Investigating Scientifically

RAISE QUESTIONS

PREDICT

FAIR TEST

MEASURE

DEVELOP TABLES

CONSTRUCT AND USE GRAPHS AND CHARTS

EXPLAIN RESULTS

EVALUATE INVESTIGATIONS

PROGRESSION IN RAISING QUESTIONS

Question	**Level of support**
My teacher has asked me to find out which surface lets the car travel the furthest.	▪ Told what to change (surface). ▪ Told what to measure (distance travelled). ▪ Set in a familiar context (toy cars). ▪ Clue as to what to do (measure the furthest distance travelled). **This is a question with considerable support.**
My teacher dropped a ball on the carpet and asked me to suggest things I could do to make the ball bounce higher. I suggested dropping it onto a hard surface like the playground	▪ Student suggests what to change. ▪ Told what to measure (height of bounce). ▪ Set in a familiar context. ▪ Clue as to what to do (measure the height of the bounce). ▪ May need to be encouraged to try several surfaces. **This question gives reasonable support.**
My teacher has asked me to find out which tights are best. I think that the best ones will be the ones that stretch the most. I will test how much they stretch.	▪ Told what to change (type of tights) ▪ Set in a familiar context. ▪ Student decides what 'best' means ▪ May need to be encouraged to measure the stretch rather than just order from most to least stretchy. **This question gives some support.**
My teacher has asked me to find out which sugar dissolves the fastest.	▪ Told what to change (type of sugar) ▪ Told what to measure (time taken to dissolve) ▪ Student needs to understand the term 'dissolve'. **This question gives support but depends on knowledge of a scientific term.**
My teacher has asked me to find out something about paper spinners so that I can answer the question 'Which paper spinner is best?'	▪ Student decides what to change ▪ Student decides what to measure ▪ Unfamiliar context ▪ No clues about what to do (ie measurement prompt) **This form of question gives little support.**

RAISING QUESTIONS

Why raise questions?

- ✓ **There is no investigation without a question.**
- ✓ **Student-generated questions help students to 'own' the investigation – leading to increased achievement, motivation and learning.**

Hints…

- ❖ **Questions that can be investigated are not always easy to generate.**
- ❖ **The students' questions will help to identify an area of interest and the question can then be modified so that it can be investigated.**

Activities to try…

Brainstorm questions as a class

Create a set of question cards.

Question journal… *What I want to know…*

Ask children to write 5 questions about a favourite sport or activity.

Pin questions on a 'question board'.

PROGRESSION IN PREDICTING

How will the size of lumps of jelly make a difference to the time it takes to dissolve…?

Prediction	What the student can do…
I think the little pieces will dissolve first.	This is a simple prediction.
I think the little pieces will dissolve first because they are little.	This prediction includes an attempt at giving a reason…
I think that the little pieces will dissolve first because my Dad breaks it into little pieces when he makes jelly.	The reason for this prediction is based on any everyday observation/experience.
I think the little pieces will dissolve first because the water can attack them more easily.	This is a hypothesis based on thinking about the ways that things dissolve.
I think that the little pieces will dissolve first because there's more surfaces in touch with the water.	This is a hypothesis with a developing understanding of the scientific concept that the greater the surface area, the faster the rate of dissolving.

Adapted by: Anne Forbes, ACU, 2008

Original concept: Goldsworthy, A. and Feasey, R. (1997). *Making sense of primary science investigations.* Hatfield: The Association for Science Education.

PREDICTING

Why predict what will happen?

- ✓ Predicting encourages students to think ahead and make plans.
- ✓ It encourages students to focus on the key variables and how they may relate to each other.
- ✓ It provides clues about what should be measured.
- ✓ A good prediction requires reflection and use of prior experiences and learning.

Hints…

- ❖ Younger students need to only guess what will happen.
- ❖ Older students should qualify their prediction.
- ❖ Once a prediction is qualified by scientific knowledge it is a hypothesis.

Activities to try…

Brainstorm
'*Things we know about…*'.

Identify predictions that are based on scientific knowledge.

Order predictions from most to least useful for the same investigation.

PROGRESSION IN FAIR TESTING

Investigating how long sugar will take to dissolve in water at different temperatures.

Explanation	What the student can do...
Putting s big spoonful in one pot and a small spoonful in the other isn't fair.	▪ This student can recognise a clearly unfair test. The teacher decided what to keep the same.
I think it was a fair test because we put a teaspoonful of sugar in each jar.	▪ One aspect of the fair test has been recognised. The teacher helped to make sure that everything else was kept the same.
Out test was almost fair because we used a teaspoonful of sugar in each jar and we used the same type of sugar but we didn't check the water and one jar had more in it than the others	▪ Two variables have been controlled in this test. The discussion afterwards revealed that the third variable had not been controlled/kept the same.
When we planned the test we knew that we would have to keep these things the same to keep it fair: the amount of sugar, the type of sugar, the volume of water.	▪ This student has identified the three relevant variables to be controlled before testing and realises that they must be kept the same in order to make it fair.
When I planned my test I knew I would have to keep these things the same: Mass of sugar 5g Type of sugar Caster Sugar Volume of water 150mL	▪ This student planned and carried out a fair test by identifying the three relevant variables and by giving each one a sensible value.

FAIR TESTING

Why use fair tests?

- ✓ **A fair test is the only way to be sure that what you have changed (independent variable) is affecting what you measure (dependent variable).**
- ✓ **Accurate and careful fair testing leads to confidence in the results.**

Hints…

- ❖ **It is easier to identify a fair (or unfair) test than it is to plan and do one.**
- ❖ **Encourage students to keep all of the control variables the same.**
- ❖ **Encourage experienced students to identify a value for their control variables.**
- ❖ **Cows Moo Softly* stands for Change one thing, Measure something and keep everything else the Same.**

Activities to try…

Identify ways that measurements could be unfair.

Demonstrate a clearly unfair test.

Have students ask themselves 'Am I doing anything that's not fair?'

Teach students about Cows Moo Softly.*

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Original concept: Goldsworthy, A. and Feasey, R. (1997). *Making sense of primary science investigations.* Hatfield: The Association for Science Education.

PROGRESSION IN MEASURING

Comparing distances rolled by a toy car starting at different points on a ramp.

Explanation	What the student can do…
It went further when we let it go at the top.	▪ This student has made a simple comparison.
We marked where it stopped on the floor, cut a piece of string that length and stuck the bits of string on the wall.	▪ In order to compare the measurements more easily the student has realised the need to record how far it went.
I used straws to tell me how far it went each time.	▪ This method of using non-standard measurements will enable a numerical comparison.
We started off using a ruler but had to keep moving it up. Our teacher gave us a long tape measure and then we measured the distances in cm.	▪ Although measuring in standard units, this student needed help selecting the most appropriate measuring equipment.
We rolled the car 3 times from each staring position on the ramp, marking where the back wheels stopped. We used the long tape measure and measured in cm. We calculated the average of 3 measurements.	▪ This student has taken repeat readings, measuring to the same point on the car each time. Both of these will improve measurement accuracy. The student also selected the long tape measure and measured in standard units.

Original concept: Goldsworthy, A. and Feasey, R. (1997). *Making sense of primary science investigations.* Hatfield: The Association for Science Education.

MEASURING

Why measure?

- ✓ When you change something you must measure (or observe) what happens to see the effect of the change.
- ✓ Taking measurements helps you to see patterns in the results.

Hints...

- ❖ Progress from direct comparison, to non-standard measurements to standard measurements.
- ❖ Measurement categories include length (mm, cm, m), mass (g, kg), volume (ml, l) time (sec, mins, hours, days) and temperature (°C). Older students should be introduced to measuring force (Newtons) and area (mm^2, cm^2, m^2).
- ❖ Explicitly teach how to take measurements and how to read scales.
- ❖ Encourage older students to take repeat readings. The middle value of 3 readings may be used if averages cannot be calculated.
- ❖ Allow older students to select their measuring equipment from a provided range.

Activities to try...

Read out a pen pal letter where the writer describes themselves with non-standard units.

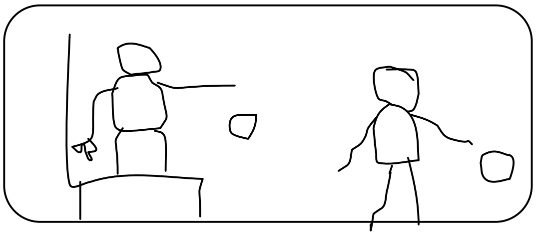
Have students prepare a guide to using a piece of measuring apparatus, so that others can follow the instructions.

Mark the height of bounce of a ball on several occasions and then discuss the benefits of multiple readings.

PROGRESSION IN CONSTRUCTING AND USING TABLES

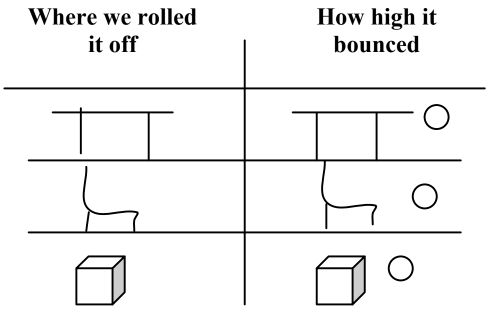
Investigating how the height from which a ball is dropped affects the height of the bounce.

Student work sample



What the student can do…

- This student has observed and recorded what happens when she dropped the ball from 2 different heights.



- The teacher has constructed most of the table, The student has carried out the 3 tests and recorded with a picture where the ball bounced.

Where did you drop it?	How high it bounced.
Top of the door	5 boxes
Bookshelf	4 boxes
Bottom of window	2 boxes
Table	2 boxes

- Headings were provided by the teacher. The student knew that she had to do 4 tests but had to decide what to write in the first column and what to record in the second column.

Height that we dropped it	How high it bounced.
1m	0.38m
1.25m	0.59m
1.5m	0.68m
1.75m	0.76m

- The student has constructed their own table, choosing their own headings, the number of tests, and the height from which the ball was dropped. The teacher suggested to drop the ball from heights between 1m and 2m.

Original concept: Goldsworthy, A. and Feasey, R. (1997). *Making sense of primary science investigations.* Hatfield: The Association for Science Education.

Height of drop	Height of bounce			
	1st go	2nd go	3rd go	Average
1m	0.39	0.40	0.35	0.38m
1.25m	0.58	0.64	0.55	0.59m
1.50m	0.68	0.79	0.80	0.76m
1.75m	0.85	0.80	0.81	0.82m
2.00m	0.82	0.93	0.89	0.88m

- The student has constructed this table on her own selecting the headings, number of tests, range of heights and the intervals between them. She also chose to repeat her tests and take an average. She knew the type of table she heights between 1m and 2m

TABLES

Why use tables?

- ✓ **Tables are a great way to organise information.**
- ✓ **Tables convey a lot of information with very little writing.**
- ✓ **Checking tables before the results are entered shows what students plan to do.**

Hints…

- ❖ **Younger students will need help to construct their tables.**
- ❖ **Encourage older students to construct their own.**

Activities to try…

Look at other ways of recording results that are not tables…
Discuss which is the easiest to understand.

Work backwards from a table to an investigation…

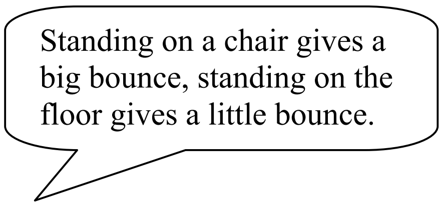
- *How do you know what they did?*
- *What do the different parts of the table tell you?*
- *If you tried this investigation do you think*

PROGRESSION IN CONSTRUCTING AND USING GRAPHS AND CHARTS

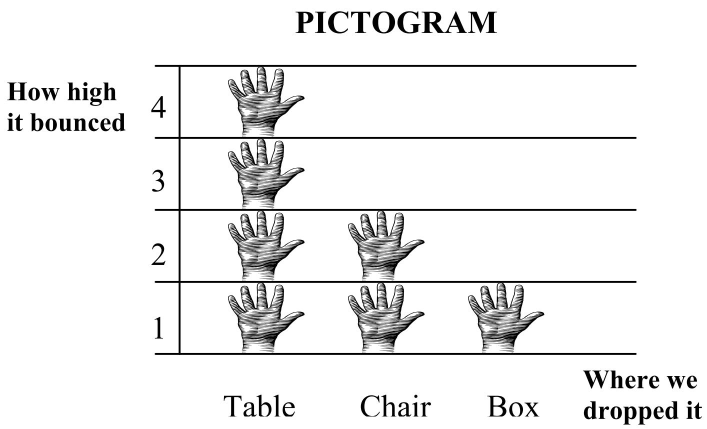
Investigating how the height from which a ball is dropped (independent variable) affects the height of bounce (dependent variable).

Student work sample

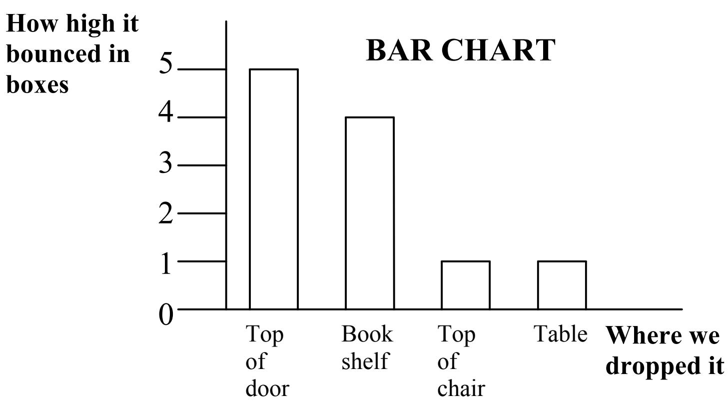
What the student can do…



- Verbal description of result – no graph can be drawn.



- The student measured in hands the height of the bounce having marked the spot on the wall. The correct number of hands have been glued one above the other in the correct column on a teacher-prepared chart.



- The teacher labelled the axes and added the vertical number scale. The student added the drop locations on the horizontal axis and coloured in the correct number of boxes in each column.

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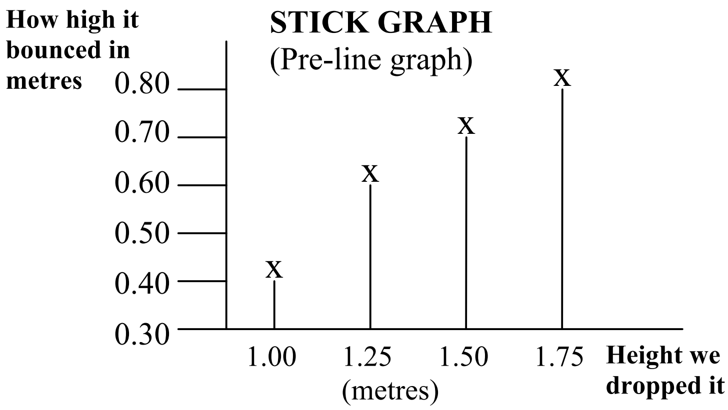
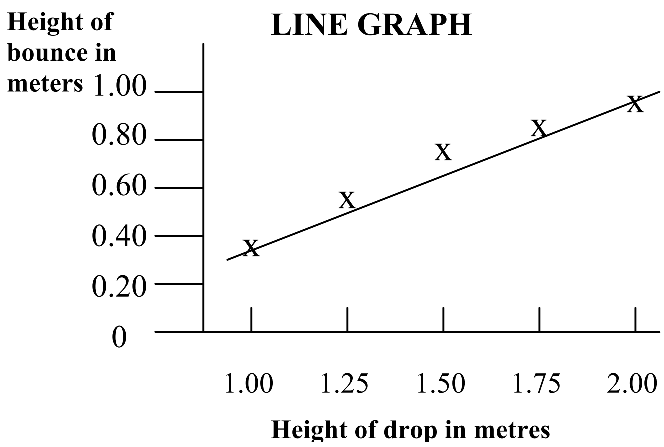


- The teacher helped the student to determine the scale for both axes. The student labelled both axes and then drew the sticks to the correct length using the vertical scale correctly. If the crosses on top of the sticks were joined it would lead into a line graph.



- The student completed the line graph independently – labelling the axes, selecting the scales, and correctly marking the crosses according to the measurements recorded in the table of results. The line of best fit could be used to predict the bounce for any drop within the range of 1-2m.

GRAPHS and CHARTS

Why use graphs and charts?

- ✓ **Graphs and charts help children to see how the independent variable (what was changed) affects the dependent variable (what was measured).**
- ✓ **Graphs and charts present information visually and help to showcase patterns and trends.**
- ✓ **Scientific knowledge and understanding can be enhanced by exposure to patterns and trends.**

Hints…

- ❖ **Constructing graphs is much harder than using them.**
- ❖ **Children need to be taught how to construct and use graphs.**
- ❖ **Students' mathematical understanding should be matched to the complexity of the charts or graphs.**
- ❖ **Younger children will need to have their graphs and charts constructed for them, older children should construct their own.**

- **Computers are helpful for drawing graphs and charts quickly and easily.**
- **<u>Bar charts</u> are helpful when…**
  - **Ordering results (type of floor covering on which cars roll furthest – tiles = best, carpet = worst)**
  - **Comparing results (the car went 50 cm further on the tiles than the carpet)**
- **<u>Line graphs</u> are helpful when…**
  - **you want to determine the relationship between the independent and dependent variables by looking at the direction of the slope (as the height of the drop gets bigger so does the height of the bounce)**
  - **you want extra information (since the slope flattens out I can tell that there is more of a difference in the height of the bounce for lower drops than there is for higher drops)**
  - **you want to predict a result within your data range**
  - **you want to predict a result outside your data range (not as reliable as within your data range)**

<u>Activities to try…</u>

Work back from a graph/chart to the beginning of an investigation.

- ✓ What investigation was performed?
- ✓ How do you know what was changed/measured?
- ✓ How many times was the ball dropped? How do we know?

How many things can you say about this graph or chart?

- 3 surfaces were tried
- It was best on tiles
- The car went 20 cm further on tiles than on wood.

The greater the number of plot points on a line graph – the greater the accuracy. Five points is usually considered enough.

Ask children to predict - by roughly sketching - what sort of graph/chart they will produce. Have them compare the end product with their prediction and ask students to explain the differences.

PROGRESSION IN EXPLAINING RESULTS

Investigating how the angle of a slope affects the number of marbles/how much force is needed to pull a load up a ramp.

Explanation	What the student can do...
We needed more marbles to pull it up when it was a steep slope. I thought we would.	▪ This child has described what happened and has related it back to their original prediction.
My prediction was right because when it was flat we only needed a few marbles to make it go but we needed lots more when it was a steep slope. I think that when the slope was steep it needed more pull to make it go up the ramp.	▪ This child has described what happened, has related it back to their original prediction and has also given a simple explanation of the results.
The columns on my bar chart go up in steps. This tells me that as the ramp gets steeper you need more marbles in the bucket to make it move. I think that more weight in the bucket gives a bigger pull force, which you need when the ram is steeper. We thought that we were going to need 2 more marbles for each extra book but we needed 3 more marbles on the last one.	▪ This child has described a pattern on their bar chart. By talking about the steps they have explained how more weight gives a bigger pull force and so is using their knowledge and understanding to make sense of the results.
My line graph goes up to the right in a fairly straight line. This means that as the angle of the slope gets more, so you need more force to make the tub move. I think that happens because when the ramp is steeper the weight of the tub pulls down more and the ramp doesn't hold it up as much. The force pulling up the ramp must be more than the force pulling down to make it move.	▪ This child has described the pattern in the line graph as well as the relationship between the independent and dependent variables. They have also linked the results to their knowledge that forces can act in different directions.

EXPLAINING RESULTS

Why explain results?

- ✓ **It helps children to make sense of an activity if they are required to use their knowledge and understanding to make sense of the results that they obtain.**
- ✓ **Explaining results helps children to see how their evidence relates to their original question, hypothesis or prediction.**
- ✓ **Explaining results helps children to explain the relationship between the independent (what is changed) and dependent (what is measured) variables.**

Hints…

- ❖ **Children need to look back at their original prediction to see whether their evidence supports it.**
- ❖ **Children need to be taught what to look for in tables, bar charts and graphs so that they can describe patterns and trends.**
- ❖ **Young children do not like to be wrong and sometimes find it difficult to be truthful about their results.**
- ❖ **Children may need to go back to the activity and take further results/observations when they try to explain what happened.**

Activities to try…

Good questions will help children to think about their results.

- Is there a pattern in your results? Describe it…
- What do you think your results tell you?
- Are there any surprises in your results?
- What do you know now that you didn't before you started?
- What have you learned form your investigation?

Enlarge graphs/tables using OHP and then ask specific questions to help the children see the patterns.

- ✓ Which things didn't go rotten?
- ✓ What happens to the pitch of the note as the band gets shorter?
- ✓ Which way does the line slope?

Give challenges which require students to use their results…

- ▪ Can you make a paper spinner that takes 1.5s to fall 2m?

Have students imagine that they are very small and part of the system that they are investigating and then ask them questions.

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PROGRESSION IN EVALUATING INVESTIGATIONS

These students are describing an investigation where they burnt similar sized candles under different sized jars and determined how long each one stayed alight.

Evaluation	What the student can do...
Candles stay burning longer in big jars. It was easy to tell which order they went out in. Results were recorded in a simple table.	▪ This child was asked to decide the order in which the candles went out. She made an evaluation that it was easy to determine this finding.
My results tell me that candles burn for longer in big jars. It was quite hard to get the time exactly right because the candle flickered a bit at the end. Results were recorded in a Bar Chart – burning time in seconds vs jar size.	▪ This child has recognised that in measuring the time taken for the candle to go out it was difficult to be accurate.
These results made me think that the bigger the jar the longer the candle burns. I think this is because there is more air inside big jars. My results are quite accurate but it wasn't always easy to see when the candle went out because the flame flickered at the end. Also, we moved the candle form one jar to the next so by the time we did the last jar it would have burnt down a bit. We used a stopclock to measure the time. I think I would use a digital stopwatch if I did it again because it measures more accurately. Results were recorded as above.	▪ This student has noticed two technical problems (flickering flame and small change in size of candle) with the test. They have also recognised that the quality of the measuring equipment may also have affected the accuracy of the results.
My graph shows that as the volume of air in the jar increases, so the candle burns for longer. I think that the candle needs more oxygen to burn and more air means more oxygen, but it could be that burning makes the air inside the jar move around and that is what blows it out. I don't think this is the reason because the size of the jar wouldn't make much difference to air moving and so the line wouldn't go up like that. I think I could trust these results a lot because we took the average of 3 readings for each jar. We made sure we used the same sized candle and we used a stopwatch which measured in 1/100 sec. We found the volume of each jar by filling it with water and then pouring it into a measuring cylinder but sometimes we spilt a bit so our graph isn't completely accurate. Someone repeating our test would get much the same results. Results were recorded in a line graph of	• This student has offered two alternative conclusions based on the results and evaluated which best fits the results. They have also evaluated the techniques used and explained why they have confidence in their results.

EVALUATING INVESTIGATIONS

Why evaluate investigations?

- ✓ **It encourages students to decide if they believe/have confidence in what their evidence is suggesting.**
- ✓ **It encourages students to look for anomalies in their results and to determine their source/cause.**

Hints…

- ❖ **Young children often find it difficult to evaluate their results as they believe that what happened 'just is'. Older students are better able to cope with uncertainty and may be prepared to undertake more testing to be sure.**
- ❖ **Children may be reluctant to evaluate their results if there is a performance issue at stake such as care is measuring. Rephrase questions so that it's the results that are reviewed – 'Were any bits hard to measure?'**
- ❖ **Evaluation of results from 'living things' investigations are often quite complex because there are likely to be many factors involved.**

Activities to try…

Good questions will help children to evaluate their investigations.

- How difficult was it to measure accurately?
- How much would you trust your results?
- Are there any results that don't seem to fit the pattern? Can you explain why this is?

✓ Ask children to evaluate results from other groups doing the same investigation. Get them to focus on the similarities and differences between the results and try to explain them. They could also offer ways to improve the investigation.

Based on: Goldsworthy, A. and Feasey, R. (1997). *Making sense of primary science investigations.* Hatfield: The Association for Science Education.