Strategies for Assessment of Inquiry Learning in Science

The best investigations are open ended, encourage creative thinking and relate to the content covered. For an assessment it is particularly important to give students criteria that will tell them whether they have achieved their target or what else they have to do to get there.

These criteria can be specifically related to the scientific theory underlying the experiment, the application of scientific methodology or more general criteria relating to team work, communication and problem solving.

The flowing Lava experiment

This experiment encourages students to investigate the speed of lava depending on its heat, viscosity and the steepness of the crater. Students are asked to find their own independent variable and construct the experiment around that. This experiment is particularly suitable to demonstrate the importance of a preliminary experiment

Equipment:

• 30cm or meter ruler
• white tile
• pipette, dropper, spoon and spatula
• different household items of different viscosity
• 50ml glass beaker

Ideally students should be allowed to choose other equipment if they want to but the above was the most used.

Assessment criteria: Scientific Methodology

Often the criteria are divided into different ability groups e.g. Criteria that all students, most or some students should achieve. For this experiment I have used the following:

Level	P Planning	O Observation	A Analysis	E Evaluation
8 *No help given by the teacher*	• Carry out preliminary experiments to inform your plan	• Carry out further calculations using your data (*e.g. calculating rate of reaction*)	• Use secondary data or information to suggest alternate explanations for your data.	• Explain reasons for anomalies and/or variation (size of range bars) in your results
7 *No help from teacher* *No spelling or grammatical errors*	• Use sources of information to help plan the method and risk assessment (Hazcards). • Identify which variables can't be controlled and explain how you will overcome this in your experiment	• Carry out calculations on your own (averages etc.) • Decide on the best way to present your information (line or bar chart) • Choose your own scales (complicated scales)	• Make a conclusion with reference to chemical or mathematical equations • Use graphical quantitative data to explain the pattern seen and indicate how this was worked out on your graph (*e.g. when ..... doubles the ..... doubles as well*) • Communicate your ideas using a full range of scientific terminology	• Explain the reliability of your data by looking at the size of your range bars (systematic error). • Suggest additional data that you could collect to make sure your conclusion is correct (*e.g. testing more IV values*)
6 *Very little help from the teachers* *Headings can be given to help structure work*	• Use scientific knowledge to explain your prediction • Describe how you will make your experiment reliable (repeats and averages, removing anomalous results) • Describe how you will make your measurements accurate (the method you use) and precise (the equipment that you use)	• Draw tables, bar charts and graphs on your own and choose your own simple scales. • Draw range bars (if appropriate) • Draw an appropriate line of best fit on your own	• Describe the patterns seen using two pieces of evidence/data • Correctly identify anomalous results (random error) in your data and graphs • Explain your conclusion using symbols and units where appropriate	• Explain how your improvements will improve the precision and accuracy of your data (equipment) • Explain how your improvements will improve the reliability and or reproducibility of your data (repeats) • Comment on your confidence in your conclusion and give a reason (*e.g. how close are your points to the line of best fit?)*
5 *Some help given by the teacher* *Sentence starters given*	• List ALL equipment, write a full and detailed method, identify all variables and explain a prediction with some scientific knowledge • State the range of measurements you will make (values, intervals) • Write a full risk assessment with precautions	• Calculate averages (excluding any anomalous results) • Draw a results table with headings and units on your own • Plot the points on a line graph (scales given by the teacher)	• Explain your conclusion and patterns in data using one piece of evidence • Explain why you saw the pattern using scientific knowledge • Use the key scientific words and correct units in your conclusion	• Suggest relevant improvements to your method or the equipment you have used THOMAS TALLIS SCHOOL SCIENCE
4 *Frequent help given by the teacher* *Fill in the blanks* *Selecting from a list*	• List most of the equipment needed • Write a method (some key elements may be missing) • Identify the Independent, Dependent and Control Variables • Describe the reason for your prediction • List at least one way you will safe in your experiment	• Record your data in a simple table (no units) • Draw a simple bar chart (scales drawn by your teacher) • Draw a simple line graph (with a lot of help from your teacher)	• Describe any patterns shown in your graph and table • Describe your conclusion • Explain your conclusion using simple scientific ideas	• Describe one problem that you had with your method or equipment • Suggest an improvement to your method with a simple reason. • Describe if your prediction was correct and give a simple reason why (no data needed)
3 *A lot of help is given by the teacher* *Matching exercises*	• State what you are trying to find out • Suggest one control variable • State a simple prediction	• Fill in a results table given to you by your teacher • Draw a simple bar chart of your results (with a lot of help from your teacher)	• With help state a simple pattern • State what you found out (*e.g. ..... was the highest*)	• Suggest one improvement to your experiment • State yes or no if your prediction was correct

(Source: TES)

Possible starter to introduce the investigation

What could we investigate about lava in the class room?

Use the index cards to write 3 things which you could investigate about lava (1 on each card)

Share your idea with a partner

Group up with another pair

As a 4 decide which one would be "best" to investigate (remember we only have the lab to do it) by putting the index card in a diamond 9

Explain why you have agreed on that order.

Example of student experiment set up

Density

The aim of the experiment is for students to find a way to calculate the density of different shapes. This experiment is ideal for assessing more general skills like team work. It is less suitable for assessing science as sometimes students have already covered the topic elsewhere and therefore are aware of the solution. The task for them will then be to explain to their peers how and why it works.

Equipment:

• different shaped objects (Styrofoam shapes, pencil, metal cubes, plastecine shapes etc.)
• different size measuring cylinder, water buckets
• weighing scales (0, 1 and 2 dp)
• rulers

Assessment criteria: General Skills

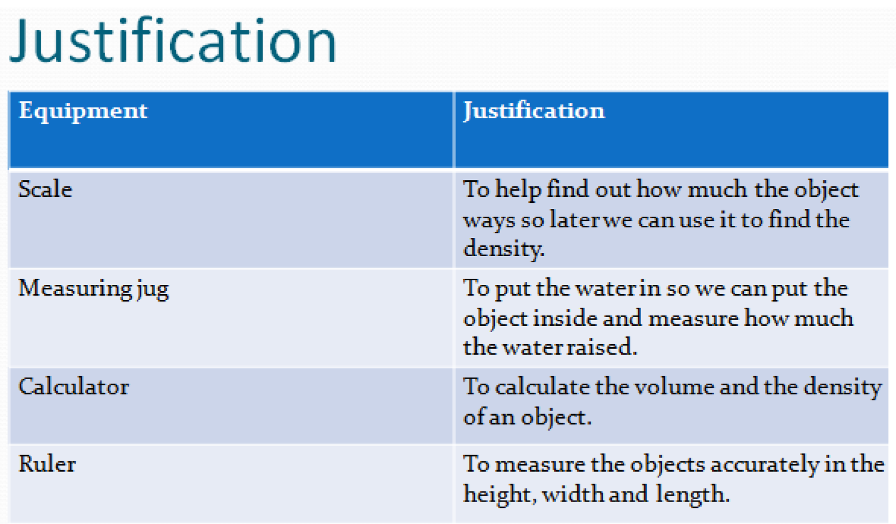
This is more suitable to assess skills needed for communication and team work.

All: contribute to a presentation of your work; identify when moderation is needed to solve a problem

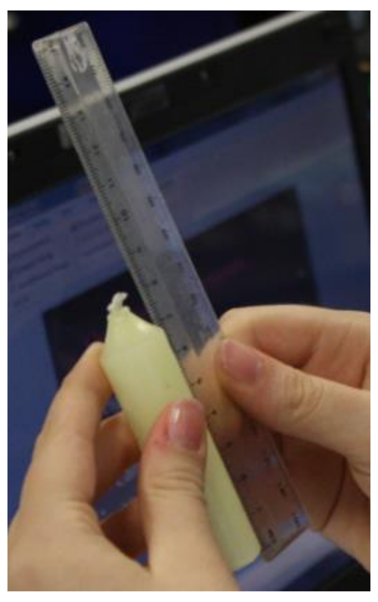
Most: contribute ideas to solve the problem at hand and listen to other ideas

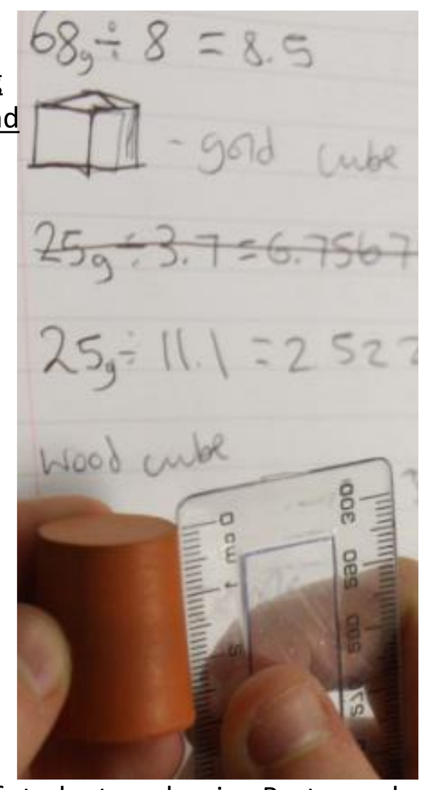
Some: evaluate other people's ideas and develop those further to solve the problem

Example of student work using Powerpoint

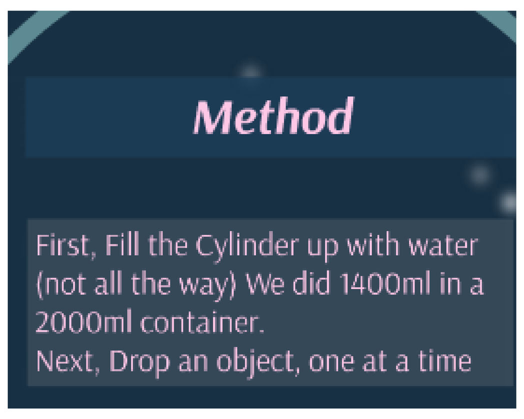


Examples of students solving volume issue by measuring and calculation



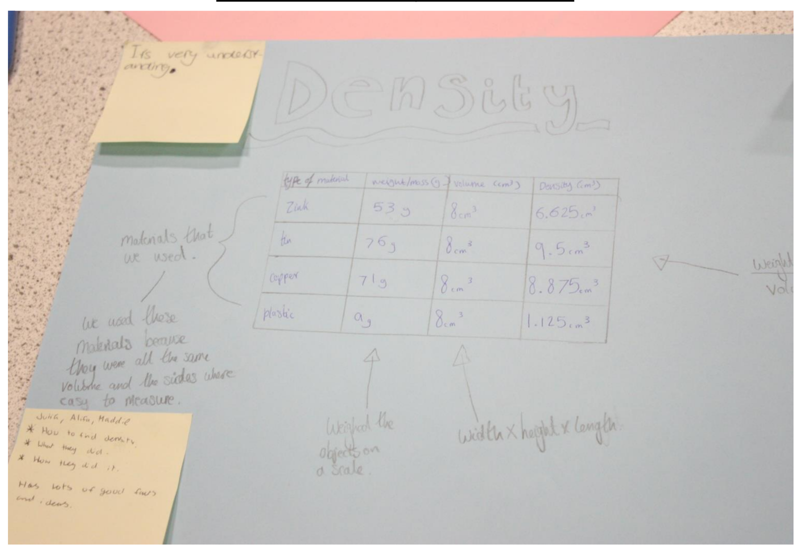


Example of student work using Prezi



Student working out volume of a crucible

Example of student work using Poster and peer assessment on post-it notes



Building a Solar Cooker

This experiment is designed for either problem solving or I have used it at the end of the Heat Transfer topic instead of a formal test. Students had to design a poster to explain how a solar cooker works using the scientific theory of Conduction, Convection, Radiation and Evaporation. However, it would also be ideal to assess team work and communication skills.

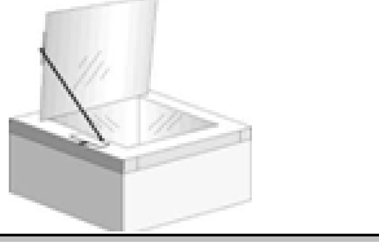
Equipment:

• lamps (substitution of sun)
• silver foil, card, paper, bubble rap or any other insulation material
• rubber bands or Sellotape to secure the insulation material
• glass beaker, Styrofoam cup and water
• thermometer or data loggers

Assessment criteria: Scientific Theory

Often the criteria are divided into different ability groups e.g. Criteria that all students, most or some students should achieve. For this experiment I have used the following:

Task:
Show how the energy is transferred from the light source to the water.
Describe how the energy is transferred.
Use particle diagrams to show what is happening.

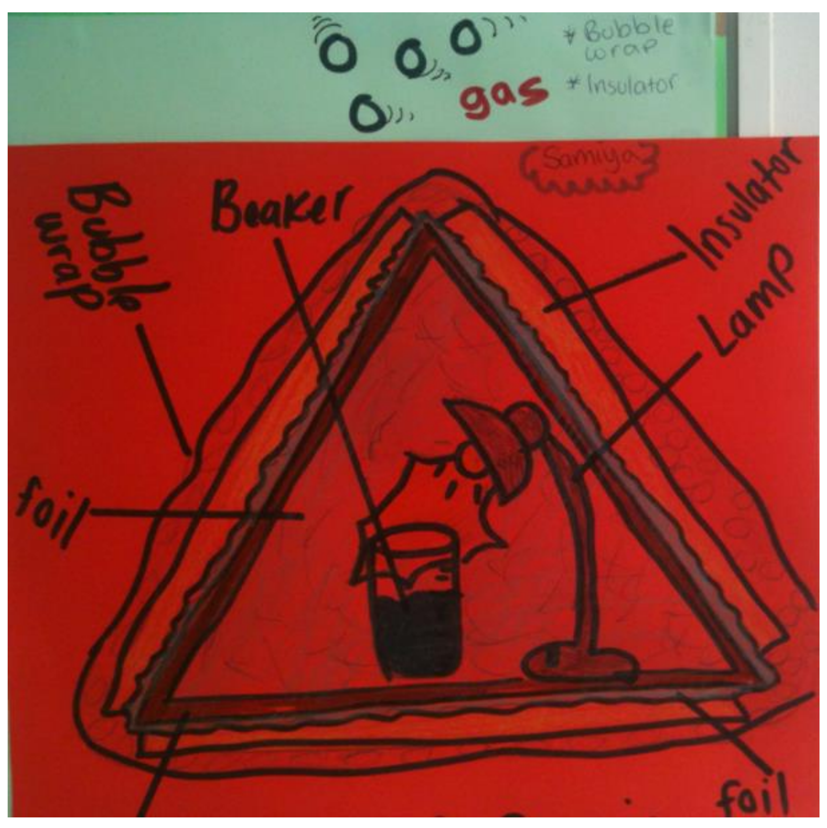


Key words: conduction, conductor, convection, energy transfer, evaporation, heating, insulator, radiation

Level ladder: What is your target level? Use the level ladder to help you reach it:

To get level	You might have:
5 all	• Drawn or used a diagram of their solar cooker • Used the key words metal, glass, water, insulator and conductor to label the diagram. • Drawn arrows to show heat energy transfers from the light source to the water. • Stated why energy is transferred from light source to water. • Identified energy transfers by conduction, convection and radiation. • Used a simple particle diagram to explain conduction.
6 most	• Drawn or used a diagram of their solar cooker. • Described the diagram using the key words metal, glass, water, insulator and conductor. • Used simple energy transfer diagrams to show heat energy transfers from the light source to the water. • Explained why energy is transferred from the light source to the water. • Used particle diagrams to explain conduction and convection.
7 some	• Drawn or used a diagram of their solar cooker. • Described the diagram using the key words metal, glass, water, insulator and conductor. • Used particle diagrams and energy transfer diagrams to show heat energy transfers from the light source to the water. • Explained in detail why energy is transferred from light source to water. • Used detailed scientific knowledge and understanding to compare energy transfer by conduction, convection, radiation and evaporation.

Example of student poster



The Ear Model

This experiment gives students the chance to be very creative. It links the scientific idea of the structure and function of the ear to a 3D model. It is ideal to assess whether students truly understand the link between sound waves and mechanical waves in the ear.

Equipment:

• cake spring form or plastic cups
• rubber bands
• ping pong balls or other floating item
• bendy straw (got to be bendy!)
• Sellotape
• cling film
• container to hold water

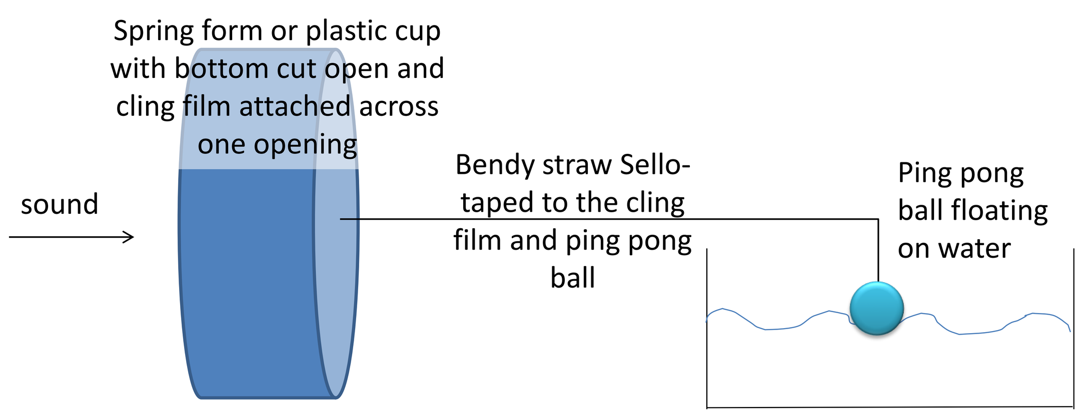
Assessment criteria: Modelling

The only assessment criterion is that it has to be a "working model", i.e. It has to demonstrate how the sound waves are converted to waves on the water that then stimulate other receptors. To differentiate it you could use the following:

All: model shows all structures of the Ear covered in lesson; identify positives and negatives about all models

Most: all members of the group can explain the function of the structures

Some: model demonstrates the functions of the structures; evaluate other models



Possible solutions

Pupil responses

Generally students react very positively and that is unrelated to their ability. In my experience especially low and high ability boys and high ability girls respond best to this kind of approach. I have experience both in the co-educational and girls school sector. I found that the open tasks really stretch the high ability learners and does not frustrate the low ability ones because even if they dislike Science everyone can achieve as long as they are willing to take a risk and just try it out. It is an incredible motivational tool to give low ability students more confidence as there is often no right or wrong answer. This is why it is important to keep the investigation as open as possible and the assessment criteria as general as possible. However, in my experience some insecure girls prefer the security of written instructions out of fear they could write down incorrect things. It also helps if students can relate to the context of the investigation. They then tend to see the "point" or the "bigger picture".

Assessment options

Students can be assessed on their work in various ways. Here are a few examples that I have used regularly:

• A very valuable tool of mine is **teacher questioning**. This allows me to assess especially the very quiet students that would otherwise be very reluctant to answer questions in front of the class. Furthermore it allows me to identify and address individual misconceptions which would otherwise not be possible.
• **Filming or audio records** are a great help as they enable me to have evidence of students' responses. This method is also invaluable for self-reflection on my own questioning techniques.
• If those experiments are done for the purpose of assessment I often ask students to record it in their books as either a **formal write up** (lava investigation) or in the form of posters or Powerpoints (Density and Solar cooker). This is particularly useful if they are to do a similar task again so that they can learn from their mistakes and avoid them next time.
• An alternative to the formal write up is a **port folio** style record of a student's work. I have used this especially with weaker more homogenous groups where I gave them a specific focus. Each of their changes to their method or evaluation including choosing a graph was documented. This also allows the students to choose which bit they want assessed.
• **Peer assessment** often takes place throughout the experiment. This allows students to reflect on their work and helps the weaker students to improve on their explanation before final submission. This also promotes interpersonal skills. However students need to be carefully trained. As you can see in the above example (Density) the peer assessment is rather vague and would not allow for big improvements. It does take a while but once established it works really well.