how long it takes to melt?	How does age affect a human's reaction time?	How does the length of time we exercise for affect our heart rate?
How does adding different amounts of sand to soil affect how quickly water drains through it?	How does the surface area of a container of water affect how long it takes to evaporate?	How does the temperature of tea affect how long it takes for a sugar cube to dissolve?	Can exercising regularly affect your lung capacity?
How does the number of layers of transparent plastic affect how much light can pass through?	How does the volume of a drum change as you move further away from it?	How does the angle of launch affect how far a paper rocket will go?	How does the angle that a light ray hits a plane mirror affect the angle at which it reflects off the surface?
How does the mass of an object affect how much force is needed to make it move?	How does the thickness of a conducting material affect how bright the lamp is?	How does the surface area of a container affect the time it takes to sink?	How does the voltage of the batteries in a circuit affect the brightness of the lamp?
How does the distance between the shadow puppet and the screen affect the size of the shadow?	How does the length of a guitar string/tuning fork affect the pitch of the sound?	How does the surface area of a parachute affect the time it takes to fall to the ground?	How does the voltage of the batteries in a circuit affect the volume of the buzzer?

Working scientifically skills

As with other types of enquiry, fair tests are a great opportunity for children to plan their own tests to collect data.
It is through fair testing that children will really learn to understand the different types of variables:

- **the dependent variable that they will change in their test,**
- **the independent variable that they are going to measure so that they can find out how the dependent variable affects it, and**
- **the control variables which the children will need to keep the same so that they don't affect their results.**

All fair tests involve the measuring and recording of data that can then be displayed in a scatter graph or line graph.
Children will be able to use their data to draw conclusions that identify a causal relationship eg 'when you increase X, Y will always decrease'.
As children progress through KS2, they should become progressively more systematic in how they approach fair tests and, as with the other types of enquiry, increasingly independent. Their written conclusions should also become increasingly sophisticated, with more focus on scientific explanations. Fair tests are a good opportunity for children to focus on their skills in evaluating their scientific enquiries. As they progress through the key stages, children will learn to critique not just their experimental methods but also their data by reflecting on reliability and accuracy.

Reporting learning

It really isn't necessary for children to write a full laboratory report for every enquiry they carry out; in fact, it is far better to focus on a particular aspect of reporting for each enquiry so that children can focus on developing skills in that area. Fair test enquiries provide opportunities for children to work on all aspects of reporting, from creating written instructions to describe their plan, to tabulating data, graph-drawing, or writing conclusions and evaluating.

Children should be learning to independently plan and draw their own tables for recording data over KS2, making sure that all columns have headings with units and, where repeat measurements are collected, children will learn to calculate the mean average of a set of data. The most common mistakes that children make when creating tables for their data are:
• not planning for sufficient rows and columns, and
• forgetting to include the units of measurement in the column heading.

The expectation that children should always collect repeat readings and calculate an average when carrying out fair tests in upper KS2 leads to children developing a strong level of confidence in using statistical methods to analyse data sets.

In upper KS2, children will learn how to plot their own scatter and line graphs, plan scales for axes, plot points accurately, and include axis labels and titles. Peer and self-assessment strategies will help children be clear on the success criteria for data analysis strategies and fine-tune their skills. Children will need repeated practice to plan even scales with appropriate ranges for their data sets.

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Additional information
There are many examples of significant fair tests that have taken place over the years, which can be interesting to explore when looking at how ideas change over time. When the children are learning about the properties of materials it would be quite interesting to learn about Hooke's Law, which was derived from a fair test involving stretching a spring with different forces. Children can repeat Hooke's experiment; and the data they collect can help them to test and create their own mass or force-measuring device.

Develop children's skills in Identifying and Classifying

Children begin identifying and classifying objects in the world around them from a very young age; this type of enquiry comes very naturally as young learners try to make sense of the world around them. In this type of enquiry, children make observations and measurements to help them look for similarities and differences. This will help them to organise things into groups and make connections. Identifying and classifying enquiries are fantastic for promoting discussion and collaborative learning. In revisiting this type of enquiry regularly, teachers can support children in becoming more highly skilled in making and recording detailed observations.

Big Questions

Here are some examples of 'big questions' that can be explored by identifying and classifying in KS1and KS2. There is at least one for every area of the curriculum, so it is easy to plan opportunities for children to revisit this type of enquiry and develop their skills.

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
How can we sort the leaves that we collected on our walk?	How can we identify the trees that we observed on our tree hunt?	How many different ways can you group our seed collection?	What are the names for all the organs involved in the digestive system?	Can you identify all the stages in the human life cycle?	How would you make a classification key for vertebrates/ invertebrates or microorganisms?
How can we organise all the zoo animals?	Which offspring belongs to which animal?	How do the skeletons of different animals compare?	How can we organise teeth into groups?	Compare this collection of animals based on similarities and differences in their lifecycle.	Which organs of the body make up the circulation system, and where are they found?
What are the names for all the parts of our bodies?	How would you group these plants and animals based on what habitat you would find them in?	Can you use the identification key to find out the name of each of the rocks in your collection?	Can you group these materials and objects into solids, liquids, and gases?	Can you group these materials based on whether they are transparent or not?	Compare the skeletons of apes, humans, and Neanderthals – how are they similar, and how are they different?
How would you group these things based on which season you are most likely to see them in?	How would you group things to show which are living, dead, or have never been alive?	How would you organise these light sources into natural and artificial sources?	Can we use the classification keys to identify all the animals that we caught pond dipping?	How could you organise all the objects in the solar system into groups?	Can you classify these observations into evidence for the idea of evolution, and evidence against?
We need to choose a material to make an umbrella. Which materials are waterproof?	Which materials are shiny and which are dull?	How can we group the food that we eat?	How would you group these electrical devices based on where the electricity comes from?	Can you label and name all the forces acting on the objects in each of these situations?	Can you identify all the colours of light that make white light when mixed together? What colours do you get if you mix different colours of light together?
Which materials will float and which will sink?	Which materials will let electricity go through them, and which will not?	Which materials are magnetic?	How would you sort these objects/materials based on their temperature?	Can you observe and identify all the phases in the cycle of the Moon?	How would you group electrical components and appliances based on what electricity makes them do?

Working scientifically skills

In KS1, children will be asking questions about the similarities and differences between things, which is a great opportunity to promote 'talk for learning' and encourage children to share their ideas. This type of enquiry lends itself to going outside to explore the world around them at all times of the year.

Going into KS2, this type of enquiry is often moved to the side with an increased focus on measuring and using data to answer 'big questions'. However, it does need to be regularly revisited. Children should continue to build on their observational skills, becoming more independent in identifying, through the use of increasingly complex tools, as well as developing higher order skills in reasoning and justification when explaining how they have chosen to group things. KS2 pupils will be expected to design simple tests to help them classify materials, as well as independently using a range of secondary sources to support them in identifying a range of living things.

Reporting Learning

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Develop children's skills in Pattern Seeking

Pattern-seeking enquiries involve children making measurements or observations to explore situations where there are variables that they can't easily control. In this type of enquiry, children are trying to answer 'big questions' by identifying patterns in the measurements and observations they record. Often, pattern-seeking enquiries may be preliminary tests that lead on to more systematic enquiries, such as fair tests or comparative tests. The key difference here is that pattern-seeking enquiries are not fair or comparative tests, because certain variables can't be controlled. Children may still identify a possible causal relationship from their data, such as 'the more you wind up a clockwork mouse, the further it will run', but they may find links between variables that can't be explained by cause and effect, such as 'children with longer arms can jump higher'.

Big questions

Here are some examples of 'big questions' that can be explored through pattern seeking in KS1and KS2. There is at least one for every area of the curriculum, so it is easy to plan opportunities for children to revisit this type of enquiry and develop their skills.

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Do trees with bigger leaves lose their leaves first in autumn?	Do bigger seeds grow into bigger plants?	What colour flowers do pollinating insects prefer?	How has the use of insecticides affected bee population?	Is there a relationship between a mammal's size and its gestation period?	Do all flowers have the same number of petals?
Is there a pattern in where we find moss growing in the school grounds?	What conditions do woodlice prefer to live in?	Do male humans have larger skulls that female humans?	Are foods that are high in energy always high in sugar?	Are the oldest children in our school the tallest?	Is there a pattern between what we eat for breakfast and how fast we can run?
Do you get better at smelling as you get older?	Which age group of children wash their hands the most in a day?	Is there a pattern in where we find volcanos on planet Earth?	Is there a pattern in how long it takes different sized ice lollies to melt?	Do all stretchy materials stretch in the same way?	Is there a pattern between the size and shape of a bird's beak and the food it will eat?
Does the wind always blow the same way?	Which habitat do worms prefer – where can we find the most worms?	Are you more likely to have bad eye sight and to wear glasses if you are older?	Is there a link between how loud it is in school and the time of day? If there is a pattern, is it the same in every area of the school?	Is there a pattern between the size of a planet and the time it takes to travel around the Sun?	Is there a pattern to how bright it is in school over the day? And, if there is a pattern, is it the same in every classroom?
Is there a pattern in the types of materials that are used to make objects in a school?	Do magnetic materials always conduct electricity?	Does the size and shape of a magnet affect how strong it is?	Which room has the most electrical sockets in a house?	Do all objects fall through water in the same way?	Does the temperature of a light bulb go up the longer it is on?

Working scientifically skills

In experiencing pattern-seeking enquiries, KS1 children will begin to look for patterns in their measurements and observations, and describe them both orally and in writing. They should also be starting to think about cause and effect relationships, and being encouraged to use appropriate vocabulary to discuss these.

For pattern-seeking enquiries, KS2 children should be thinking for themselves when it comes to deciding what they should measure and observe, as well as making decisions about the most appropriate equipment to use to collect data. Children in upper KS2 should be challenged to think even more about their planning, including identifying the variables that they cannot control and suggesting the potential impact those variables might have on the data they collect. Whenever appropriate, KS2 pupils should be choosing to use a data logger to collect the most accurate data they can. KS1 learners will need more support with making decisions about what to observe or measure, but should still be challenged to make their own suggestions.

Children in KS2 should be using far more data analysis techniques to spot patterns, including using tabulated data and a variety of charts and graphs. When describing the relationships, children should use data and graphs to support their explanations. As

mentioned earlier, this type of enquiry works well as a preliminary test; so children can use their findings to form and justify their own predictions, going on to propose further investigations to test these predictions.

Reporting Learning

Pattern-seeking enquiries are a great opportunity for children to develop their measuring skills and look for different ways to record and analyse their data. In regularly practising this type of enquiry, children will go from making and recording simple data values in KS1 to more systematic and accurate measuring in KS2 that can then be analysed using more complex methods.

Year 1 and 2 children could be using tally charts to record, and then developing these into pictograms to look for patterns. As they progress into KS2, children will be making measurements of quantities, such as length (cm), temperature (°C), volume (dB), and time (s), learning how to display this data accurately in tables, and then using bar charts to analyse their findings.

By the time they get to upper KS2, children will be looking more carefully at the accuracy of their measurements, including measuring lengths to the nearest mm, or temperatures to one decimal place. At this stage, children will be selecting the most accurate measuring equipment available and repeating measurements to check the reliability of their data. This will provide some great opportunities for children to regularly develop their skills in calculating the mean, average and range of a data set. Upper KS2 learners will then go on to learn how to independently draw scatter graphs and line graphs of their data to help them describe the patterns they notice in a more quantitative way, again regularly practising mathematical skills.

The data analysis that happens here provides a great opportunity for children to develop their conclusion writing; however, it also forms an ideal platform from which children can work on the development of predictions and proposing further enquiries to test their ideas. In asking children to form predictions based on data from a pattern-seeking enquiry, the children can use the data they have collected to justify their ideas for how things might be in a different but related situation, or even to generalise about how things might always be. Such predictions can enable learners to go on to create their own 'big questions', and plan tests to see if their prediction is correct. Taking this approach not only allows for more pupil-centred enquiry, it also gives children a more realistic appreciation of how the scientific process works, and how one question always leads on to even more.

Additional information

There are many real examples of pattern-seeking enquiries that lead to fascinating discoveries about the world and universe around us that you might want to share with pupils.

There are many examples of patterns in nature that have been investigated and interpreted by a whole range of scientists. Symmetry, fractals, and spirals have been endlessly observed and modelled using mathematics. The Fibonacci Sequence is a fascinating mathematical model that describes patterns in nature that you can find more here **https://www.livescience.com/37470-fibonacci-sequence.html** and a wonderful book to use with classes when learning about the Fibonacci Sequence is *Blockhead: The life of Fibonacci* by Joseph D'Agnese.

Astronomers use pattern-seeking enquiries to discover more about our unknown universe, and it is this pattern-seeking that has led to the discovery of hundreds of new planets, orbiting different stars. The Planet Hunters citizen science project enables participants to look for patterns in the light from distant stars to help identify whether they may have planets orbiting them or not. **https://www.planethunters.org**

Develop children's skills in Research

Research enquiries are a great opportunity to use science lessons to practise reading and listening skills developed in English; children get to use a range of secondary sources to help them find the answers to their 'big questions'.
Alternatively, children could plan research tools, such as questionnaires and interviews, to collect their own data. They are also an ideal type of enquiry to encourage collaborative learning in children, both in the researching and sharing of information, but also in presenting their findings to a variety of audiences. Research enquiries help to develop children's scientific literacy, as children learn to compare and evaluate information from different sources.

As children learn to recognise the differences between fact and opinion, and consider the concept of bias, they develop life skills that will support them in being citizens of the twenty-first century.

Big questions
Here are some examples of 'big questions' that can be explored through research in KS1and KS2.

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
What are the most common British plants and where can we find them?	How does a cactus survive in a desert with no water?	What are all the different ways that seeds disperse?	Why are people cutting down the rainforests and what effect does that have?	What are the differences between the life cycle of an insect and a mammal?	What do different types of microorganisms do? Are they always harmful?
How are the animals in Australia different to the ones that we find in Britain?	What do you need to do to look after a pet dog / cat / lizard and keep it healthy?	Why do different types of vitamins keep us healthy and which foods can we find them in?	How do dentists fix broken teeth?	Why do people get grey/white hair when they get older?	How have our ideas about disease and medicine changed over time?
Do all animals have the same senses as humans?	What food do you need in a healthy diet and why?	Who was Mary Anning and what did she discover?	What are hurricanes, and why do they happen?	What are micro-plastics and why are they harming the planet?	What happened when Charles Darwin visited the Galapagos islands?
Are there plants that are in flower in every season? What are they?	How does the habitat of the Arctic compare with the habitat of the rainforest?	How does the Sun make light?	How has electricity changed the way we live?	How have our ideas about the solar system changed over time?	Why do some people need to wear glasses to see clearly?
How are bricks made?	How have the materials we use changed over time?	How have our ideas about forces changed over time?	How does a light bulb work?	What unusual objects did Jocelyn Bell Burnell discover?	How has our understanding of electricity changed over time?
Which materials can be recycled?	How are plastics made?	How does a compass work?	Do all animals have the same hearing range?	How do submarines sink if they are full of air?	How do astronomers know what stars are made of?

Working scientifically skills
Using research to find the answers to 'big questions' allows children to practise and develop a range of skills. Reading for information and note-taking form an important part in this process but, as children become more skilled in carrying out independent research, they will learn to interpret the information they find and critically consider its relevance in answering their 'big questions'. Children will learn to use a range of secondary sources, including books, websites, and video, to find their information. Where possible, children can listen to presentations from experts and science professionals to get their information, or ask them questions in interviews and letters. As children move into KS2, they should be finding more data in their research and using this to help answer questions; it is even better if they start to collect their own data through questionnaires and interviews. At this stage, children should also be encouraged to evaluate the quality of the information they have found and how well it has enabled them to draw conclusions and answer their 'big question'.

Reporting Learning
This a fantastic type of enquiry for children to propose their own 'big question' to find out even more about the subject they are studying. It is much easier to manage a class full of children all following their own lines of enquiry with research than it is with any other type of enquiry. Research enquiries allow children to be creative in how they present their findings.

Depending on what they are researching, children can create posters, leaflets, newspapers, reports or letters to report their findings in writing. Alternatively, children can use multimedia to share their learning by creating videos, presentations or even podcasts. Research enquiries also support children in learning about how scientific ideas have changed over time, and this can lead to the creation of timelines in various forms. This type of enquiry is also ideal for learning about how real scientists work, both interesting characters from history, but also scientists working in your local community.