Unit 9M Investigating scientific questions

About the unit

In this unit pupils:
- identify questions that are suitable for scientific enquiry
- use a variety of strategies to answer scientific questions of different kinds
- plan and set targets for a piece of work
- consider the strength of the evidence, or the quality of the product, in relation to the question investigated
- compare the different investigative methods used
- work together in a group

Note

This unit provides an opportunity for pupils to focus on the variety of strategies that are used to answer scientific questions and to evaluate their own and others' investigations. It enables pupils to bring together skills learnt in other units and apply them to specific questions. The unit can be taught across years 8 and 9 or as a whole, towards the end of key stage 3. It is not intended to replace the work on scientific enquiry in other units.

This unit is expected to take 7–12 hours.

Where the unit fits in

The skills developed in this unit link to investigative work from all other units in the scheme of work. Other contexts can be used to exemplify a range of investigative strategies. The examples used here relate to other units as shown:
- *How much of an apple is water?* Unit 8A 'Food and digestion' and unit 9C 'Plants and photosynthesis'
- *Why do elephants throw water over themselves?* Unit 8I 'Heating and cooling'
- *Are the types and abundance of plants on the school field affected by moisture?* Unit 7C 'Environment and feeding relationships' and unit 8D 'Ecological relationships'
- *How could you classify the plants that grow in and around water?* Unit 8D 'Ecological relationships'
- *What affects the pH of rainwater?* Unit 7E 'Acids and alkalis' and unit 9G 'Environmental chemistry'

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: identify questions that can be tackled through scientific enquiry and identify strategies appropriate to different questions; select and use a suitable strategy for solving a problem, carrying out preliminary work where necessary; decide when it is appropriate to use secondary sources of information and choose appropriate sources; describe the strength of evidence or the quality of the product, in their own and others' enquiries

some pupils will not have made so much progress and will: identify more than one strategy for investigating questions and recognise that secondary sources may sometimes be necessary to obtain information or data; carry out an enquiry using a suitable strategy and recognise that one enquiry might yield stronger evidence or a better product than another

some pupils will have progressed further and will: suggest strategies for tackling different questions and explain why these are appropriate; describe how secondary sources vary in the quality and relevance of the information or data they provide; use their scientific knowledge and understanding to justify and/or challenge their own or others' conclusions and methods, and identify the limitations of the evidence produced from a variety of different enquiries

Prior learning

It is helpful if pupils:

- have used different strategies to investigate scientific questions in their previous investigative work
- know that evaluation of the strength of evidence or the quality of the product is an important part of scientific enquiry

Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:

- plan and carry out their own investigations

Model risk assessments used by most employers for normal science activities can be found in the publications listed in the *Teacher's guide*. Teachers need to follow these as indicated in the guidance notes for activities, and consider what modifications are needed for individual classroom situations.

Language for learning

Through the activities in this unit pupils will be able to understand, use and spell correctly words and phrases relating to:

- investigative strategies, *eg scientific method, developing a technique, controlling variables, fair testing, carrying out a survey, sampling, using secondary sources*
- evaluation, *eg reliability (trustworthiness) of data, validity of conclusions, most appropriate equipment*

Resources

Resources will need to be matched to the investigations undertaken. Resources needed for the investigations suggested in this unit include:

- apples or other fruit
- an oven
- a digital balance
- plastic bottles
- kitchen towels or other material for wrapping around bottles
- temperature sensors and software
- a moisture meter

Secondary source references on:

- elephants (their behaviour and habitat)
- plants that grow near water
- pH of rainwater in various locations

Out-of-school learning

Pupils could:

- look for articles in the media about scientific research
- find out about the investigative methods used by working scientists

1	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What sort of questions can be investigated scientifically?				
	• to suggest questions about a topic • how to identify ideas that can be investigated • how to choose an appropriate strategy	• Present pupils with a range of questions, which could be related either to one attainment target, *eg materials and their properties*, or to one area with links to all three attainment targets, *eg water*. Ask pupils to suggest other questions which they might ask in this area and compile a list of questions, *eg* – *How much of an apple is water?* – *Why do elephants throw water over themselves?* – *Are waterfalls beautiful?* – *Are the types and abundance of plants on the school field affected by the level of moisture in the soil?* – *How could you classify all the plants that grow in and around water?* – *What is the best way to clean dirty water?* – *Which gases dissolve in water?* – *Where is the rainiest place on Earth?* – *How does the concentration of salt in a solution of salt water affect buoyancy?* • Ask pupils to identify which questions would be suitable for scientific enquiry, *eg How much of an apple is water?*, and which would not, *eg Are waterfalls beautiful?* • Ask pupils to discuss briefly the strategies they would use to tackle these questions, and ensure that pupils recognise that there is a variety of strategies for answering scientific questions. • Ask pupils to select a question for further scientific investigation.	• suggest questions for investigation • identify and explain which questions can be answered through scientific enquiry • suggest and explain why a strategy is or is not appropriate for a particular question	• This activity helps pupils to identify appropriate strategies for answering different sorts of scientific question. It is followed by activities related to different kinds of investigation. • The questions given relate to water. Many other topics, *eg woodlice, rocks and soils, sports,* can yield questions requiring a range of different strategies for investigation.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Using and evaluating a way of finding out how much of an apple is water			
• how to search for information • how to use preliminary work to find out whether a possible approach is practicable • what apparatus is available for particular techniques • how to recognise common hazards in working techniques • how to relate results to scientific knowledge and understanding • how to control risks from identified hazards	• Help pupils to work out a technique for determining dry mass, using either secondary sources or preliminary work, *eg leaving a slice of apple in an oven and weighing it at regular intervals until the mass is constant, trying different oven temperatures and different time intervals for weighing*. • Ask pupils to consider the available apparatus, identify the hazards and decide what they would need to do to minimise the risks from each of these. • Help pupils to decide how to calculate the percentage of water in an apple from the dry mass of a slice. • Ask pupils to carry out procedures safely and effectively, record their data and carry out the calculations needed to determine approximately how much of an apple is water. • Ask pupils to evaluate the method used and identify ways in which their results may be inaccurate, *eg water vapour may be reabsorbed if the apple is left to cool in the air and a desiccator is not available; the apple may not be of uniform composition; substances other than water may have been driven off,* and to consider how many measurements they would need to make to have confidence in their results. • Ask pupils to explain the significance of the amount of water in an apple by using their knowledge of the ways in which water is used by plants and in plant cells.	• suggest an appropriate way of determining the dry mass of an apple, *eg through research or by carrying out preliminary work* • explain why each step in their technique is necessary • use suitable apparatus, *eg an oven, digital balance*, and carry out procedures safely • calculate the percentage of water in an apple • evaluate the accuracy of their technique • explain why plants have a high percentage of water	• Different groups of pupils could investigate how much water is in different apples or different fruits. The groups could then compare results. • A similar strategy is used in investigating limestone in unit 8H 'The rock cycle'. ⚠ **Safety** – teachers will need to check plans for health and safety before practical work begins. Warn pupils not to taste the apple

3	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note

Using a model and data from a fair test to find out why elephants throw water over themselves

- how to use preliminary work with a model to decide what to measure and to determine the number of measurements to be taken
- to record measurements
- how to record data on a graph and draw an appropriate curve/line to fit data
- to identify and describe patterns in graphs
- to evaluate the conclusion by considering how good the data is

- Introduce the idea that elephants throw water over themselves, *eg by using a video clip*, and tell pupils that one reason they might do so is to help them cool down. Ask pupils how they could use a model to test whether this could be true.
- Suggest pupils model/represent an elephant with a pop bottle filled with warm water, and ask them to decide a strategy for considering the effect of water evaporation on temperature, *eg by comparing the change in temperature of two containers of warm water, one wrapped in damp kitchen paper and the other wrapped in dry kitchen paper.* Ask pupils to use preliminary work to help them decide which apparatus to use for required accuracy, *eg standard thermometer or temperature sensor and datalogger*; what to measure, *eg temperature of water in container* at *two-, five- or 10-minute intervals*; and how to control factors, *eg by considering the values for the starting temperature of water, the volume of water in the container and the number of layers of kitchen paper.*
- Ask pupils to carry out procedures safely and effectively and to decide how to record their data, *eg as line graphs showing cooling curves for the two containers*.
- Ask pupils to describe the patterns shown in their data to explain what these show about the cooling of the two containers, and to relate the results to wet and dry elephants.
- Encourage pupils to consider the limitations of the model/representation of the elephant as a pop bottle cooling down in a classroom, by researching relevant information about elephants, *eg approximate values for body temperature, body mass and volume, surface area of skin, temperature and humidity of their environment,* and comparing it to similar information about the pop bottle in the classroom. Ask pupils to suggest other reasons why elephants might throw water over themselves.

- describe how they used preliminary work with a model to decide what to measure and the number of measurements to be taken
- read and record measurements accurately
- record data on a graph and draw an appropriate curve/line to fit data
- describe the patterns in the data, *eg by describing the similarities and differences in the two cooling curves*
- evaluate the conclusions by considering how good the model and the data were

- Pupils will need to allow time to take readings as the water cools down. A fan blowing on both bottles can reduce the time needed for a difference in temperature to become apparent.
- Similar strategies are used in investigating:
  - seasonal changes in unit 7L 'The solar system and beyond'
  - digestion in unit 8A 'Food and digestion'
  - solar panels in unit 7I 'Energy resources'
  - insulation in unit 8I 'Heating and cooling'

⚠ **Safety** – teachers will need to check plans for health and safety before practical work begins. If domestic mains fans are used, they need to be checked with a portable appliance tester

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Carrying out a survey, using a suitable sample size, to find out how the moisture level in the soil affects the variety and abundance of plants on the school field			
• how to use preliminary work to decide what to measure and observe and whether the approach is practicable • to consider what other factors, including those that cannot be controlled, might affect the results and how to deal with them • to collect and record data appropriately • to identify and describe trends in data • to evaluate the limitations of the evidence by considering sample size and the possible effect of other factors • to use scientific knowledge and understanding to interpret results	• Help pupils to carry out useful preliminary work to consider whether a study will yield useful data, *eg by identifying common species of plant found on the field, testing different areas to see if moisture levels are different*. Consider other factors that might contribute to the effect, but which cannot be controlled, *eg aspect, light levels, inclination, pH of soil*, and how to deal with them, *eg by noting other factors at each site.* • Ask pupils to collect data, making other observations where appropriate, *eg differences in same species growing in different areas*, to record information appropriately, *eg in tables*, and to identify and describe patterns in the data related to moisture, including qualitative observations. • Help pupils to look critically at results to decide how strongly they show a trend, particularly in relation to sample size and the number of other factors that might affect the variety and abundance of plants on the school field. • Ask pupils to interpret results in the light of their scientific knowledge, *eg that competition for resources can affect the size of populations*.	• suggest an approach which will allow them to collect enough data, in the time available, to consider the effect of moisture levels on the variety and abundance of plants on the school field • identify other factors which might affect the variety and abundance of plants and say whether they were able to take these into account • make relevant observations when collecting data • record data clearly • identify how strongly the results show a trend, making particular reference to sample size and effect of other factors • interpret results using knowledge about competition for resources	• Pupils' plans should take time limitations into account. Suggest they estimate the time needed by doing preliminary work, *eg timing how long it takes to identify plants within one quadrat or along a section of a transect*. • Similar strategies are used in investigations in unit 7C 'Environment and feeding relationships', unit 8D 'Ecological relationships' and unit 9D 'Plants for food'. ⚠ **Safety** – teachers will need to check plans for health and safety before sampling starts. Pupils should wash their hands after working
Developing a classification system for a variety of plants that grow in and around water			
• how to search for information and decide which sources of information are appropriate • to select appropriate information from secondary sources • to use preliminary work to find out whether an approach is practicable • to implement an approach, refining where necessary • to use knowledge to explain results • to evaluate the methods used in terms of the quality of the product	• Help pupils to use secondary sources to make a list of plants that grow in and around both fresh and sea water. Identify sources which describe enough relevant features of water plants to allow their classification. • Ask pupils to plan an approach to classification which will discriminate between species, *eg type of root/holdfast, method of reproduction, type of stem,* to use their classification system to group similar types of plants together, and to use scientific knowledge to explain why some organisms share certain features, *eg all those with holdfasts have to attach themselves to rock*. • Ask pupils to evaluate the strategy, *eg how well it discriminated between groups, how well it worked for plants not on the original list, how often it was necessary to refine or extend categories.*	• search for information and decide which sources of information have appropriate levels of detail to classify plants • select features of different plants to develop a classification system • apply a classification system • explain results by identifying why plants in the same group or set share characteristics • evaluate the quality of the classification system	• Pupils have opportunities to classify living organisms and materials in unit 7D 'Variation and classification', unit 8D 'Ecological relationships', unit 8E 'Atoms and elements' and unit 9D 'Plants for food'.

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Using secondary sources to develop and test hypotheses about factors that might affect the pH of rainwater			
• to decide which factors may be relevant to an enquiry • when it is appropriate to use data from secondary sources • how to search for information • how to decide which sources of information are appropriate • to select appropriate data from secondary sources • to identify and describe patterns in data • to present information appropriately • to look critically at sources of secondary data • to look critically at results to decide how strongly they show a trend • to interpret results using scientific knowledge and understanding	• Ask pupils to consider what might affect the pH of rainwater, *eg location, wind direction, volume fallen, time of year, weather pattern*, and put forward a hypothesis. • Ask pupils to consider why it is appropriate to use secondary sources to get information, *eg it might not rain for several days, it would be difficult to collect enough data to identify trends using rainwater collected over a short period of time.* • Help pupils search for an environmental database on the pH of rainwater, *eg on websites, on CD-ROMs or in reference books*. • Ask pupils to search for patterns in data, *eg by considering whether pH is generally more acidic when wind is from the east, or whether pH is less acidic following stormy weather*, to describe any patterns found and present the data they have used as evidence of these patterns. • Ask pupils to look critically at the source of secondary data, *eg* – *Is the data collection carried out by volunteers?* – *Is there data from some areas but not others?* • Ask pupils to identify the limitations of their own selection of evidence, *eg* – *I only looked at the link between wind direction and pH over 30 days. If I had considered evidence over a longer period I would have more confidence in my results* – *Factors such as location and weather patterns may have affected the pH and I have not had time to investigate these* – *All areas I had data about were in towns and cities; pH in rural areas might be different* • Help pupils to interpret results in the light of their scientific knowledge and understanding, *eg oxides of non-metals such as sulfur and nitrogen are acidic, so when the wind blows towards us from countries with high emissions of these oxides, the rainwater is likely to be more acidic.*	• suggest factors that might affect the pH of rainwater • explain why it is appropriate to use secondary sources • select appropriate data from appropriate sources • search for patterns in data • describe any patterns found • present the evidence they used to identify patterns • evaluate their data in terms of the quality of the source of information and the limitations of their own selection of evidence • use their scientific knowledge to explain results	• A database such as the National Environmental Database Project carries relevant information on the pH of rainwater. • A similar strategy is used in investigating whether we are fitter than our grandparents, in unit 9B 'Fit and healthy', and to investigate changes in pollution, in unit 9G 'Environmental chemistry'.
Concluding the unit on investigating scientific questions			
• to compare investigative methods used by others • to look critically at results to decide how strongly they show a trend/relationship • to consider the limitations of the evidence • to evaluate the methods used in terms of the quality of the data or product	• Ask pupils to describe the different types of investigation used by themselves and others. • Ask pupils to state and justify their conclusions and describe the limitations of their evidence. Encourage pupils to challenge each other's descriptions of the strength of relationships shown, and the quality of the data or the products.	• describe the different methods used to answer questions and recognise some similarities and differences in the methods used • justify or challenge conclusions, taking into account the limitations of the evidence produced and the quality of the data or product	