Minibooster 1: Progressing to level 6 and beyond

Accuracy and reliability

Background

A pupil working at:

Level 4

- knows that the accuracy of measurement is limited by the equipment used (e.g. mm on a ruler);
- repeats results but does not know why;
- confuses accuracy with reliability (has no real understanding of what 'reliable' means).

Level 5

- begins to appreciate that the range of data collected can affect the reliability of evidence;
- understands that repeating results affects reliability;
- knows when and when not to repeat readings;
- decides appropriate approaches to a range of tasks, including selecting sources of information and apparatus.

Level 6

- selects and uses methods to collect adequate data for the task, measuring with precision using instruments with fine scale divisions, and identifies the need to repeat measurements and observations;
- uses and applies qualitative and quantitative methods to obtain and record sufficient data systematically;
- can recognise differences between accuracy and reliability;
- uses and applies independent and dependent variables in an investigation by choosing an appropriate range, number and value for each.

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Level 7

- selects and uses methods to obtain reliable data, including making systematic observations and measurements with precision, using a range of apparatus;
- can explain the difference between accuracy and reliability;
- can explain how inherent variation (e.g. from human error, sensitivity and accuracy of instruments) needs to be considered when collecting data.

To move pupils from level 4 to level 5

1. Look at a range of measuring instruments and make judgements on how accurately you can measure with each.
2. Use model data to encourage judgements on accuracy.
3. Use model data (tables and/or graphs) to show explicitly that a limited range of data can sometimes yield **unreliable evidence**.
4. Use model data where results are repeated. Make sure that one value in this data set does not fit (is anomalous). Point out that readings that are the same or similar support one another and are therefore considered reliable.
5. Consolidate pupils' understanding by letting them carry out a simple experiment to demonstrate whether they are capable of collecting accurate and reliable results.

To move pupils from level 5 to level 6+

1. Pupils should make decisions about appropriate range, degree of accuracy and number of repeats.
2. Pupils should explain verbally, and in writing, the meaning of the terms range, accuracy and reliability.
3. Pupils should justify why they have chosen particular ranges, measuring instruments and number of repeats.
4. Pupils should question whether a suitable range, accuracy and number of repeats has been chosen.

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Activities

Some of the activities in the suggested teaching sequence from the original Minibooster: *Accuracy and reliability Science intervention materials* DfES 0077 2004 are appropriate for moving pupils from level 5 to level 6+. Material from the original Minibooster is included here.

Activities 1 and **2** are at levels 4/5.

Activity 1 could be extended for level 6+ by asking pupils to identify where errors that might lead to unreliable results could occur when using these measuring instruments, and whether the error is likely to be from a faulty instrument or human error.

Ask pupils to discuss whether any of the instruments could give reliable results whilst at the same time being inaccurate (e.g. a Newton meter).

Activity 2 Pupils could be given the results and then asked to devise questions that explore whether the results are accurate and reliable.

Activities 3, **4** and **5** are at level 6 and are appropriate for developing skills needed at level 6+. It would be useful for pupils to try the activities first and then to draw out the key messages for themselves.

Additionally teachers could

- Encourage pupils to justify why they have chosen particular ranges for variables, particular measuring instruments and numbers of repeats in plans.
- Give pupils the opportunity to carry out some short trial runs of simple investigations to generate some preliminary data that they could use to make decisions about appropriate range, degree of accuracy and number of repeats (e.g. how far a book slides across a table for a given force; how the length of a paper spinner's wings affects the time to fall 2 m).
- Give pupils plenty of opportunities to explain verbally, and in writing, the meaning of the terms: range, accuracy and reliability. This could be done as paired work using sticky notes. Answers could be compared, shared and agreed as a class snowball activity to evolve and agree definitions. Ideally these should match the definitions identified in the Key Stage 4 science specifications used in your department.
- Use anonymous data from previous pupils' coursework for pupils to critically evaluate and question whether:

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- a suitable range and values of variables have been chosen to investigate the hypothesis;
- repeat readings have been taken and anomalous results followed up;
- the instruments chosen were appropriate for the task;
- there was anything about the methodology that could have led to unreliable results;
- the readings were 'good enough' (i.e. within an acceptable degree of accuracy).

Adapted from: Minibooster 1 *Accuracy and Reliability; Science intervention materials* DfES 0077 2004

Suggested teaching sequence

The following activities could all be done in one lesson or divided into separate activities and spread over more than one lesson.

1. **To teach pupils to look at a range of measuring instruments and make judgements on how accurately you can measure with them**
   - Look at a range of measuring instruments (e.g. range of measuring cylinders, range of Newton meters, rulers that measure to the nearest cm and mm, trundle wheel, etc.) Discuss what they are used to measure, and look at the scale to identify the maximum the instrument will measure and what steps the scale goes up in.
   - Pupils work in groups to discuss how accurately they could measure with each measuring instrument.
   - Use Worksheet 1(i) '*Which measuring instrument?*' Ask pupils to decide the most appropriate measuring instrument for each task. Other examples can be added, for example, to use a voltmeter, ammeter, cathode ray oscilloscope (for sound).

2. **To teach pupils to make judgements about accuracy**
   - Use Worksheet 1(ii) '*How accurate?*' which could be used on an interactive whiteboard or with a digital projector. The sheets provide data on the mass of magnesium before and after heating, and times for pupils running 100 m, with questions for pupils to discuss. Use this activity to illustrate explicitly that sometimes evidence can be unreliable because of the limitations of the selected measuring

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instrument and how accurately it is able to measure. There may also be differences between similar pieces of equipment, which you can demonstrate by asking pupils to measure the same item (e.g. temperature of boiling water, weight of a 100 g mass) on a series of measuring instruments.

- Discuss with pupils the meaning of 'accurate'. First, there is accuracy of the measuring instrument; pupils need to select equipment with the right degree of precision for an investigation – this links with the activity above. Second, accurate measurement can be difficult because of the conditions (e.g. the height a ball bounces or the extension of a spring that wobbles).
- Use *AKSIS Investigations: developing understanding in scientific enquiry*, pp. 96–98. Available from the ASE ISBN 086-357-310X.

3. **To teach pupils that a limited range of data can sometimes yield unreliable evidence**

   - Look at Worksheet 1(iii) *'Making cheese'*. Ask pupils to discuss in pairs any simple conclusions that they can draw from groups 1, 2 and 3 – 'What do the results tell you?' This is a good opportunity for pupils to revisit fair testing and the key words **independent** and **dependent** variables by asking:
     - What is the **independent** variable?
     - What is the **dependent** variable?
     - What things (variables) should they keep the same?

     Pupils also have the opportunity to practise describing the relationships between the variables. Make it clear that different conclusions would be drawn from groups 1 and 2 than from group 3, because of the number and range of measurements. One aspect of reliability is therefore to collect sufficient evidence.
   - Discuss with pupils the meaning of 'reliable evidence'. If results are reliable, then every time the experiment is repeated, the results are similar. Sometimes reliable results can be inaccurate if the measuring equipment is faulty.
   - Refer to *AKSIS Investigations: developing understanding in scientific enquiry*, pp. 99–101. Available from the ASE ISBN 086-357-310X.

4. **To teach pupils that repeat readings are useful to judge the reliability of results**

   - Use Worksheet 1(iv) '*Stretching a spring*'; this could be used on an interactive whiteboard. You may wish to have equipment available to demonstrate briefly what the pupils did in the experiment. Use

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this to illustrate when results support each other (are reliable) and when they are not. Discuss how close results should be to be considered close enough. This will be brought out when pupils discuss the table, where they have to decide whether or not results are reliable.

- Pose the question: 'What could we do about the unreliable result?'. Suggestions should include repeating a third time, comparing this result with the other two, identifying the anomaly and judging which numbers to include in the average.
- Refer to *AKSIS Investigations: developing understanding in scientific enquiry*, pp. 65–68, on taking repeat readings. Available from the ASE ISBN 086-357-310X.

5. **To consolidate that pupils have understood 'accurate' and 'reliable'**

- Choose a simple experiment (friction is a good one) and ask pupils to collect results that they consider to be both accurate and reliable. You could provide a checklist, or use discussion to generate a class checklist, that which will help them justify the accuracy and reliability of their results. For example:
  - Have they selected the most appropriate measuring equipment?
  - Have they measured as accurately as they can with the apparatus chosen?
  - Performed all measurements twice, and a third time only when a result seems odd?
  - Have they collected sufficient evidence to be able to look for trends or patterns or to answer the question?

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Worksheet 1(i)

Which measuring instrument?

What would you use to measure each of the following?

1. Your mass.
2. The diameter of your head.
3. The mass of a bean seed.
4. 10.5 g of rock salt.
5. The distance across the school field.
6. 1 cm^3 of alcohol.
7. 250 cm^3 of water.
8. The weight of an apple.
9. The change in temperature in the classroom over a weekend.
10. Your body temperature.
11. The time it takes for your pulse to return to normal after exercise.
12. To time every 2 minutes – so that you can take the temperature of the water as it cools?
13. The amount of air in your lungs.
14. The pH of pond water.
15. The amount of light under a tree.
16. The height of a plant every day.
17. The mass of a slice of cucumber before and after it is dried.
18. Different volumes of water from 10 to 100 $cm^{3.}$
19. The length of a woodlouse.
20. The brightness of a light bulb.
21. The time for a spinner or parachute (made in the classroom) to fall.
22. How far an object slides on different ramps.
23. The length of dandelion leaves.
24. 0.5 g of copper sulfate.
25. The number of seconds a pendulum swings for.

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Worksheet 1(ii)

How accurate?

1. **Burning magnesium**

   Two groups of pupils used balances to find the mass of magnesium powder at the start of an experiment and then after they had burnt it in air.

   Group 1

   Mass of magnesium

   At the start = 1.2 g

   At the end = 1.2 g

   Group 2

   Mass of magnesium

   At the start = 1.19 g

   At the end = 1.24 g

   Some questions about these results

   - Do you think the two groups used the same balance? Explain your answer.
   - Do the results tell you the same thing? Do they show any change in the mass of magnesium?
   - Why did group 1 get the same readings before and after heating the magnesium?
   - Why did group 2 get different readings even though they were doing the same experiment?
   - Which group's results gave the most accurate result? Explain why?

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2. **Running 100 metres**

Four pupils decided to use three different stopwatches for the same race. They wanted to see if the type of stopwatch they used to measure the time it took them to run 100 m really made a difference to their results. This is what they found out.

Results – 100 m sprint times

Stopwatch 1

Pupil	*Time (seconds)*
Siân	14
Chris	14
Des	15
Phil	14

Stopwatch 2

Pupil	*Time (seconds)*
Siân	14.4
Chris	14.1
Des	14.6
Phil	14.1

Stopwatch 3

Pupil	*Time (seconds)*
Siân	14.42
Chris	14.13
Des	14.62
Phil	14.08

Some questions about these results

- What do you think were the differences between the three stopwatches?
- Who ran the fastest in each race?
- Did the type of stopwatch make any difference to deciding the winner?
- Who came second in each race?
- Did the type of stopwatch make any difference to deciding who came second?
- How did you decide who came second?
- Which do you think was the best stopwatch to use for this investigation? Explain why.

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Worksheet 1(iii)

Making cheese

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Making Cheese

Farmer Stilton makes cheese on his farm by reacting milk, collected from his cows, with a chemical called Maxiren. He wanted to know the answer to this question: 'How does the temperature of the milk affect the amount of cheese made?'

Three groups of Year 9 students did an experiment to find out.

Here are their results.

Group 1 took two readings

Temperature of milk (°C)	*Mass of cheese (g)*
20	1.4
40	2.9

What do their results tell them?

Group 2 took four readings

Temperature of milk (°C)	*Mass of cheese (g)*
10	0.5
20	1.4
30	2.2
40	2.9

What do their results tell them?
Try to sketch the shape of the graph of these results.

Group 3 took eight readings

Temperature of milk (°C)	*Mass of cheese (g)*
10	0.4
20	1.2
30	2.3
40	3.0
50	2.4
60	1.5
70	0.7
80	0.0

What do their results tell them?
Try to sketch the shape of the graph of these results.

Worksheet 1(iv)

Stretching a spring

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Stretching a Spring

Pupils hung different masses on the end of a spring and measured how much the spring stretched.

Three groups did the same thing, using similar equipment. This is what they found.

Mass (in grams)	Group 1	Group 2	Group 3
0	2	2.4	2.4
10	3	3.1	3.0
20	4	4.1	3.6
30	4	3.9	4.1
40	5	4.5	4.5

- What was the general trend as more masses were added to the spring?
- Is that the same trend for every group?
- Look at the results for each mass across the three groups. If the results from all three groups are close then we could say that the results are reliable. Use the table below and decide whether the results from all three groups are reliable or unreliable for each mass and why you think that.

Mass used	Tick for reliable; cross for unreliable	Why did you make that decision?
0		
10		
20		
30		
40		

- How do you think you could make the results from this investigation more reliable? Can you explain your answer?
- Do any of the results seem odd? How do you think you could find out whether the result is reliable?