Aspects of *How science works* steps table

This strand is about helping pupils to develop some of the more challenging aspects of the practical *How science works* skills. While many pupils can draw graphs well, fewer understand how to interpret the graphs and the principle of the 'line of best fit'. Variables can remain a mystery to many as they do not understand the interplay between the different types or how the choice and range can influence the results of an experiment. How often have pupils written 'I could of done it better' [sic] or 'I needed to do more readings' [sic] as their evaluation? Pupils need to be able to identify and explain about sources of experimental error and to take account of these in their experimental design.

Step 1 pupil characteristics	Strategies to ensure progression	Step 2 pupil characteristics	Strategies to ensure progression	Step 3 pupil characteristics	Strategies to ensure progression	Step 4 pupil characteristics
Graphical skills Pupils can: • present work or data as a graph although the scales may be incorrect; • identify the pattern shown by the graph and possible anomalous results.	*A) Model how to:* • *assign appropriate scales* • *read a graph* • *describe what a graph is showing, i.e. increase, decrease, no change.* *B) Demonstrate how to break up line graphs into discrete sections, read each section and then*	Pupils can: • choose an appropriate type of graph and scale(s) to display the data effectively; • explain what the shape of the graph represents and interpret graphs with a negative scale on one axis.	*A) Model how incorrect plotting or inappropriate scales can change or distort the pattern of the graph.* *B) Create a number of opportunities to represent data through a range of complex graphs. This should include drawing graphs with negative scales.*	Pupils can: • use lines of best fit appropriately; • make allowances for anomalous results in their graphs; • explain what the shape of the graph represents and interpret this correctly; • manipulate and transform data to represent	*A) Create opportunities for pupils to explain how they have made numerical predictions from the interpolation or extrapolation of graphical readings.* *B) Demonstrate the effect of insufficient readings and/or anomalous results on the graphical representation of*	Pupils can: • interpolate and extrapolate with accuracy; • explain and suggest reasons for anomalous results in their graphs.

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	sequence them to build up the whole story of the graph. *C) Create opportunities to interpret a range of graphs including those with simple negative scales on one axis, e.g. change of mass.*		*C) Model how to decide whether a line of best fit is needed and how to draw it correctly, i.e. should it go through the origin? Help pupils to realise that any point on a graph is only ever an approximation.* *D) Create experimental opportunities to calculate negative values, e.g. mass before and after; temperature change during reactions.*	negative changes, *e.g. osmosis, exothermic or endothermic reactions*.	*data.*	

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Variables, reliability and accuracy Pupils can: • identify the key factors to be considered and generally assign sensible values to them; • measure a variety of quantities with precision.	*A) Support pupils in using the correct language when talking about variables.* *B) Demonstrate how the choice and range of variables might affect the quality of the investigation, e.g. pupils carry out the same investigation using different ranges and numbers of variables and compare results.*	Pupils can: • identify relevant independent and dependent variables; • choose an appropriate range, number and value for each variable; • make enough measurements, observations and comparisons for the task.	*A) Create opportunities for pupils to identify the key variables in scientific news articles or adverts.* *B) Demonstrate how accuracy can be affected by the choice of equipment or technique, e.g. pupils carry out the same investigation using different equipment and compare results.* *C) Explain the difference between categoric, ordered and continuous variables and require pupils to assign the correct classification to different investigations.*	Pupils can: • identify and manipulate relevant independent and dependent variables and recognise that some cannot be controlled; • plan for accuracy through the choice of equipment and technique;	*A) Discuss with pupils investigations where not all variables can be controlled and ask pupils to explain how to account for this in their experimental design.* *B) Demonstrate how to increase reliability through repeat readings, use of a control and trial runs; create opportunities for pupils to develop these techniques.*	Pupils can: • identify key factors in complex contexts and in contexts where variables are not easily controlled; • plan for reliability through trial runs, repeat readings and accurate practical techniques.

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Analysis and evaluation Pupils can: • draw conclusions consistent with the evidence and generally analyse data qualitatively; • explain how their planning and implementation could be improved.	*A) Explain the use of a table as* ▪ *an organiser within the experimental plan* ▪ *a way of presenting data in a report.* *B) Create the opportunities for pupils to* • *compare the relative advantages and disadvantages of presenting results as tables or graphs predict the design of an experiment from the table or graph* • *organise data into different tables and compare them.*	Pupils can: • draw conclusions consistent with evidence and use scientific knowledge and understanding to explain them; • explain how planning and implementation could be improved and how this could help overcome experimental error.	*A) Create opportunities for pupils to:* ▪ *identify mathematical trends or patterns and use these to make a prediction* ▪ *devise criteria to decide whether the evidence is valid.* *B) Create opportunities for pupils to assess each other's experimental designs and explain where they see possible sources of error.* *C) Discuss with pupils the range of errors associated with taking measurements.*	Pupils can: • consider whether the data they have collected is sufficient for conclusions to be drawn; • explain how they have made a numerical prediction based on the trend or pattern in results; • evaluate their planning and implementation and explain how this could account for errors and anomalies.	*A) Discuss with pupils how and why bias in the evaluation of evidence might arise.* *B) Model for pupils how a change in experimental parameters can alter the validity of the data.* *C) Create opportunities for pupils to assess each other's experimental designs and conclusions to identify and explain inconsistencies between the two.*	Pupils can: • identify and suggest reasons for anomalous results and allow for these when drawing graphs; • explain how the selective presentation of data can bias the conclusion drawn; • evaluate their planning and implementation and explain how this could account for errors and anomalies and the subsequent impact on the conclusion drawn.

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	C) Model how to interpret patterns in graphs and tables and to be aware of the limitations of the data. *D) Model how to identify possible sources of experimental error in the planning and implementation.*					

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