

# Using assessment to change teachers' practices and views

*Robin Millar*



# Why is assessment so important?

Because there is a very big difference between what is taught and what is learned.

“If what students learned as a result of the instructional practices of teachers were predictable, then all forms of assessment would be unnecessary; student achievement could be determined simply by inventorying their educational experiences. However, because what is learned by students is not related in any simple way to what they have been taught, assessment is a central—perhaps even *the* central—process in education.” (p. 254)

(From: Wiliam, D. (2010). What counts as evidence of educational achievement? The role of constructs in the pursuit of equity in assessment. *Review of Research in Education*, 34, 254-284.)

### Three stories:

1. Tools and instruments, not general principles, stimulate change
2. The error of dealing with assessment as an afterthought
3. Improving clarity and coherence: a model for integrating assessment and curriculum planning

Some reflections on what I think I have learned

# Story 1: The EPSE research network (1999-2006)

## Research Network: Towards Evidence-based Practice in Science Education (EPSE)

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# EPSE Research Network: Aim

To improve our understanding of the relationship between research and practice in the teaching of a curriculum subject such as science  
- in order to enhance the impact of research on practice and policy

# Four EPSE projects

Project 1: Using diagnostic assessment to enhance science teaching and learning

Project 2: Developing and evaluating research evidence-informed teaching sequences

Project 3: Teaching pupils 'ideas-about-science': is there 'expert' consensus about what to teach, and how can we best do it?

Project 4: Science teachers' and educators' views of the influence of research on their everyday work

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# The problem

- A lot of research has been carried out on learners' ideas about the natural world, in many countries.
- This shows that many students have ideas which differ from the accepted ones.
- Many of these ideas are resistant to change.
- This research has had little systematic impact on how these difficult topics are taught, or on science teaching more generally.



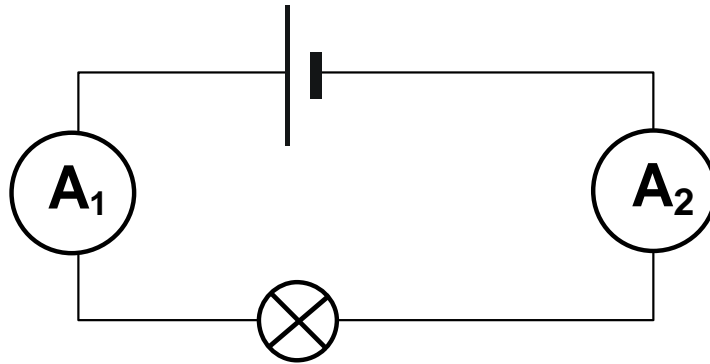
# Strategy

- Rather than trying to communicate to teachers the **findings** of research,
- provide teachers with **tools** used by researchers, so they can collect better evidence of their own students' learning.
- Monitor how teachers use these tools.
- Review with them what they find, how they react, what changes it stimulates.

# What we did

- Worked with a group of teachers, teacher educators and CPD providers
- Developed large banks of diagnostic questions for three science topics (forces, electric circuits, particle model of matter), at levels appropriate to 11-16 year-old students
- Used questions developed by researchers as a starting point where possible
- Wrote new ones where necessary
- Tested and revised questions, and reworked them into forms that could be more readily used during teaching

In this circuit, the bulb is lit.



(a) What can you say about the readings on the two ammeters?

*Tick ONE box (✓)*

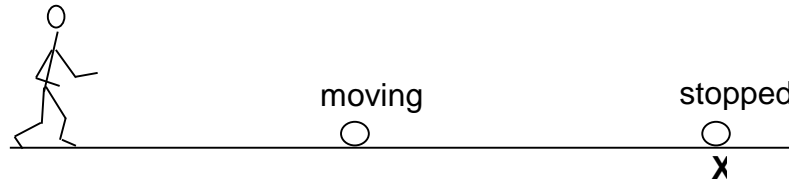
- The reading on ammeter A<sub>1</sub> is bigger.
- The reading on ammeter A<sub>2</sub> is bigger.
- The readings on the two ammeters are the same.

(b) How would you explain this?

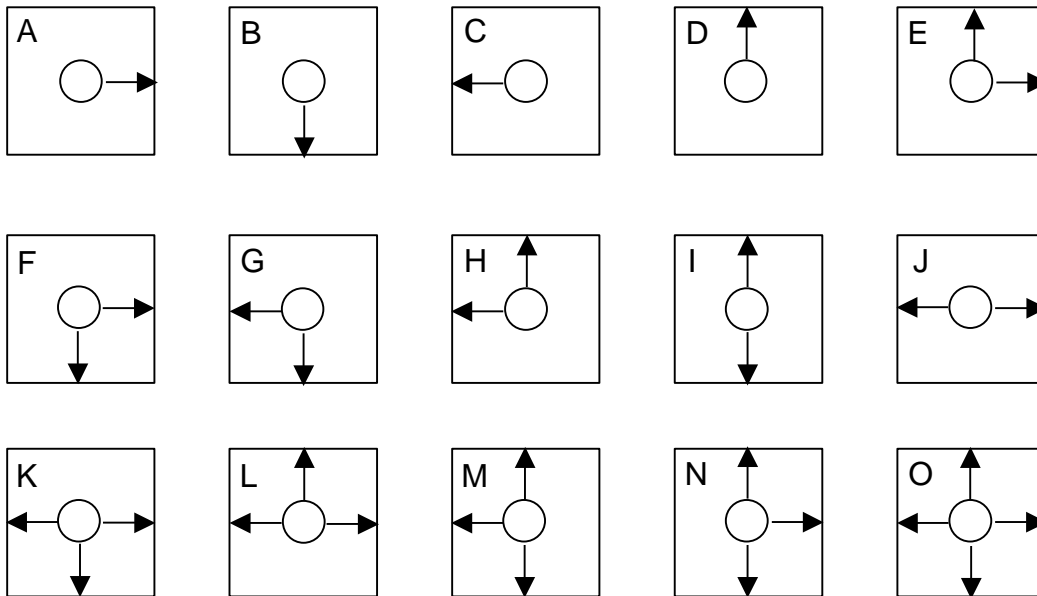
*Tick ONE box (✓)*

- The current is the same all round the circuit.
- Some** of the current is used up by the bulb.
- All** of the current is used up by the bulb.

Andy kicks a football across a level pitch. It rolls to the point X and then stops. Think about the football when it is in the middle and still moving.



(a) The pictures below show the forces acting on the football while it is moving. The arrows just indicate the direction of the forces, not their size.



Which picture best shows the forces acting on the moving football?

# Throwing a ball in the air

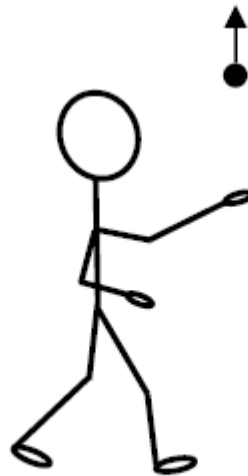
Kim throws a tennis ball straight up into the air for a short distance and catches it when it comes down again.

In the diagrams below, the ball is **on the way up**.

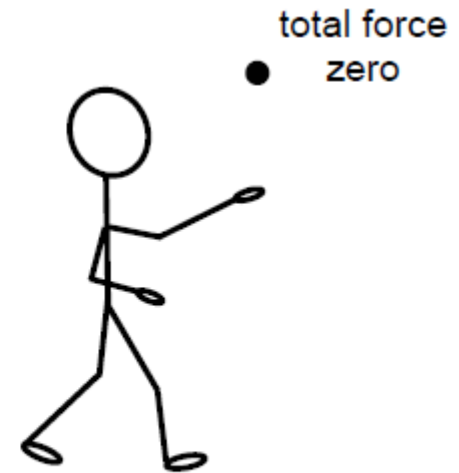
Which diagram best shows the **total force** on the ball?



**A**



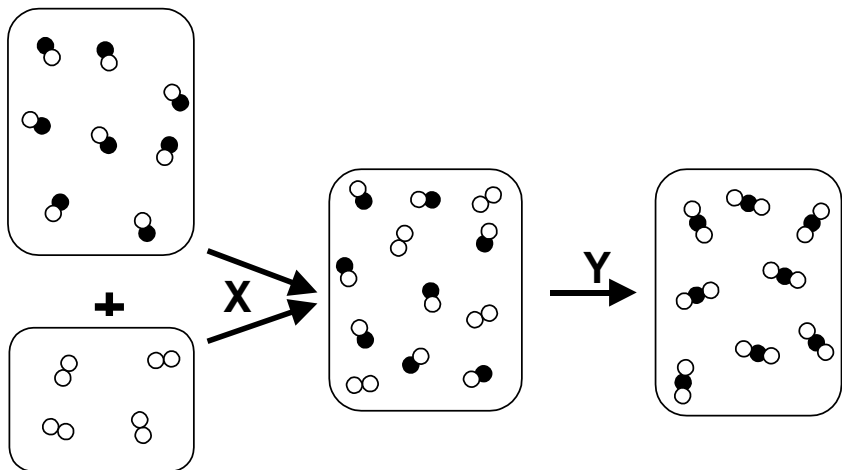
**B**



**C**

In the diagrams below, the atoms of different elements are represented by the symbols ○ ● .

The diagrams represent the changes which occur when two gases are put together.



(a) Is change X a chemical change?

Tick ONE box (✓)

yes

no

Explain your answer: \_\_\_\_\_

\_\_\_\_\_

(b) Is change Y a chemical change?

Tick ONE box (✓)

yes

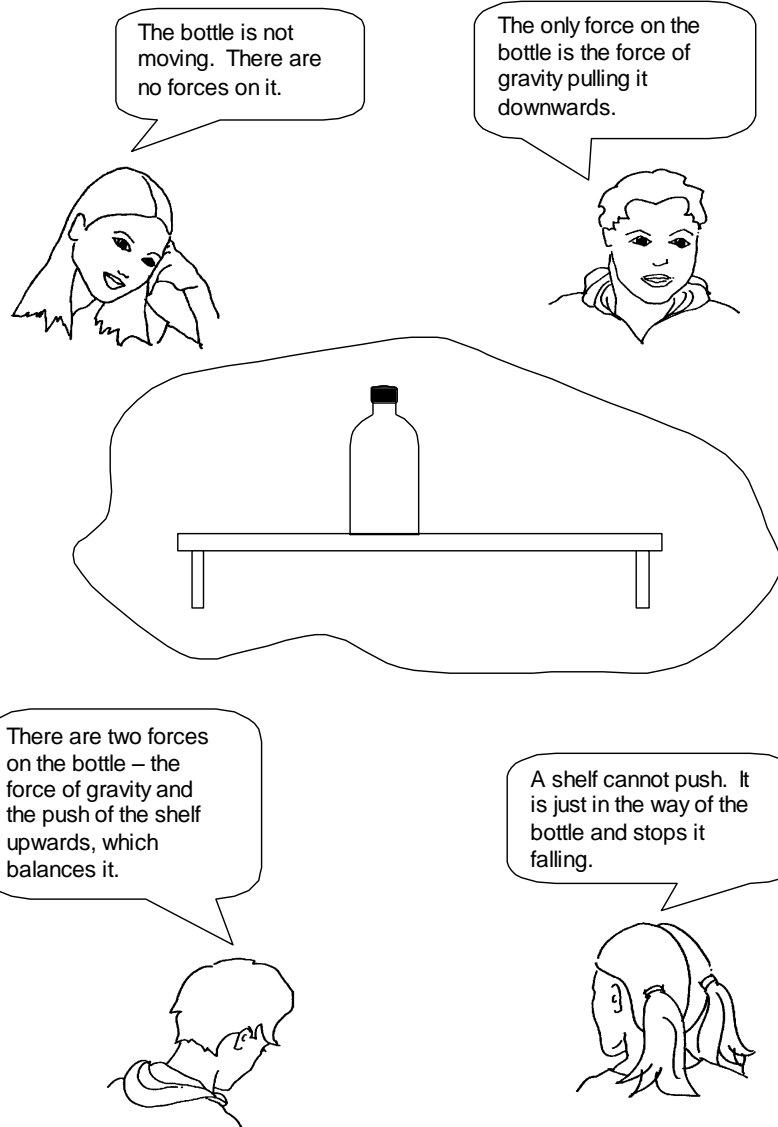
no

Explain your answer: \_\_\_\_\_

\_\_\_\_\_

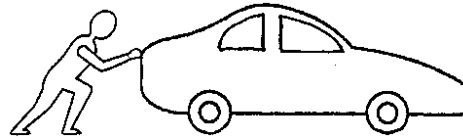
## Bottle on a shelf

A bottle is sitting on a shelf. Some pupils are talking about the forces acting on the bottle.




A driver is pushing his car which has broken down.

The car is moving along slowly.



In the boxes below, you are asked to mark the forces acting on each object involved in this situation.

Represent forces:

- by drawing arrows to show the direction of each force, 
- with the **length** of the arrow representing the **size** of the force.

Label each force to indicate what it is.

(a) On this diagram, mark all the horizontal forces acting **on the car**.  
(Ignore any vertical forces.)



(b) On this diagram, mark all the horizontal forces acting **on the driver**.  
(Ignore any vertical forces.)



(c) On this diagram, mark all the horizontal forces acting **on the ground**.  
(Ignore any vertical forces.)





# Two studies using the diagnostic questions

1. Assess students' understanding of some key ideas at ages 11, 14, 16
2. Monitor how teachers use banks of diagnostic questions in their own teaching, and the effects of this

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# Study 2: Outline

- Gave some teachers a bank of diagnostic questions on one science topic, to use as they wished in their teaching.
- Brief training session, suggesting the use of questions as stimuli for small-group discussion rather than as individual written-response items.
- Monitored how the teachers used the question bank over a school year, and the effects of this on their actions and thinking.

# Sample and data

- 10 schools (8 secondary, 2 primary)
- 23 teachers
- 16 interviewed in depth (some twice)
- Questionnaires completed by all
- Collected samples of pupils' work

# Teachers' views and comments

# First impressions

T1: [when I first saw these questions] I thought, oh good, questions. Because we're so short of good questions.

We needed a new test ... so I looked in the pack and ... just pulled a selection out.

# Second thoughts

T8: I flicked through them and thought, oh yeah, they look like tests, you know, tons of it. Then when you look at it, you think, oh, no, no. And they were so interesting to use. The use for me is opening up the discussion, thinking about how they're actually perceiving things, that was the interesting bit.

# Feedback to the teacher

T14: ... without the questions, I might never have been aware of how widespread particular misconceptions were.

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T3: However we teach a topic, pupils always have misconceptions. But if they're more open about them and we can talk about them, then you're likely to challenge the misconceptions and move them forward. So, I think that's what it did, brought them out into the open a bit more.



# 'On task' discussion

T10 (in an unsolicited email):

... question 5, about the motion of a football, proved to be a real problem for them. ... the question as to whether or not there was a forward force provoked a heated debate.

What I got - from one EPSE question - was an entire unplanned lesson with pupils fully engaged and making real progress with their thinking.

# Across the ability range

T10: With the upper sets I expected them to want to talk about these things .. But the bottom, that Set 5, were talking about it just as well ... listening to each other, they actually talked about things, I thought, very well.

# Changing teaching

T9: Oh it has [influenced my teaching], without question, in a beneficial way. I mean if I was the sort of teacher that was always prompting discussion then it probably wouldn't have been a necessity, I wouldn't have needed that. But I did need that and it's helped, without question it's helped. I'm having more discussions in class than previously, which is a good thing.

# Teaching across the sciences

T15: I've taken an approach with this that has been much more the approach that I would take with chemistry ... much more open, you know, rather than me just giving information and working through things, a much more sort of interactive, discursive approach, which is a style of teaching I prefer. I think it's a better way of going about things, but perhaps I haven't been as confident in physics before to risk it. .... I come up with ideas myself for biology and chemistry, but I find it much more difficult to come up with them for the physics area.

# Beginning teacher

T13: I'm not very experienced and, especially with forces and things .... - when you have the force opposing motion, what would happen to the speed and so on - I tend to find that I more or less give it to them in a way, because trying to get them to discuss it, to bring it in, I find it quite hard. Whereas it was done for us, for them to discuss. And I was able to do the diagrams on the board and they came up and did the forces and arrows and things. We came to it together, which is a lot better. I thought like I'd actually done proper teaching then.

# Summative assessment

I: You didn't use any of the questions for an end of topic test, summatively?

PT2: No, I didn't do that because, in a sense, by using them way I did, I'd found out what I needed to know.

# Staff development

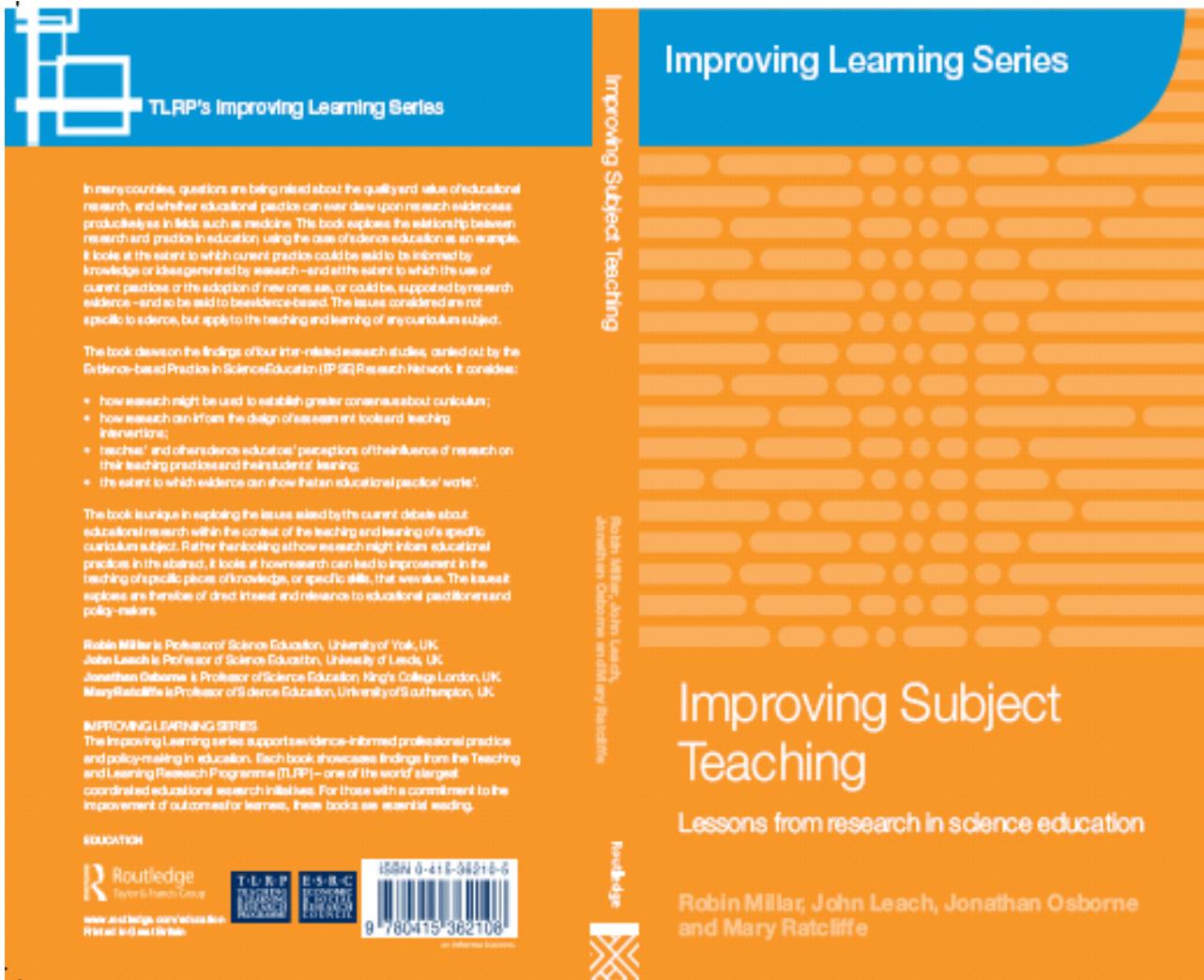
T2: ... it stimulated debate like I've never seen before in terms of the ways in which you understand things, and how you grasp things and how you learn things, really. ... we've never had time to sit down and actually try and think about how children learn. Some of the younger staff were saying, 'well, you know, how do you learn this? I can't remember when I actually suddenly grasped this.'

# Conclusions (what did I learn?)

- Change is stimulated more effectively by providing teaching materials and instruments than by disseminating general principles
- Questions are particularly effective tools for stimulating teachers' actions and thinking
  - Teachers see questions as familiar tools
  - Low entry threshold (using a question can take only a few minutes)
  - Data from your own classes is more likely to make you think about how effective your teaching is



# For more detail



Millar, R., Leach, J.,  
Osborne, J. &  
Ratcliffe, M. (2006).  
*Improving subject  
teaching. Lessons from  
research in science  
education.*  
London: Routledge.

## Story 2: Learning from experience

# A lesson from curriculum development

(or 'How to take four years to find out something you should have known from the outset')

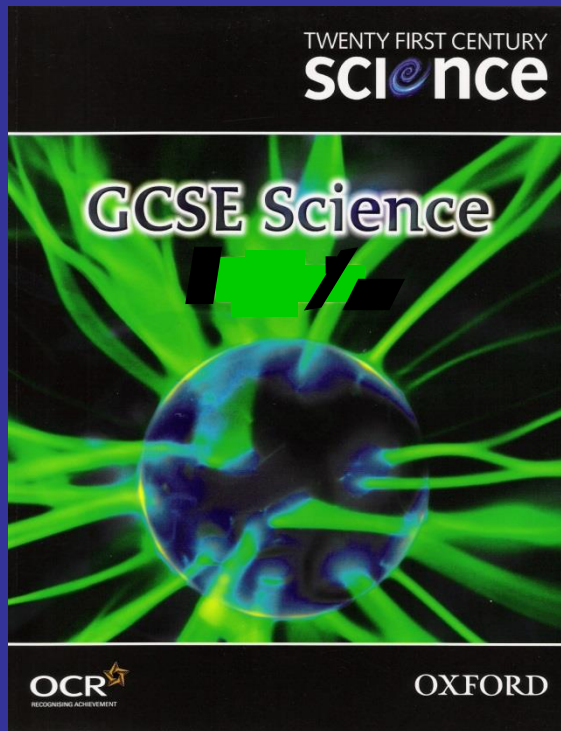
# Beyond 2000 report



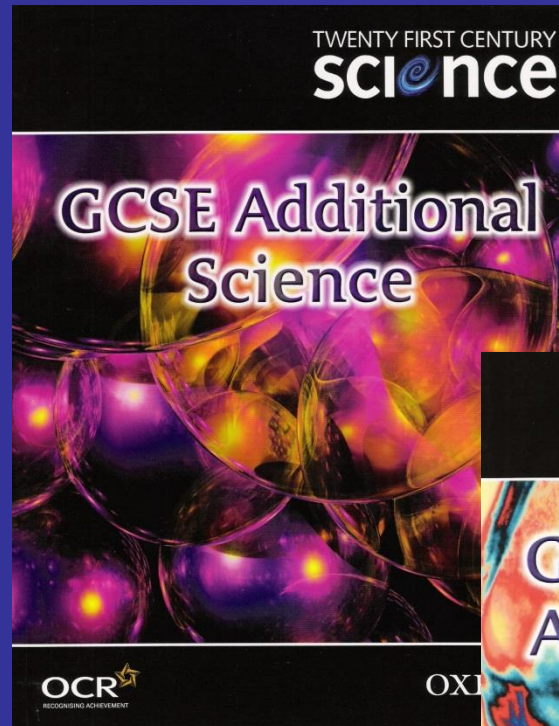
(Millar & Osborne, 1998)

- “The science curriculum from 5 to 16 should be seen primarily as a course to enhance general ‘scientific literacy’.”
- How can we achieve this, whilst also catering for the needs of future specialists?

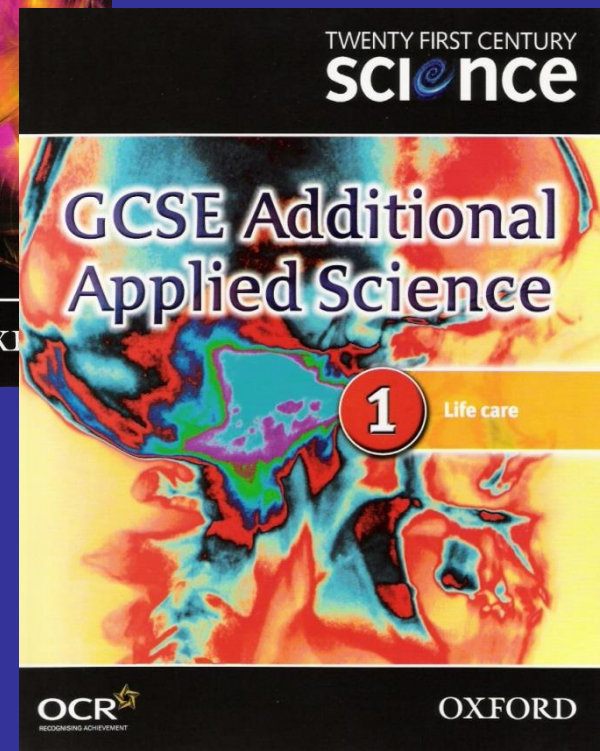
# Twenty First Century Science



Core: for all students



Additional options: for some students





# *Twenty First Century Science*



The 'core' course,  
taken by all  
students, with a  
scientific literacy  
emphasis

# Scientific literacy: The central aim

- To help students to access, interpret and respond to science, as they encounter it in everyday life outside the classroom
- So how do you design a course to do this?
- Our answer: alongside science content, we need also to develop students' 'ideas about science'



# Which 'Ideas about science'?

1. Data: know that all data (observations and measurements) are uncertain; how to assess and deal with this
2. Correlation and cause: variables, controlling variables, comparing groups, sample size and composition, correlation  $\neq$  cause
3. Evidence and explanation: distinguish data (evidence) from explanation; recognise that all explanations are to some extent tentative
4. The important role of the scientific community: critical scrutiny of claims, peer review
5. Risk: interpret data on risk; evaluate specific actions in terms of risks and benefits
6. Science and decision-making: recognise issues raised by specific applications of science (technical, economic, social, ethical); cost-benefit analysis; criteria for evaluating arguments and views



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So what exactly do we want students to learn?



# Evidence and explanation

	Ideas about science
3.1	A scientific explanation is a conjecture (a hypothesis) about how data might be accounted for. It is not simply a summary of the data, but is distinct from it.
3.2	An explanation cannot simply be deduced from data, but has to be thought up imaginatively to account for the data.
3.4	Scientific explanations are tested by comparing predictions made from them with data from observations or measurements.

Clearer – but more is needed

# Evidence and explanation

	Ideas about science	A student who understands this ..
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# Evidence and explanation

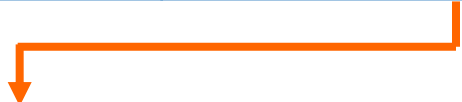
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3.2	An explanation cannot simply be deduced from data, but has to be thought up imaginatively to account for the data.	can recognise where imagination might have been involved in the development of an explanation
3.4	Scientific explanations are tested by comparing predictions made from them with data from observations or measurements.	can draw valid conclusions about the implications of given data for a given explanation .....

This is how the course specification was presented for all of the 'Ideas about Science'.

... but this still was not enough

# More specific guidance is needed

	Ideas about science	A student who understands this ..
3.1	A scientific explanation is a conjecture a hypothesis) about how data might be accounted for. It is not simply a summary of the data, but is distinct from it.	<p>can identify statements which are data and statements which are all, or part of, an explanation</p> <p>can recognise data that agree, or conflict, with an explanation</p>



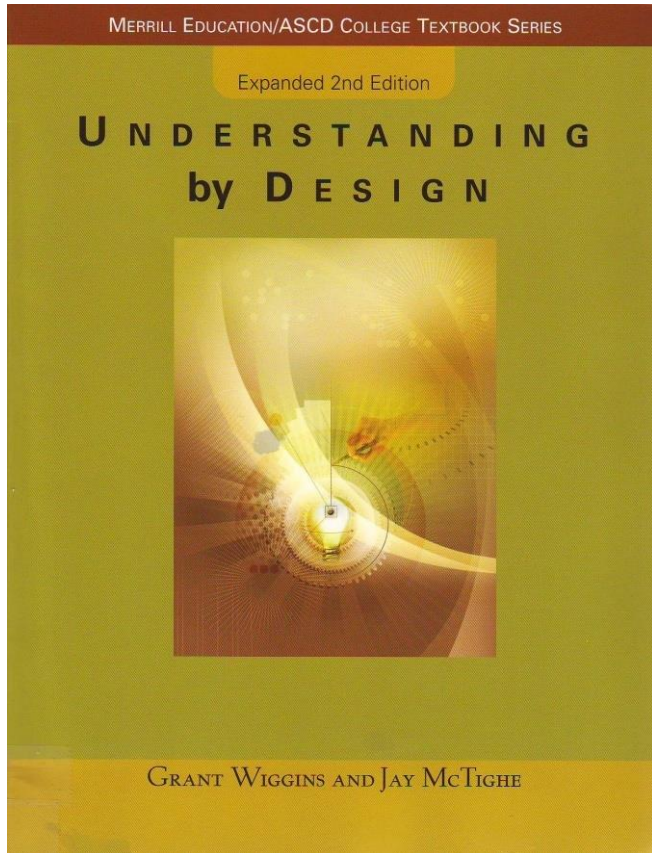
3.1a	Provide a list of statements. Ask student to identify those which are data and those which are explanations, or parts of explanations.
3.1b	In a given paragraph, identify a sentence that reports data; identify a sentence that states a possible explanation.
3.1c	Provide an explanation. Present a list of pieces of data. Ask student to say whether each is consistent with the explanation, conflicts with it, or is neutral.
3.1d	Present information about a situation, and several statements about it. Ask student which can be asserted from the data, and which are inferences that go beyond it.

# What we learned from this

- How a component of the curriculum is assessed has a major influence on how it is taught
- If it is new or different, you can never provide teachers and examiners with too much guidance
- You also need to have thought it out fully yourself
- Unless the guidance includes specific examples, it is likely to be misinterpreted
- And the ways in which it is misinterpreted can seriously undermine your initial intentions
- Next time, give a lot more attention and time to assessment



# The idea of 'backward design'



Wiggins, G., & McTighe, J. (2006). *Understanding by design*, 2<sup>nd</sup> edn. Upper Saddle River, NJ: Pearson.

- When designing a course, or teaching module
  - **Begin** by writing a set of questions and tasks that would provide you with evidence that a student had (or had not) achieved each of the intended learning outcomes
  - **Only then** start to plan activities and a teaching sequence to help students learn what they need to learn to do such questions and tasks.

## Story 3

# The *York Science* project

# York Science: Aim

- to develop materials to improve science teaching and learning at lower secondary level

# York Science: The basic strategy

- Shift the focus of teachers' attention from what is taught to what is learned
  - from the **intended curriculum** (what teachers are supposed to teach) to the **attained curriculum** (what students learn)
- Help more science teachers to use assessment formatively
  - By providing a large collection of good assessment items
  - Using formats that enable teachers to develop more assessment items for themselves
- Facilitate and encourage a 'backward design' approach to curriculum planning

# Why focus on assessment ?

1. Assessment clarifies the intended learning objectives of a lesson, or programme, or course.

“... by its very nature assessment *reduces ambiguity*. The fifth-grade mathematics standard for many states requires students to be able to compare two fractions to find the larger, but when we assess, we have to decide which pairs of fractions should be included and which should not.

... In fact, the choice of the fractions to be compared makes a huge difference to the rate of student success” (p. 254)

(From: Wiliam, D. (2010). What counts as evidence of educational achievement? The role of constructs in the pursuit of equity in assessment. *Review of Research in Education*, 34, 254-284.)

# The problem of vague specifications

‘It is easy enough to assert that students should *know* something, *appreciate* something, *understand* something, or have a *conceptual understanding* of something. But such words are so ill defined that they are almost meaningless. For example, what exactly would one have to do to assess whether a student *knows* calculus? ... Similarly, what would one have to do to assess whether a student *appreciates* the need to conserve natural resources?’

The difficulty with such vague specifications is that they don’t adequately specify what tasks a student should actually be able to perform.’ (p. 12)

From: Reif, F. (2008). *Applying cognitive science to education: Thinking and learning in scientific and other complex domains*. Cambridge, MA: The MIT Press.

# Teaching for understanding

- “Many students do not really understand potential difference.”
- “Students have difficulty in understanding Darwin’s theory of evolution by natural selection.”
- “Most of my students don’t really understand the difference between a physical and a chemical change.”

What, exactly, would we want students to be able to do for us to judge that they ‘understood’ things like these?

What would count as good evidence?

- “Many students are not able to design and carry out a scientific investigation.”
- “My students’ cannot construct a sound scientific argument to support their viewpoint.”
- “Many students do not understand that scientific knowledge is not fixed, but is open to revision.”

Again, what would count as good evidence that students have learned what we want them to learn?



# Why focus on assessment?

1. Assessment clarifies the intended learning outcomes.
  - Unless you can say how you could judge whether a student has achieved a given outcome or not, you haven't defined the outcome clearly enough (and probably don't really know what it means).
2. Clarity about intended learning outcomes leads to teaching that is much better focused.
3. This provides a context in which feedback, to teachers and to students, can make a significant difference to learning outcomes.

# The *York Science* development process

For every major strand of science, identify the main ideas we want to introduce at each stage  
**A curriculum 'map'**

For every teaching unit (based on this 'map'), write down the story we want to tell to students  
**Narrative**

For each part of the Narrative, identify the things we want students to do to provide evidence of their learning  
**Evidence of learning statements**

For every *Evidence of learning statement*, write a question or task that could provide evidence of learning  
**Evidence of learning items**

Writing the **Narrative** identifies the essential ideas and the links between them.

Writing **Evidence of learning statements** clarifies the **Narrative**.

Writing **Evidence of learning items** clarifies the **Evidence of learning statements** – and perhaps also the **Learning intentions**.

**Not a linear process, but an iterative one.**

# Step 1: 'Map' the topic

## A curriculum 'map' for *Radiation*

<i>Stage</i>	<i>Content</i>
<b>KS1</b>	Sources of light (lamps, flames, the Sun, etc.). Darkness is the absence of light.
<b>KS2 (lower)</b>	A shadow is formed when an object stops some of the light from a source.
<b>KS2 (upper)</b>	Light travels in a straight line from a source (indefinitely unless something gets in its way), getting fainter as it goes. Opaque, translucent and transparent objects and materials. <del>Using a simple model of light rays as fine beams of light, to explain and predict the position and shape of shadows.</del>
<b>KS3 (lower)</b>	General radiation model: a disturbance travelling out from a source, getting weaker as it goes, because it is spread over an ever-increasing area. Light is an example of radiation.  Interaction of light with matter: transmission (goes straight through), absorption (makes the absorber slightly warmer), scattering (bounces off in many directions). We see a luminous object when light from it enters our eye. We see a non-luminous object when light scattered from it (diffuse reflection) enters our eye (light travelling from a source cannot be seen until it hits an object and is reflected).  White light can be separated into a set of colours (a spectrum). The effect of coloured filters. Three primary colours of light: the effect of mixing coloured lights and viewing objects under different colours of light. Mixing coloured pigments (paints). The human eye as a sensor: three types of detector for different colours  The existence of invisible radiations beyond the ends of the visible spectrum: infrared and ultraviolet. Emission of infrared by all objects; amount and colour dependent on temperature. Absorption/emission dependent on surface colour and texture of absorber/emitter.
<b>KS3 (upper)</b>	Reflection of light at a very smooth plane surface (mirror, shiny metal, liquid surface). Using the ray model of light: <ul style="list-style-type: none"> <li>• Formation and location of an image in a plane mirror.</li> <li>• Formation of an image by a pinhole.</li> </ul> Refraction of light at a plane boundary between two transparent media. Convex lenses: bringing a parallel light beam to a focus. How the human eye works. Recognise use of lenses in spectacles, cameras, microscopes and telescopes to modify the path of light (no explanation at this stage of how this occurs).
<b>KS4 (core)</b>	Wave model of radiation: transferring energy and information with no bulk transfer of matter. Light shows the properties of reflection, refraction, diffraction and interference; it behaves like a wave.

## Step 2: Write the 'narrative'

The first part of a narrative on the topic 'Light and sound':

### PLC1 The source-radiation-receiver model of 'interaction at a distance'

Some objects can affect others at a distance by emitting *radiation* which travels from one object (the *source*) to another (the *receiver*), through the material or the space (the *medium*) between them. Radiation spreads out from a source in all directions, unless its path is blocked by an *opaque* object, causing a shadow region. Its effects get steadily less the further it goes, because it is spread over an ever-increasing area, and because it may be gradually absorbed by the medium it is travelling through. When radiation strikes another object, it may go straight through (*transmission*), bounce off (*scattering* or *reflection*), or be stopped (*absorption*) – or a combination of these. When radiation is absorbed, it is not stored in the absorber and cannot be later re-emitted as the same sort of radiation. Usually its only effect is to make the absorber slightly hotter. Light and sound are examples of radiation.

# Step 3: State the learning intention(s)

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Learning intentions		
Students should:		
<ul style="list-style-type: none"> <li>understand and be able to use the source-radiation-receiver model of 'interaction at a distance'</li> </ul>		

# Step 4: Say what would provide evidence of learning

Learning intentions	Evidence of Learning Statements	
Students should:	Students will be able to:	
<ul style="list-style-type: none"> <li>understand and be able to use the source-radiation-receiver model of 'interaction at a distance'</li> </ul>	<ul style="list-style-type: none"> <li><u>identify</u>, in a given situation, the radiation source, the receiver of radiation, and the medium through which radiation is travelling.</li> </ul>	
	<ul style="list-style-type: none"> <li>explain and predict the shapes and sizes of shadows (cast by point sources)</li> </ul>	
	<ul style="list-style-type: none"> <li>explain why a source of light looks dimmer (or the sound from a source gets fainter) the further you are away from it</li> </ul>	
	<ul style="list-style-type: none"> <li>use the radiation model to explain familiar phenomena and events and make predictions</li> </ul>	
	<ul style="list-style-type: none"> <li>identify evidence for specific aspects of the radiation model</li> </ul>	
	<ul style="list-style-type: none"> <li><u>explain</u> what happens when radiation is absorbed: (i) to the absorber; (ii) to the radiation.</li> </ul>	
	<ul style="list-style-type: none"> <li>explain and predict the shapes and sizes of shadows (cast by extended sources)</li> </ul>	



# Step 5: Write questions and tasks that could elicit this evidence

Learning intentions	Evidence of Learning Statements	Evidence of Learning items
Students should:	Students will be able to:	
<ul style="list-style-type: none"> <li>understand and be able to use the source-radiation-receiver model of 'interaction at a distance'</li> </ul>	<ul style="list-style-type: none"> <li><u>identify</u>, in a given situation, the radiation source, the receiver of radiation, and the medium through which radiation is travelling.</li> </ul>	
	<ul style="list-style-type: none"> <li>explain and predict the shapes and sizes of shadows (cast by point sources)</li> </ul>	PLC1.7 Shadows PLC1.8 Making shadows
	<ul style="list-style-type: none"> <li>explain why a source of light looks dimmer (or the sound from a source gets fainter) the further you are away from it</li> </ul>	PLC 1.1 Night vision PLC1.2 Long distance sound PLC1.3 Using a light sensor PLC 1.4 Investigating light
	<ul style="list-style-type: none"> <li>use the radiation model to explain familiar phenomena and events and make predictions</li> </ul>	PLC1.6 Foggy day
	<ul style="list-style-type: none"> <li>identify evidence for specific aspects of the radiation model</li> </ul>	PLC1.5 Evidence of radiation
	<ul style="list-style-type: none"> <li><u>explain</u> what happens when radiation is absorbed: (i) to the absorber; (ii) to the radiation.</li> </ul>	
	<ul style="list-style-type: none"> <li>explain and predict the shapes and sizes of shadows (cast by extended sources)</li> </ul>	

# Some sample *Evidence of learning items*

- from a range of topics



# Simple multiple-choice

Imagine you go into a cupboard under the stairs and close the door. There are no windows and the door is a very tight fit.

You switch off the light.

After sitting there for a while, what will you be able to see?



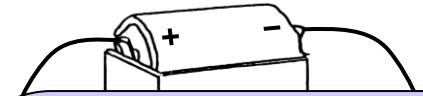
- A** After a while, you will be able to see everything, but very dim.
- B** The only thing you will see is the cat's eyes shining.
- C** You will see the mirror shining dimly, but everything else will be dark.
- D** You won't be able to see anything at all, no matter how long you wait.

**Ali:** Positive and negative charges come out of the two terminals of the battery. They meet at the lamp, and this makes it light.

**Ben:** Electric charges come out of one end of the battery, carrying energy. They travel along the wire. When they reach the bulb, they transfer their energy. The used charges travel on through the wire, back to the other end of the battery.

**Des:** The battery transforms chemical energy into electrical energy. This is then transformed into light energy by the bulb.

**Cath:** The wires and the battery are full of electric charges all the time. They are free to move. The battery makes them all move round together. Their motion through the bulb filament makes it get hot.



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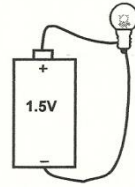
the students believe

you imagine it?

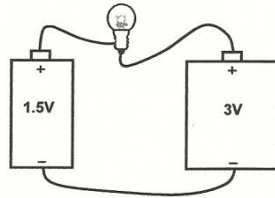


# Two-tier multiple choice

This bulb lights when it is connected to a 1.5V battery.



A 3V battery is then connected into the circuit, like this:



(a) What happens to the bulb now?

- A It is lit – and brighter than before.
- B It is lit – similar brightness as before.
- C It is lit – but a lot dimmer than before.
- D It is not lit.

(b) How would you explain this?

- A The two batteries together add to 4.5 V.
- B The two batteries together add to 1.5 V.
- C Current cannot pass through a battery in the wrong direction.
- D The bulb is connected to the positive terminal of both batteries, so there is no current through it.

Teachers report that two-tier MC questions stimulate more discussion in student groups than single-tier followed by 'Explain your answer'.

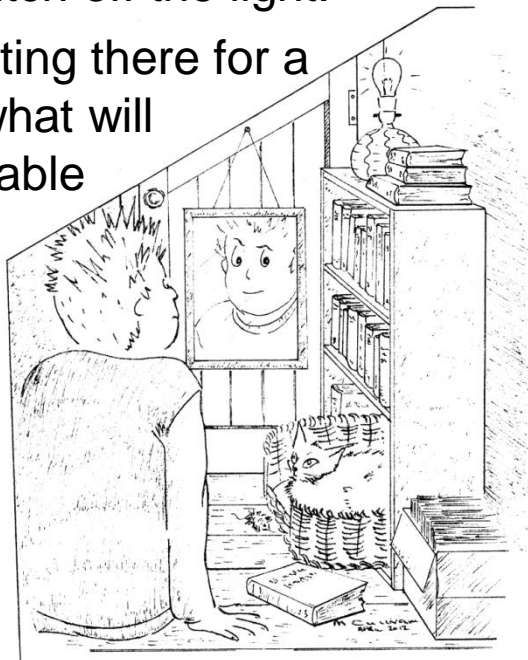
# Confidence grid

## In the dark

Imagine you go into a cupboard under the stairs and close the door. There are no windows and the door is a very tight fit.

You switch off the light.

After sitting there for a while, what will you be able to see?



	I am sure this is right	I think this is right	I think this is wrong	I am sure this is wrong
<b>A</b> After a while, you will be able to see everything, but very dim.				
<b>B</b> The only thing you will see is the cat's eyes shining.				
<b>C</b> You will see the mirror shining dimly, but everything else will be dark				
<b>D</b> You won't be able to see anything at all, no matter how long you wait				

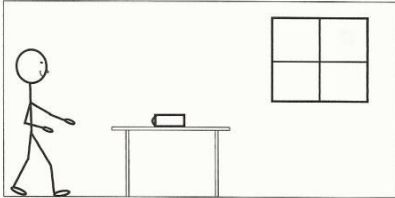
# Explanation story

LC2 How we see  
LC2.5 Seeing an explanation

YORK SCIENCE  
Light and colour

## To do

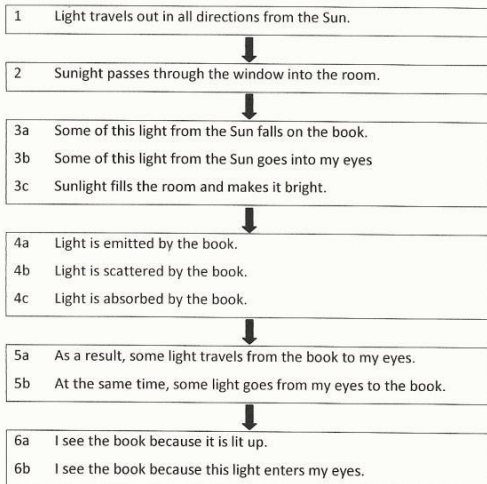
Imagine you are in a room lit by sunlight and you are looking at a book on the table.



The statements in the boxes below link together to form an explanation of how you see the book.

Some boxes contain more than one statement. In each of these boxes, pick the statement that you think is **correct and fits into the whole explanation**. Indicate your choice by putting a line through the other statement(s) in the box.

Continue until you have chosen one statement from every box, to produce a complete scientific explanation for how you see the book.



Essentially, this is a complex multiple-choice item

.... but the parts are related, so the item provides evidence of understanding of the whole 'story'.

# Explanation story: alternative layout

1. Light travels out in all directions from the Sun.

2. Sunlight passes through the window into the room.

3a. Some of this light from the Sun falls on the book.

3b. Some of this light from the sun goes into my eyes.

3c. Sunlight fills the room and makes it bright.

4a. Light is emitted by the book.

4b. Light is scattered by the book.

4c. Light is absorbed by the book.

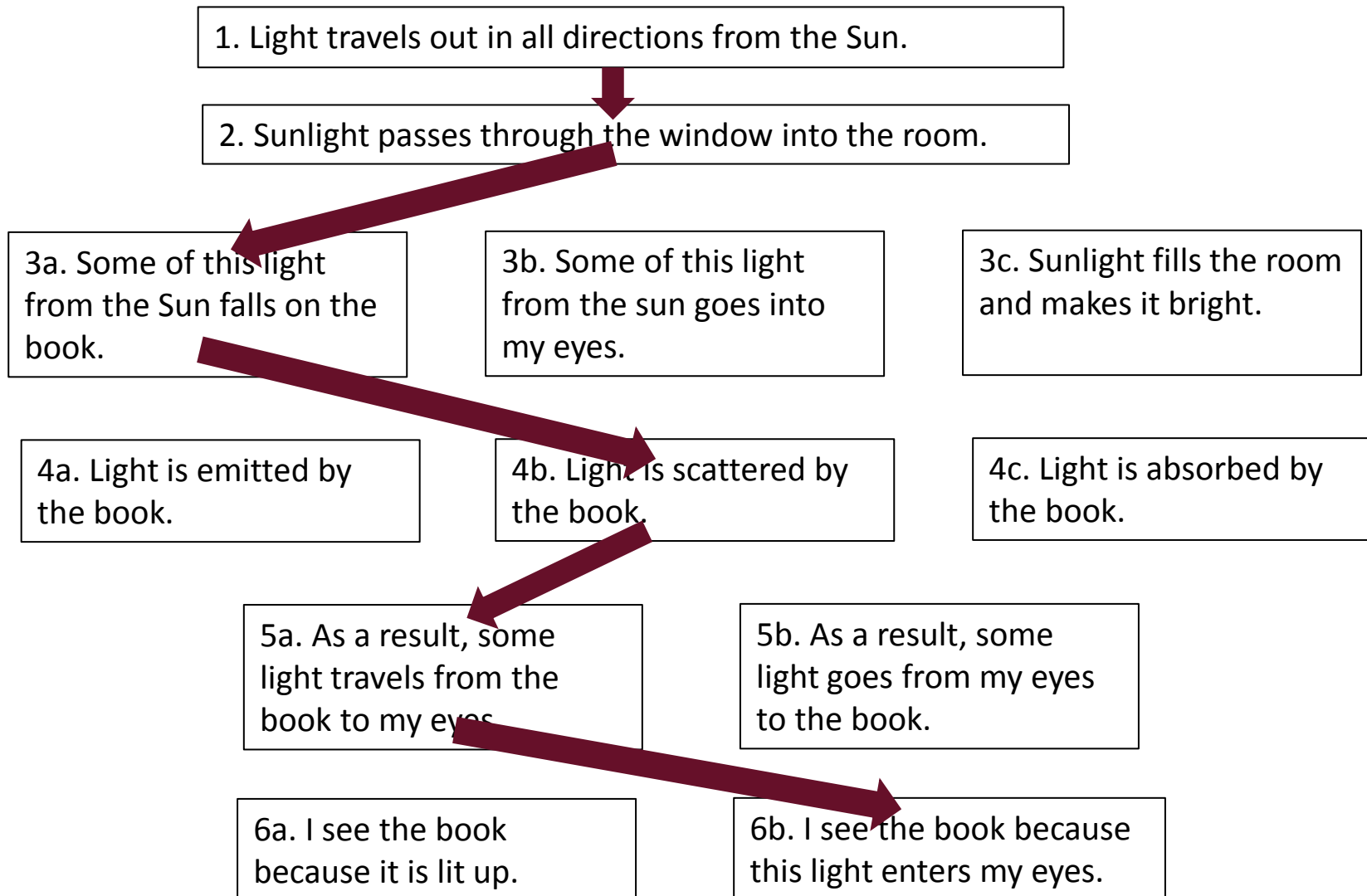
5a. As a result, some light travels from the book to my eyes.

5b. As a result, some light goes from my eyes to the book.

6a. I see the book because it is lit up.

6b. I see the book because this light enters my eyes.

# Explanation story: alternative layout



# Predict-explain-observe-explain

## Purpose of this practical task

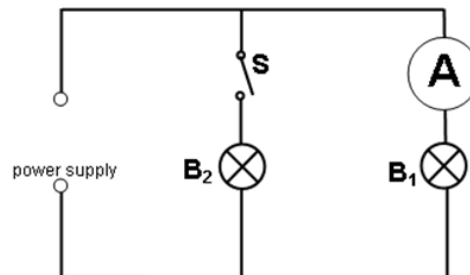
To find out what happens to the current in branches of a circuit.

Set the power supply to 3 V.

Connect the circuit as shown.

Leave switch S open.

Bulb  $B_1$  should be lit, and there should be a reading on the ammeter



## Predict

What do you think will happen to the reading on the ammeter, and the brightness of bulb  $B_1$ , when switch S is closed?

Ammeter reading .....

Brightness of  $B_1$  .....

## Explain

Explain the thinking behind your prediction.

.....  
 .....

**Now close switch S and see if you were right.**

## Observe

Describe what happens

.....  
 .....

## Explain

Now that you have seen what happens, can you explain your observations? (If your prediction and explanation earlier were right, just say so – no need to write it again!)

.....  
 .....



# Using a model

## The liquid state

The box below contains some statements about the particle model of a liquid.

All the statements are **correct**.

In a liquid:

- A The particles are very closely packed together.
- B The particles are not rigidly bound to their neighbours.
- C The particles are not arranged in a regular pattern.
- D The particles vibrate and jostle around.
- E If you heat a liquid, the average speed with which the particles vibrate gets bigger.

Which of the statements above help to explain each of the following?  
Write a letter (or letters) on the line to show your answer.

- (a) Liquids flow easily and can be poured. \_\_\_\_\_
- (b) Liquids are difficult to compress. \_\_\_\_\_
- (c) Above a certain temperature, a liquid boils and turns into a gas. \_\_\_\_\_

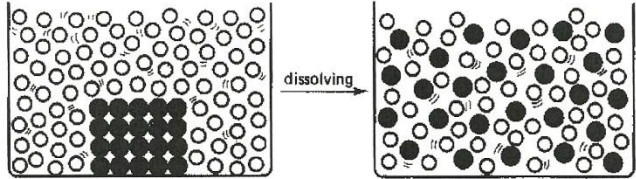
More complex  
selected-response  
item.

Emphasis on using a  
model, not on recalling  
it.

# Evaluating a representation

**Pictures of dissolving**

This diagram from a textbook illustrates the particle model of a solid dissolving in a liquid:



State three ways in which you think the diagram is a **good picture** of a solid dissolving in a liquid:

- 1 \_\_\_\_\_
- 2 \_\_\_\_\_
- 3 \_\_\_\_\_

State three ways in which you think the diagram is **not an accurate picture** of a solid dissolving in a liquid:

- 1 \_\_\_\_\_
- 2 \_\_\_\_\_
- 3 \_\_\_\_\_

Constructed-response, but quite quick to interpret responses.

Provides insights into students' understanding of the model which the representation is trying to illustrate.

Can be applied to many textbook illustrations.

# Analysing text

## Theories of vision

Read the short story below about how scientists reached agreement on how we see.

Since ancient times people have wondered how we see. Some of the ancient Greek philosophers thought that our eyes send out light rays. If a ray hits an object, we see it. Others thought that we see an object when light comes from it and enters our eye.

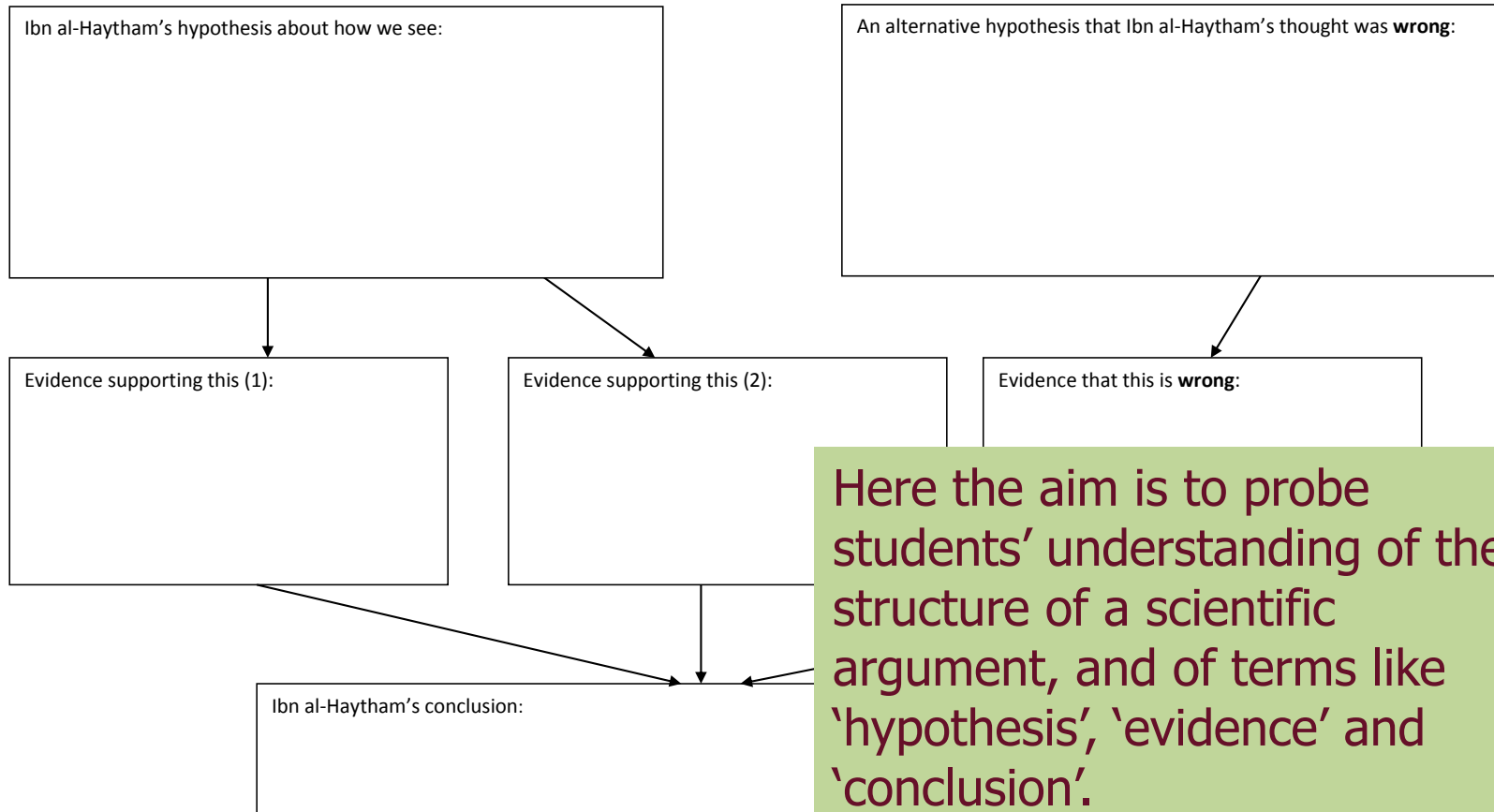
This debate rumbled on for almost 2000 years. It was finally settled by the scholar Ibn al-Haytham. He was born in Basra in the 10<sup>th</sup> century. He noticed that our eyes are dazzled if we look at a very bright light, and close automatically. Also, if you stare at a bright fire at night, you can still see an image of it for a few moments after you look away into the darkness. So light affects your eyes. He also reasoned that a ray could not go out from our eyes and reach the distant stars the instant after we open our eyes.

So he thought that light must come from the object we are seeing to our eyes. Using the idea that light rays travel to the eye from every point on an object, he developed an explanation of vision that other scientists quickly accepted – and which is basically the view that we still hold today.

# Analysing text (contd.)

## To answer

Use the information in the story about to complete the diagram below:



Here the aim is to probe students' understanding of the structure of a scientific argument, and of terms like 'hypothesis', 'evidence' and 'conclusion'.

# York Science project

- What we have done so far:
  - Developed banks of *Evidence of Learning Items* for 6 science topics at lower secondary school level
  - Explored how teachers use these materials, after minimal guidance, and how this influences their practice and thinking
- What we are now doing:
  - Extending this to cover all of the ‘big ideas’ of science in the lower secondary curriculum
  - Working with CPD colleagues to support teachers in using these resources as effectively as possible
  - Supporting teachers who want to develop teaching schemes using ‘backward design’ principles

# Evaluating impact

# Data collection

- Teachers in 45 schools each given materials for one science topic
  - Pack included suggestions on ways of using these
- After several months, teachers completed questionnaires
  - Descriptive data (What had they used? How had they used it?)
  - Evaluative data (What did they think of the materials? Any suggestions for improvement/addition?)
  - Reflective data (How might this influence their teaching and planning?)
- Interviews with 13 teachers to explore the same issues in more depth

# Some teachers' questionnaire responses

They are good because they are not basic recall questions. Students need to apply knowledge and understanding. (FD)

... they provide a good way to check understanding and actual learning of a topic not just rote learning of facts or words. (SW)

I have ... been really impressed with what I've seen so far. Many of the questions have had me thinking 'I know that is the correct answer but can I explain why the others are wrong!?' (EW)

The materials have caused me to reconsider my approach to lesson planning, and have been an excellent aid. (MM)

... this would get an inexperienced teacher off to a good start in assessing understanding and also help formalise some ideas of experienced teachers. (NT)

When I first looked at and discussed the York Science materials with the department, it felt like being a proper scientist again. (MD)



# Unexpected feedback

“When I was given the trial pack to try it out, I was in the middle of teaching light and I thought ‘Oh, I’ll try some of these, they’ll be able to do them, no problem for students.’ But they couldn’t. It was the activity about: you’re in the cupboard and the door’s closed and there’s a cat. What will the eyes of the cat look like? And they all thought the cat’s eyes would glow in the dark. They had no idea.” (T02)

“One student got it right, the most common response by far was this”

After sitting there for a while, what will you be able to see?

Statement	I am sure this is right	I think this is right	I think this is wrong	I am sure this is wrong
A After a while you will be able to see everything, but very dim.	<del>✓</del>	✓		
B The only thing you will see is the cat's eyes shining.	<del>✓</del>	✓		
C You will see the mirror shining, but everything else will be dark.			✓	
D You won't be able to see anything at all, no matter how long you wait.				✓

# Insights into students' thinking

“I really like how I’m able to get down to the nitty-gritty of what the kids are thinking ... how are they actually thinking about it” (T02)

“It makes you look at things more completely from an understanding level and also informs you on an understanding level as well.” (T09)

# Insights into students' thinking (2)

“The nice thing about this, it’s multiple choice, you have various different answers, but there are some which if your thinking isn’t quite right, that’s the one you’ll go for. And that’s really really helpful and really useful. You can listen to the thought processes, they have discussions about it, what do you think, what’s this, how does this work, and that really helps you into what they’re thinking and how it works.” (T11)

# Changing how you teach a topic

“The YS materials pick up the misconceptions in such a way that it’s clear what they don’t understand and how they don’t understand it. So it’s better than simply getting a wrong answer on a test, you’ve actually got some sort of idea about what they don’t understand and a potential way in to fix it. And it’s mainly go back to the particular lessons where I knew there was a problem and take another look at them as well. When I’ve taught it again, I’ve approached it in a different way.” (T11)

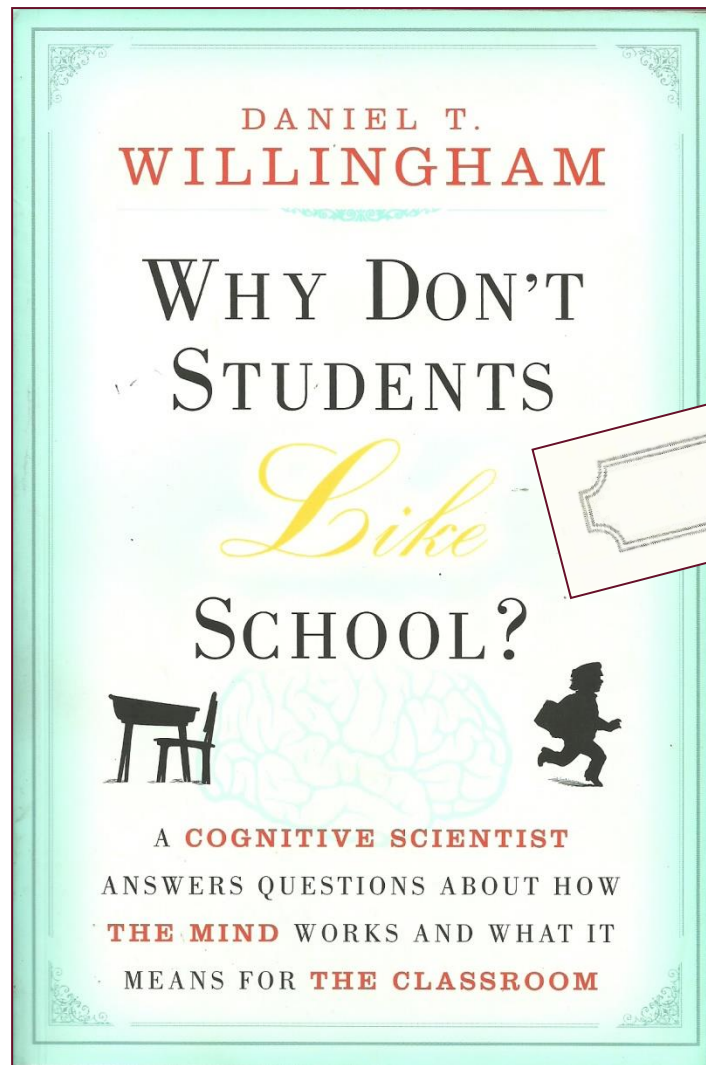
# Teachers' responses: Summary

- Strongly positive about the materials
  - materials and approach seen as directly relevant to issues teachers are currently grappling with
- Surprise at prevalence of 'misconceptions'
  - also in topics they thought they had taught successfully
- Several reported that they had developed similar items for other topics
- Many commented on how they would teach the topic 'next time round'

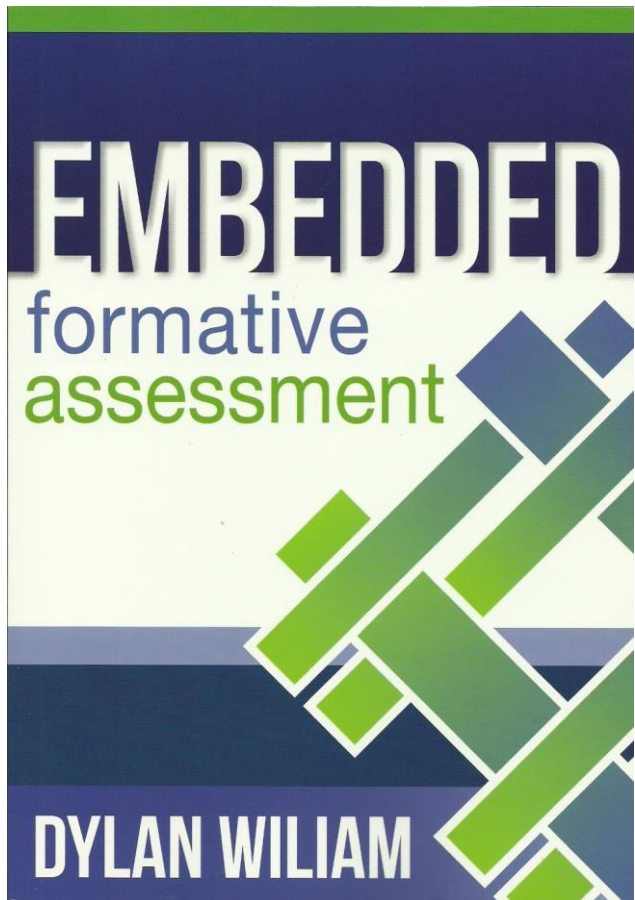
**To sum up**

- Change is stimulated more effectively by providing teaching instruments and tools, than by disseminating general principles
- Questions are particularly effective in stimulating teachers' actions and thinking
- Good questions are powerful teaching tools because they make students think





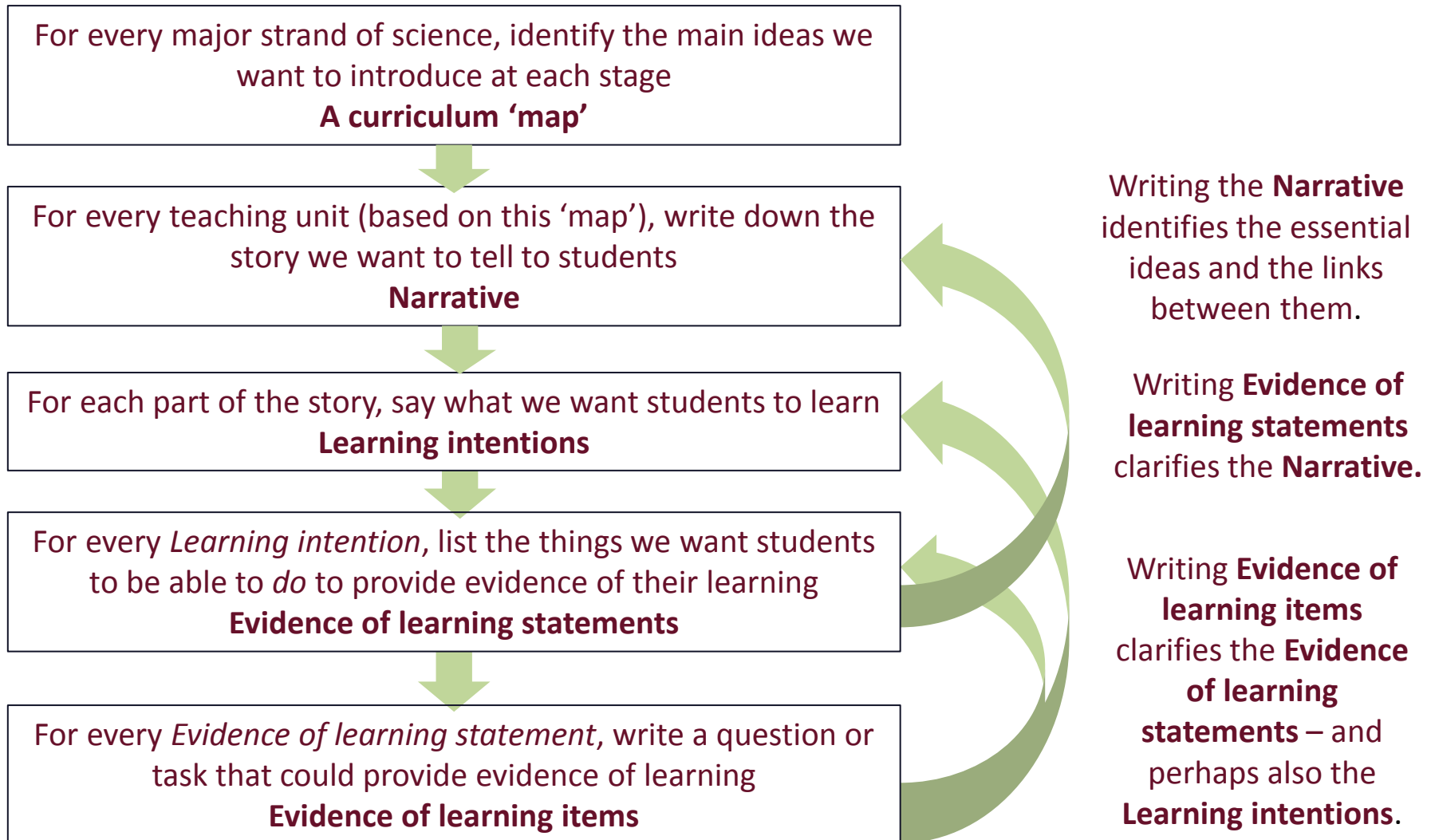
Memory is the residue of thought.



“sharing high quality questions may be the most significant thing we can do to improve the quality of student learning.” (p. 104)

Wiliam, D. (2011).  
*Embedded formative assessment*.  
Bloomington, IN: Solution Tree Press.

# Integrating assessment into curriculum planning



# Integrating assessment into curriculum planning

