Activity J

Chemical Reactions & Measurement:
Deciding What Measurements to Take in an Enquiry

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Introduction

Pupils can learn how to carry out enquiries by simply doing them. A much more focused way of learning how to investigate is to teach specific aspects of enquiry explicitly. This can be done either in the context of whole enquiries or as small tasks targeted at teaching specific aspects of enquiry. These materials focus on teaching pupils about range, interval and repeat readings.

Pupils often think that it is possible to measure a value with certainty and do not realise that error is present in any measurement. This means that their response to the question of how to collect better evidence is that measurements should be taken more carefully or by using better instrumentation.

When asked how many values of the independent variable should be selected, pupils often give an answer such as, "Five"! They are often unable to justify this response and fail to realise that the range and interval between values is determined by the pattern being explored and by the variability in the data being collected.

Objectives

Pupils will learn about the process of science, in particular the need for reliable evidence.

Outcomes

By the end of the lesson, pupils will be able to:

- select a suitable range and interval of values to measure in order to draw meaningful conclusions;
- decide when it is appropriate to take repeat readings of a particular value and how many repeat readings to take;
- evaluate whether the data generated in an enquiry supports the conclusions drawn.

Notes for Teachers

Pupils observe a simple demonstration and use the data generated to plot a graph. Pupils then suggest how to improve the quality of the data by considering the range of values selected and using repeat readings. Pupils then carry out a different enquiry again focusing on how to improve the quality of the data collected. Both enquiries are fair–testing ones and are set within the context of a study of combustion. Some useful links with ignition can be made from a conceptual point of view – wax needs to be hot and vaporised to ignite. So also paper – the corners or thin bits ignite more easily.

The following books provide a useful introduction to how to teach the concepts of evidence introduced in these materials:

- Watson, R. and Wood-Robinson, V. (2002*) Investigations: Evaluating evidence* pp. 89-107 in (eds.) Sang, D. and Wood-Robinson, V. Teaching Secondary Scientific Enquiry. London, John Murray ISBN 0 7195 8618 6
- Goldsworthy, A., Watson, J. R. and Wood-Robinson, V. (2000) *Investigations: Developing Understanding* Hatfield, Association for Science Education., pp. 50-55 and pp. 65-68.

Teaching Sequence

- *Task 1 (30 minutes)*

First demonstrate the candle experiment. The question being investigated is 'What effect does the size of the container have on the time for which a candle burns?' Bring five pupils up to the front to help you. Each of these five pupils gets a candle, a stop clock and one of the five beakers. Light the candles and get the pupils to put the beakers over the candles and start the stop clock, all at the same time. Record the results in a table on the board and plot a graph of the results on the board.

- Ask each pupil to write:
    - an interpretation of the graph;
    - an explanation of the graph in terms of scientific knowledge;
    - an evaluation of the quality of the evidence and how it could be improved.

- Discuss the quality of the evidence with the class. It might be expected that the points would all fall on a straight line, which crosses the y-axis (if the volume of the candle is significant). The discussion of the graph should include the following:

    - The interval between values is not satisfactory. The five values should be spread evenly (e.g. 50, 100, 150, 200, 250 cm^3). The number of values is also barely enough to be able to be confident of the shape of the line.

- The five readings will probably not fall on a straight line. This indicates the need to take repeat readings. You could get the pupils to do two repeats and then see if an average value gives a better straight line.

- Other problems mentioned may be poor measurement (e.g. pupils did not start the clocks at the same time, or more significantly accepting that the beaker size is its actual size. The beaker size needs measuring by filling it with water from a measuring cylinder), not carrying out a fair test (e.g. different sized candles or different sized wicks), poor technique (e.g. air getting in through the lip of the beaker. You could fill this gap with plastic putty).

- *Task 2 (60 minutes)*

It is important not to rush this task and to leave sufficient time for pupils to evaluate their own and one another's work so that they can act upon the evaluations and improve their data.

- First demonstrate two pieces of paper burning, one which is 2 x 10cm and one which is 4 x 5cm (same area). Ask the class whether there is a difference in the burn time, whether they are sure of their answers and what they would do to be more certain. Now repeat this with two pieces of paper that are the same size and shape, but different colours. Repeat the questioning of the class.

- Next pupils work in groups to investigate what factors affect the time taken for pieces of paper with an area of $20cm^2$ to burn.

  ! Safety note:
  It is important to limit the size of paper being burnt to $20cm^{2.}$

  Possible variables to investigate are the effects colour of paper, thickness, weight, length of paper etc. By keeping the area constant, the continuous variable of width or thickness of the strip could be investigated, but pupils may need help in realising this as their input (independent) variable. This would result in a graph and bring out some of the issues that the candle experiment highlighted.

- Pupils report their investigation in the form of a poster. The poster must include the name of the group, the data, a graph and an interpretation of the results and a scientific explanation of this interpretation. The point here is to focus on the quality of evidence rather than provide a complete write-up.

- Put up the posters around the room and allow about 5-10 minutes for pupils to complete the worksheet 'Evaluating the Evidence'. Each group should look at the posters of at least five other groups. Whilst the pupils are doing this select three or four posters that will be the focus of your whole class discussion. If two different groups have investigated the same independent variable, but reached different

conclusions, this can be a good starting point for the class discussion. The main questions for the class discussion are:

- Do you trust the data? Why?
- How could the data collection be improved?

Summary of main points

When collecting data in an enquiry there is always error in measurements made. There are two ways of coping with error:

- Improve the methods of data collection, e.g. by using better measuring instruments.
- Make sure that the values of the data are spread out sufficiently to be able to see patterns in the data (i.e. consider the range and interval).
- Use methods designed to cope with measurement errors such as collecting several readings of each value and taking the average, or by using graphs.

It is important to realise that there is no magic formula for deciding the range, interval or number of repeat readings needed. This depends on the pattern being explored and on the variability of the data.

Practical notes

Resources

Candle experiment to demonstrate:
A collection of candles
Beakers, one each of 50 cm^3; 100 cm^3; 250 cm^3; 500 cm^3; 1000 cm^3
Matches
Plastic putty
5 stop clocks
250 cm^3 measuring cylinder

Burning paper experiment for pupils:
Lots of paper of different kinds.
Scissors
Rulers
Tweezers or tongs to hold the burning paper
Matches
Tapers
Stopclocks x 10
Poster pens
Large poster paper
Graph paper

Chemical Reactions

Scientists use evidence from experiments to support their conclusions. Have the other groups in your class collected good quality evidence? Does their evidence support their explanations?

In this assignment your job is to look critically at the evidence of the other groups and to ask questions to check that their explanations are supported by good quality evidence.

Look at the posters from other groups in the class. For each group write down one question that you would like to ask the group about their experiment. Points to consider are:

- Is there enough data? (Range, interval, repeats, anomalous results)
- What questions would you like to ask about how the data were collected?
- Do the data support the conclusions?
- Is the explanation a good scientific explanation that uses knowledge of combustion to explain the results?
- Have different groups investigated the same thing but reached different conclusions?

Name of group	Our question

Turn over and use the back if you need more space.