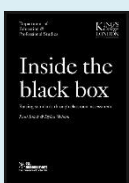


## Approaches

### Diagnostic questions

There is, as Black and Wiliam noted in *Inside the Black Box*, a body of firm evidence that effective use of formative assessment can have a powerful effect on student learning. But what makes assessment truly formative? And what is the difference between formative assessment and a diagnostic question?

#### Different types of assessment



“

There is a body of firm evidence that formative assessment is an essential feature of classroom work and that development of it can raise standards. We know of no other way of raising standards for which such a strong *prima facie* case can be made on the basis of evidence of such large learning gains.

”

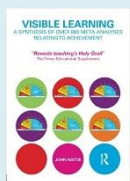
Paul Black and Dylan Wiliam, *Inside the Black Box* (1998)

Assessment provides information about students' learning. This evidence can be used for different purposes.

In **summative assessment**, the information is used to make a judgement about learning, for example to give students a grade or to put them in a rank order. It can also be used to give evidence about the quality or impact of teaching, and can be linked to school accountability measures. However, summative assessment does not usually provide more information about students' knowledge and understanding than a grade, mark or level.

When the evidence provided by an assessment is used to help a teacher work out what a student thinks, this is **diagnostic assessment**. For example, it could provide evidence of what ideas a student can recall from previous teaching, or whether they hold particular misunderstandings that could be barriers to progression.

Assessment is **formative** if it provides feedback to the learner *and* to the teacher which is then used to help decide what to do next. Both summative and diagnostic assessments can be used in formative ways. The key to this is using the evidence gained to contribute directly to the learning process by informing what should happen in response. Hence, it is not the format of an assessment but the use to which it is put that makes it formative.



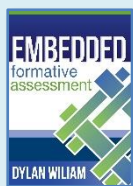
“

It was only when I discovered that feedback was most powerful when it is from the *student to the teacher* that I started to understand it better. When teachers seek... feedback from students as to what students know, what they understand, where they make errors, when they have misconceptions – then teaching and learning can be synchronised and powerful.

”

John Hattie, *Visible Learning* (2008)

## Diagnostic questions



Sharing high quality questions may be the most significant thing we can do to improve the quality of student learning.

Dylan William, *Embedded Formative Assessment* (2011)



Often, a learning objective will require students to *know* or *understand* a scientific idea, but we cannot gauge whether or not a student knows or understands anything unless we collect evidence. Assessments provide evidence of learning, usually because a student can or cannot select or provide an answer that indicates they understand the scientific idea that was the subject of the learning objective.

A diagnostic question goes further, providing greater insight into what students are thinking. This can include an indication of how confident they are in the answer they have chosen, or their ability to provide a scientific explanation for their answer.

A good diagnostic question can also provide evidence of common misunderstandings (and problematic conceptions derived from everyday life) that are held by the student, which could prevent progression in developing the required level of scientific understanding.

## Embedding diagnostic questions into teaching

Diagnostic questions can be used formatively, and most effectively, in lessons when the questions are short and focussed on a single idea. Multiple-choice formats are a useful way of making diagnostic questions that are quick to complete, highly focussed, and very powerful. A range of useful formats is presented and discussed in the appendix of this article.

Multiple-choice questions can be used at the start of a teaching episode to check prior knowledge, part way through to check progress, or at the end to check whether students have grasped the idea sufficiently to move on. They can be displayed at the front of class and students asked to indicate their support for each answer using a voting system. Alternatively, students can complete the question individually, or in pairs or small groups to encourage discussion and metacognition.

## Revealing misunderstandings

In the diagnostic question shown on the right, option D is the best explanation of melting. It indicates understanding of the particle model of matter and how it helps us explain changes of state.

The other options are not so obviously wrong that they can be dismissed easily – if they were, the question would lack diagnostic power. Options B and C reveal common misunderstandings (that particles are embedded in the bulk substance, and ascribing properties of the bulk substance to the particles from which it is made, respectively). Option A is an explanation that applies ideas about particles, but lacks complete understanding.

**Explaining melting**

These pictures show wax that has melted on heating.

→ heating →

Which option **best** explains the change from solid to liquid?

A The particles move apart.

B The wax around the particles melts.

C Solid particles (hard) change to liquid particles (runny).

D The particles start to move about from place to place, keeping close together.

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The diagnostic questions in the *Best Evidence Science Teaching (BEST)* collection have been developed from research evidence on common and everyday misunderstandings that can prevent progression towards scientific understanding, and come complete with teacher notes that describe the underlying research. There are a number of readily available books that describe misunderstandings commonly held by students (for example: Driver, Guesne and Tiberghien, 1985; Driver et al., 1994; Allen, 2014), in addition to a wealth of papers published in peer-reviewed journals.

### How to respond – what next?

Diagnostic questions are a key means of identifying students' difficulties in science, and it is important that the evidence they provide about students' thinking is used formatively to adapt subsequent teaching. But deciding exactly what to do next in response to the information provided by a diagnostic question can be difficult.

Every diagnostic question in the *Best Evidence Science Teaching (BEST)* collection is provided with teacher notes that describe what the answers reveal about students' misunderstandings, and suggest approaches for responding. Most diagnostic questions in the BEST collection are paired with **response activities** that are specifically designed to challenge misunderstandings and help overcome barriers to conceptual development.

You can read more about responding to diagnostic questions in our approaches article entitled 'Response activities'.

### Acknowledgement

Article written by Alistair Moore (UYSEG). The author would like to thank Robin Millar and Mary Whitehouse, formerly of UYSEG, for their many years of work and presentations on formative assessment and diagnostic questions, which provided much of the inspiration for this article.

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## Appendix: Useful formats for diagnostic questions

### Simple multiple choice


- Students must select what they think is the correct or best answer from several options. The options can be presented in words or as pictures.
- Provides a quick way to gather evidence of learning. Can be completed individually, in small groups to encourage discussion, or with a whole class using a voting system.
- The 'distractors' (the incorrect options) are developed from research on common misunderstandings, to reveal whether students hold these ideas.

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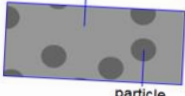
### Empty space

Imagine you could see the particles in this jar of methane gas.

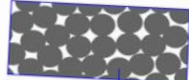


Which diagram best matches what you would see?


A



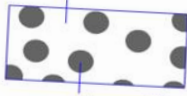
B



C



D



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**Two-tier multiple choice**

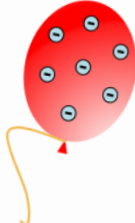
- Provides more information about students' understanding than a simple multiple choice question.
- In the first tier, students must select what they think is the correct or best answer from several options.
- In the second tier, students must select the correct or best explanation for the answer they chose in the first tier.

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**Positive or negative?**

This balloon was given a negative charge by rubbing it with a wool jumper.



1. Why does this balloon have a negative charge?

a What electric charges are there on this balloon?  
Put a tick (✓) in the box next to the correct answer.

A Only negative electric charges

B Some negative electric charges and the same number of positive ones

C Some negative electric charges but more positive ones

D Some positive electric charges but more negative ones

E No electric charges

b How would you explain your answer?  
Put a tick (✓) in the box next to the best answer.

A Negative electric charges have been added

B Negative electric charges have been taken away

C Positive electric charges have been added

D Positive electric charges have been taken away

E No electric charges have moved

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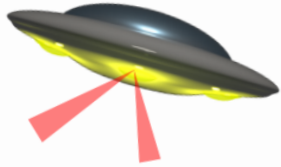
**Confidence grid**

- Provides more information about students’ thinking than a simple multiple choice question.
- Students must evaluate each statement in turn, rather than homing in on the correct answer.
- For each statement they must indicate their confidence in ruling-in or ruling-out the answer, by selecting one option from:
  - I am **sure** this is right
  - I **think** this is right
  - I **think** this is wrong
  - I am **sure** this is wrong

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### Alien invasion!



Imagine that an alien spaceship is firing its death rays at Earth!

- The death rays will destroy everything that is made of cells.
- Things that are not made of cells will not be affected.

Look at the statements in the table. Some are right and some are wrong.  
Tick **one** box for each statement.

Statements	I am sure this is right	I think this is right	I think this is wrong	I am sure this is wrong
1 People will be destroyed.				
2 Brick walls will be destroyed.				
3 Plants will be destroyed.				
4 Very small organisms will <b>not</b> be destroyed.				
5 Dead bodies will be destroyed.				
6 Bacteria will be destroyed.				

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**Talking heads**

- An alternative format for a simple multiple choice question, in which the answer options are presented in speech bubbles.
- Students may feel less intimidated, and less hesitant to rule-out some answers, if they are being “said” by people – especially if the “speakers” are represented as young people of the students’ age.
- This format can make it easier to include distractors comprising controversial statements, points of view, or statements concerning morals or ethics.

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### Silence on the island

Read the following article, which is taken from a news website:


**Crickets fall silent to survive**

Crickets are insects that make a chirping noise by rubbing their wings together. The noise can often be heard on summer nights.

However, back in 2013 scientists on an island in Hawaii found some crickets that no longer made the chirping noise. This was due to a change in the crickets’ genome.

The scientists think that not chirping helps the crickets to avoid a predator.

Now most of the crickets on the island are silent.



A male cricket

Four friends discuss the article.

Alex

It was very clever of the crickets to fall silent to avoid the predator.

Artie

The crickets evolved so that they could survive!

Karen

Natural selection caused the change in the crickets’ genome.

Matt

I think the change in the genome was random. It’s just coincidence that it was helpful.

1. Who do you agree with?
2. How would you correct each person you don’t agree with?

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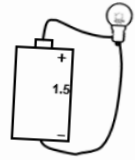
**Focused cloze**

- A particular type of ‘fill the gaps’ (cloze) activity, in which there are only two words from which the student can choose to fill the gaps.
- The words provided to fill the gaps are a pair of words that are commonly confused, such as breathing/respiration, melts/dissolves, or current/voltage.
- By providing lots of gaps but only two words, and by carefully constructing sentences that avoid grammatical cues as to which word fits in each gap, the activity thoroughly tests students’ understanding of the difference between the two words.

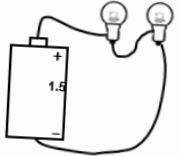
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### Current or voltage?



Circuit with one bulb



Circuit with two bulbs

**To do**  
Fill in the gaps to describe what happens in these circuits.  
You should only use the words **current** and **voltage**.

**Circuit with one bulb**  
The battery has a ..... marked on it. This tells me how hard the battery can push ..... around the circuit.  
To make the bulb brighter I can use a battery with a bigger ..... This will push more ..... through the bulb.

**Circuit with two bulbs**  
If I add another bulb, it will make the ..... smaller. This is because it is harder to push ..... through two bulbs than one.  
To make two bulbs as bright as one bulb was, I will need to use a bigger .....

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### Explanation story

- Probes students' ability to answer a question that requires a longer answer.
- Students must choose the correct or best statement in each row, and then join their choices together to make a complete answer or explanation that can be read from the top row to the bottom.
- The higher reading load may not suit all students, but the format guides students through the process of constructing a longer, multi-step answer to a question.

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### Explaining needs

Animals and plants need some things to keep them alive.

1 **Animals need air.**  
Some of the statements in the boxes below link together to explain why.

Join the correct boxes with arrows to make a complete explanation.  
Start at the top.

1 Air is a mixture of different substances.

2 Animals need carbon dioxide from the air. Animals need oxygen from the air. Animals need water vapour from the air.

3 It is used by the cells that make up the body. It is only used by cells that make up the lungs. It is used by the body but not by cells.

4 It is used in a chemical reaction to break down molecules of sugar from food.

5 This provides energy for life processes such as movement... This uses energy from life processes such as movement...

6 ...and does not make any waste. ...and makes carbon dioxide as waste.

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