Webinar 5. Teaching strategies for AO2/3

Dr Tony Sherborne
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mastery science

Carrotgate

A student investigated the effect of sugar solutions on pieces of carrot. ..

Concentration	% change in mass
0.0	+24
0.2	+12
0.4 etc	+1 etc

Suggest why the student calculated the % change in mass

Tony

Why we created Blueprint

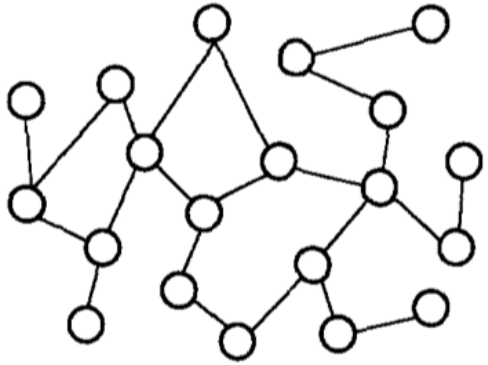
The examiners reported that, overall, AO1 (knowledge) questions were answered well, including answers to simple factual questions and questions which required basic calculations such as percentage change. The problems were with in-depth knowledge: answering AO2 questions (apply knowledge) and AO3 questions (analyse, interpret, evaluate, draw conclusions). [2018]

Students found the concept of speciation difficult to apply when describing natural selection in the context of orchid colour.

Students struggled to apply their knowledge of what happens during the digestive process to the visking tubing experiment.

Candidates who did less well on this paper generally did the following:

- Found it difficult to apply what they had learnt to unfamiliar situations.



AO2/3 means expert knowledge

- Force predicts motion
  - Newton's 1st law
    - Resistive forces
    - Inertia
    - Vectors
  - Newton's 2nd law
    - Balanced & unbalanced
    - Acceleration

3 takeaways

1. Scaffold: teach cognitive strategies
2. Hug: use increasingly complex problems
3. Bridge: learn the deep structure

Scaffold

Teach cognitive strategies

Gemma

Scaffold

How would you solve these?

1 The radio waves have a frequency of 4.8×10^9 Hz

Wave speed of electromagnetic waves = 3.0×10^8 m/s

Calculate the wavelength of the radio waves.

Give your answer to 2 significant figures.

2 Plants need nitrate ions in order to make proteins.

A plant is growing in soil flooded with water.

Explain why the plant cannot absorb enough nitrate ions.

Scaffold

Domain-specific strategy

1 The radio waves have a frequency of 4.8×10^9 Hz

Wave speed of electromagnetic waves = 3.0×10^8 m/s

Calculate the wavelength of the radio waves.

Give your answer to 2 significant figures.

1. Identify need for procedure: wave equation
2. Use maths skill to rearrange equation
3. Substitute values
4. Calculate answer

Scaffold

Domain-general strategy

2 Plants need nitrate ions in order to make proteins.

A plant is growing in soil flooded with water.

Explain why the plant cannot absorb enough nitrate ions.

- Detect that the question is about active transport
- Recall everything you know about this concept
- Solve the problem using this information

Scaffold

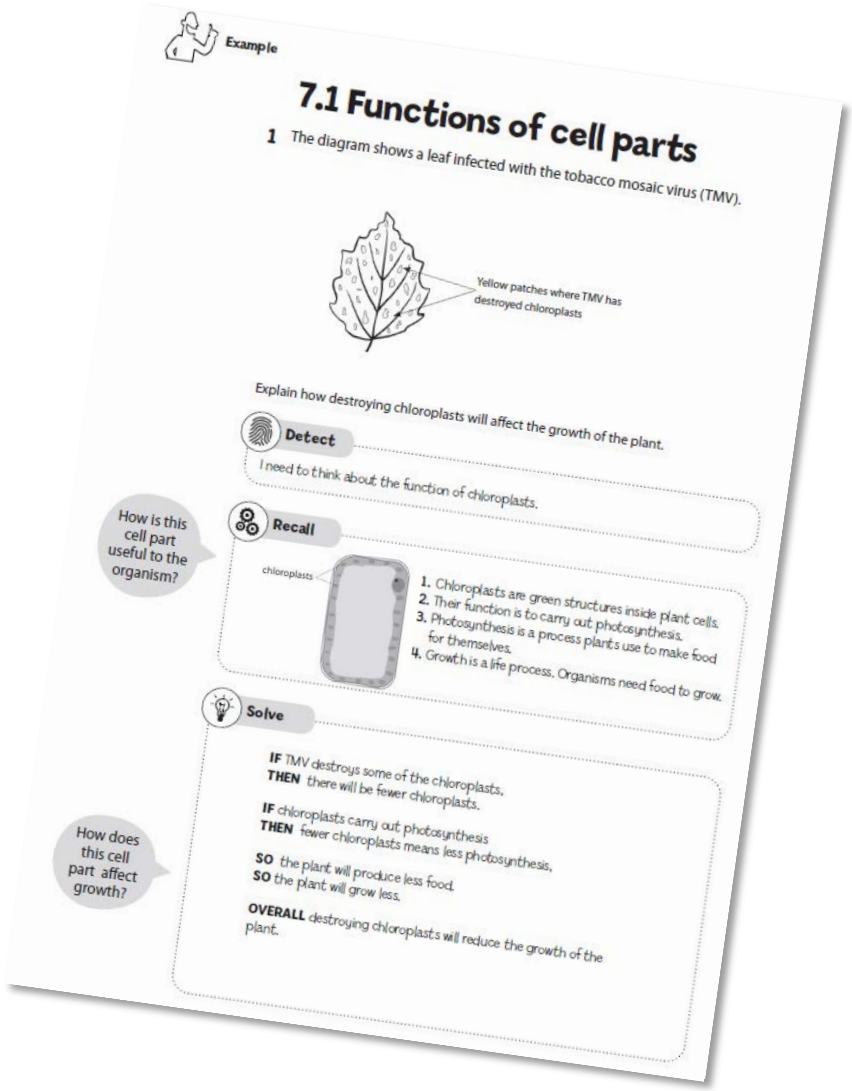
Why teach cognitive strategies?

- Many students don't learn them spontaneously
- Scaffolding complex task
- Support metacognition
- Research says they work

Scaffold

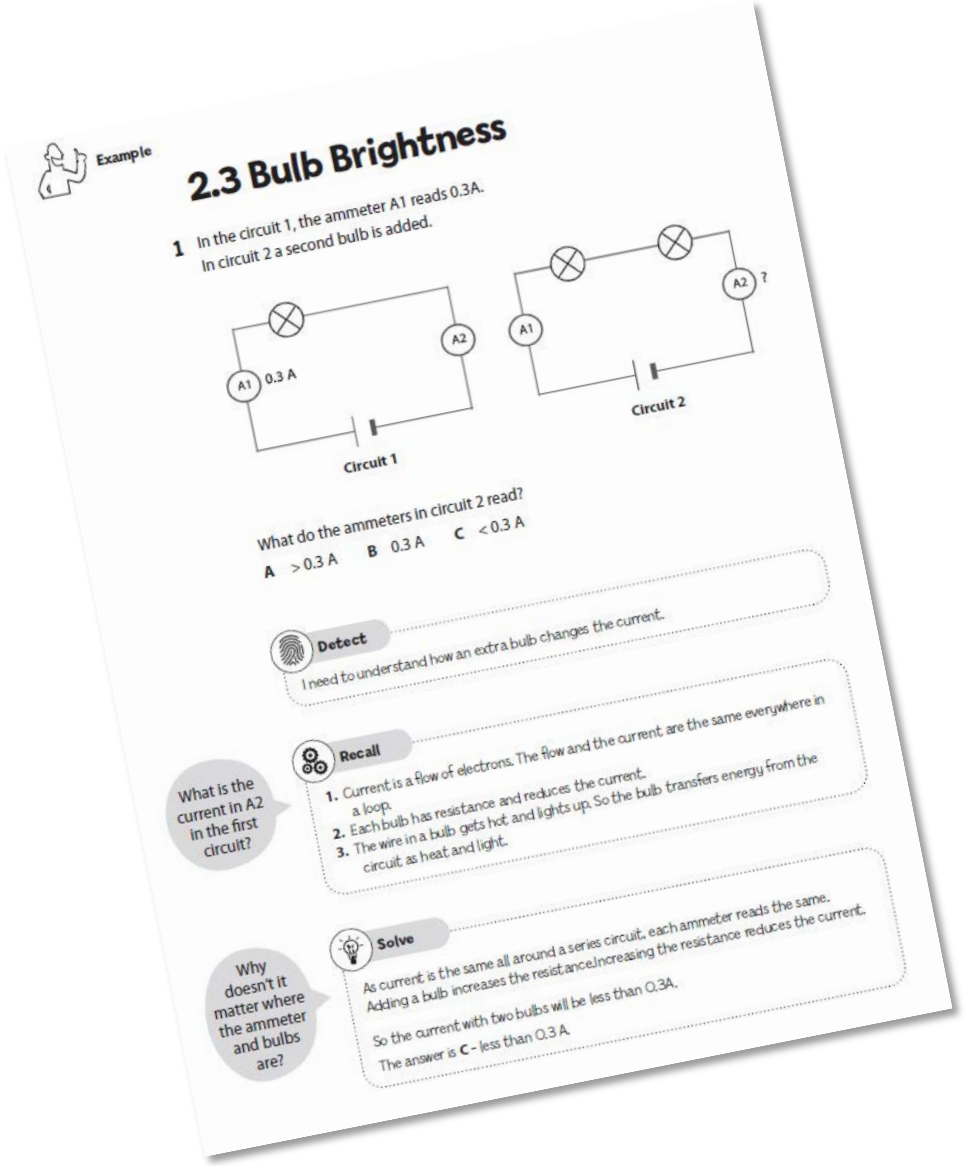
The worked example

- Domain-specific strategy
- Model expert thinking



Scaffold

The worked example



Example

2.3 Bulb Brightness

1 In the circuit 1, the ammeter A1 reads 0.3A.
In circuit 2 a second bulb is added.

What do the ammeters in circuit 2 read?

A > 0.3 A **B** 0.3 A **C** < 0.3 A

Detect

I need to understand how an extra bulb changes the current.

What is the current in A2 in the first circuit?

Recall

1. Current is a flow of electrons. The flow and the current are the same everywhere in a loop.
2. Each bulb has resistance and reduces the current.
3. The wire in a bulb gets hot and lights up. So the bulb transfers energy from the circuit as heat and light.

Why doesn't it matter where the ammeter and bulbs are?

Solve

As current is the same all around a series circuit, each ammeter reads the same.
Adding a bulb increases the resistance.Increasing the resistance reduces the current.

So the current with two bulbs will be less than 0.3A.

The answer is **C** – less than 0.3 A.

- Proven to benefit novices
- Reduces cognitive load

Scaffold

Teaching cognitive strategies

7.3 Types of cell transport

Plants need minerals A,B and C for healthy growth. The table shows the concentration of these minerals in plant root cells and in the surrounding soil in normal conditions.

Mineral	Concentration in plant root cells in mol/dm^3	Concentration in surrounding soil in mol/dm^3
A	0.7	0.5
B	0.2	0.4
C	0.8	1.0

Heavy rain can leave the soil waterlogged, which decreases oxygen reaching the root cells.
For which mineral will the movement into the cells be reduced?
Explain your choice.

Scaffold

Detect

2. Find the key information

Plants need minerals A,B and C for healthy growth. The table shows the concentration of these minerals in plant root cells and in the surrounding soil in normal conditions.

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Scaffold

Detect

2. Find the key information

Plants need minerals A,B and C for healthy growth. The table shows the concentration of these minerals in plant root cells and in the surrounding soil in normal conditions.

Normal conditions

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C	0.8	1.0

Heavy rain can leave the soil waterlogged, which decreases oxygen reaching the root cells.

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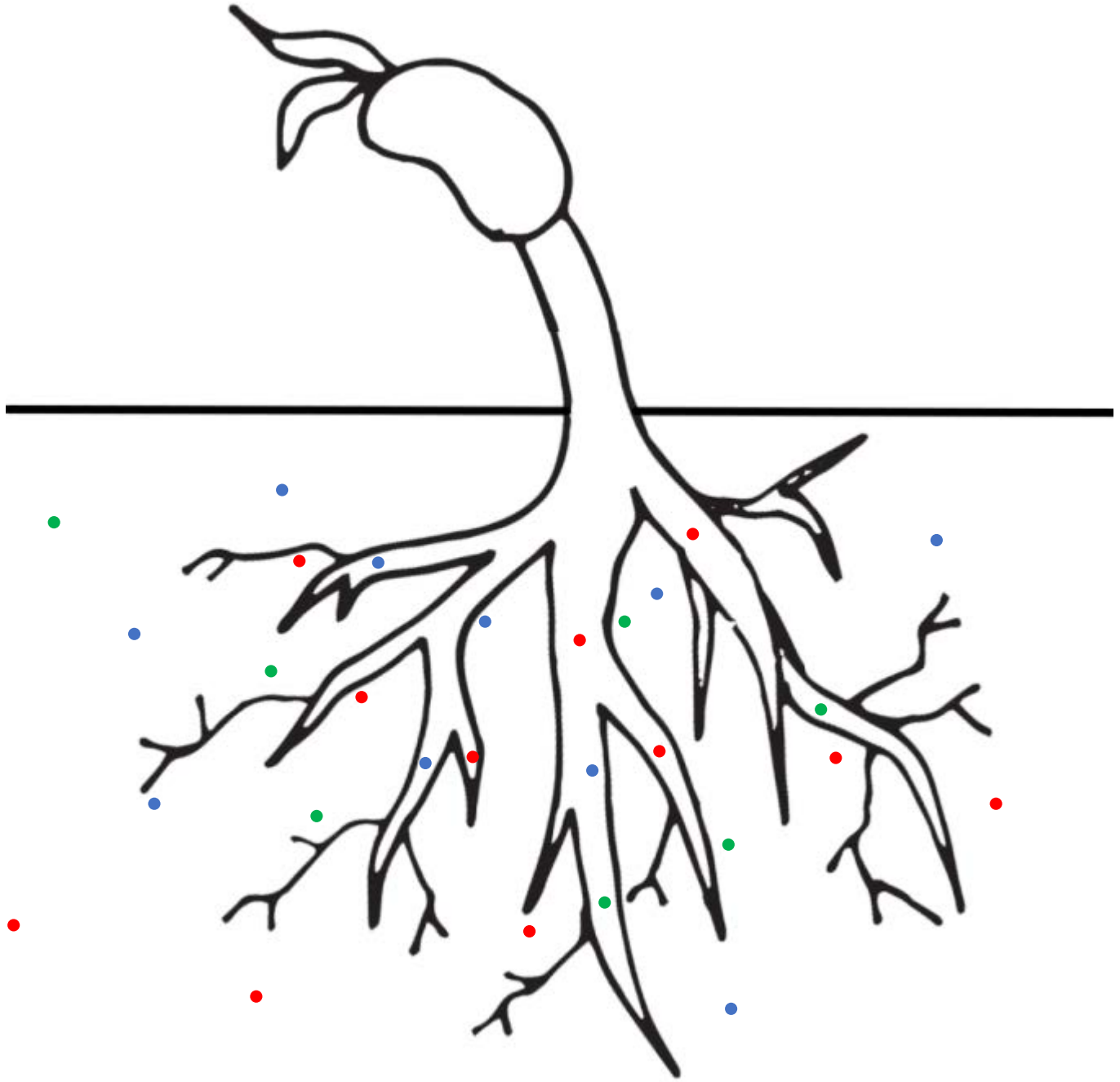
Explain your choice.

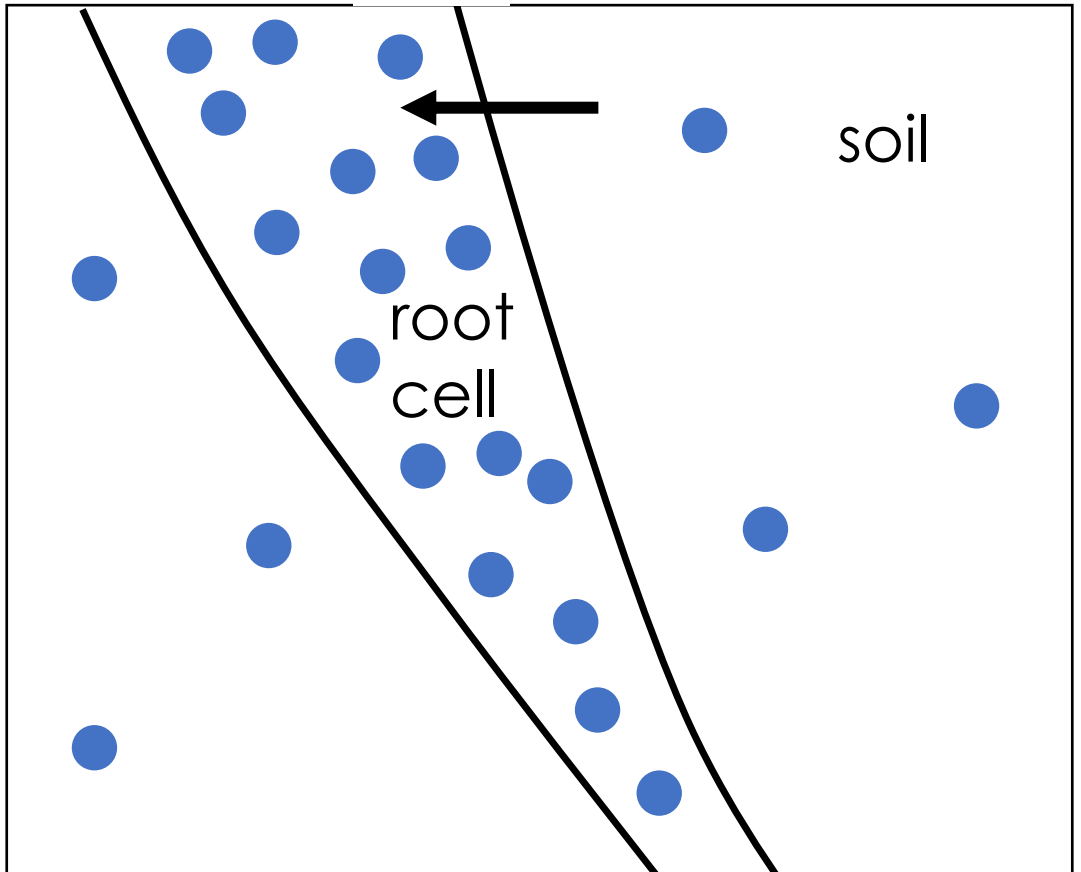
Scaffold



- mineral A
- mineral B
- mineral C

Scaffold

Mineral	Concentration in plant root cells in mol/dm³	Concentration in surrounding soil in mol/dm³
A	0.7 >	0.5



Scaffold

Detect

3. Identify the Unknown

Plants need minerals A,B and C for healthy growth. The table shows the concentration of these minerals in plant root cells and in the surrounding soil in normal conditions.

Mineral	Concentration in plant root cells in mol/dm^3	Concentration in surrounding soil in mol/dm^3
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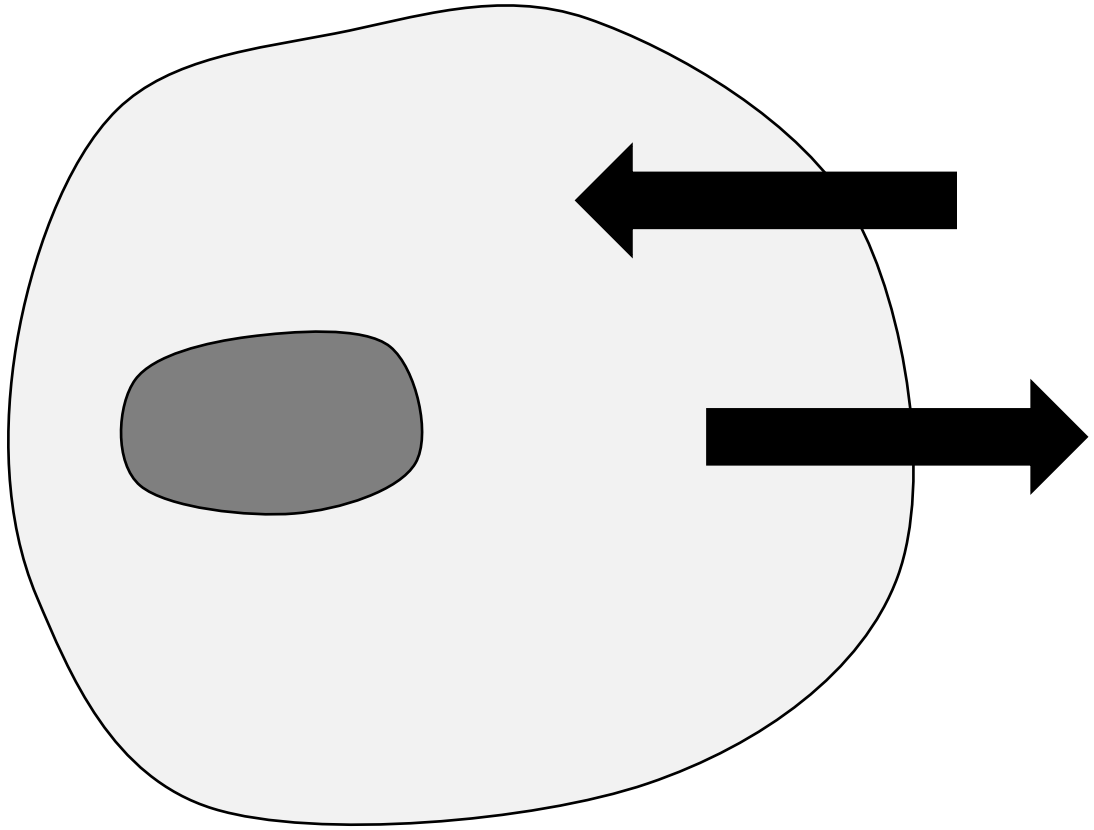
Different conditions

Heavy rain can leave the soil waterlogged, which decreases oxygen reaching the root cells.
For which mineral will the movement into the cells be reduced?
Explain your choice.

Scaffold

Detect

4. Decide the key concept



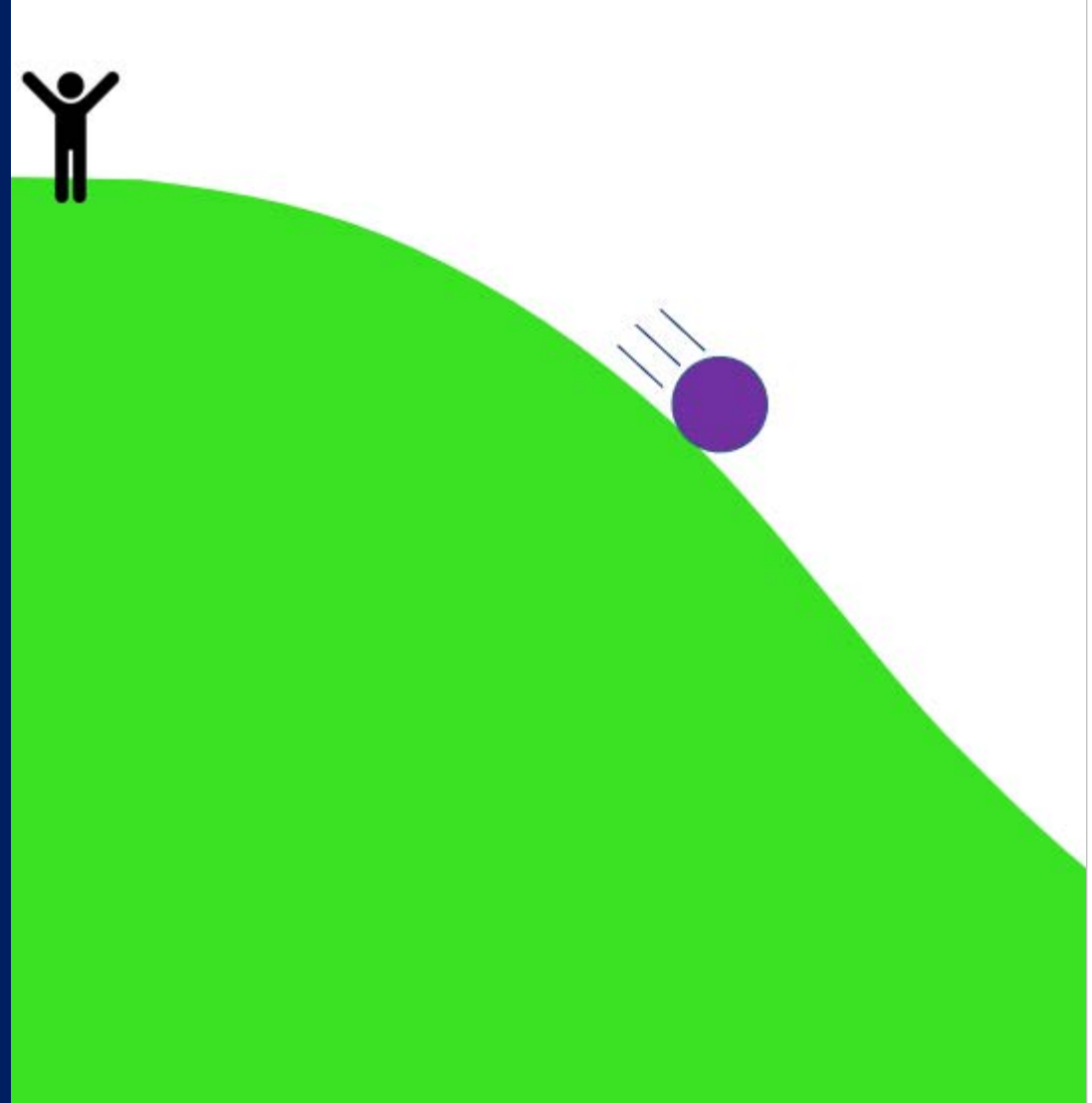
Cell transport:

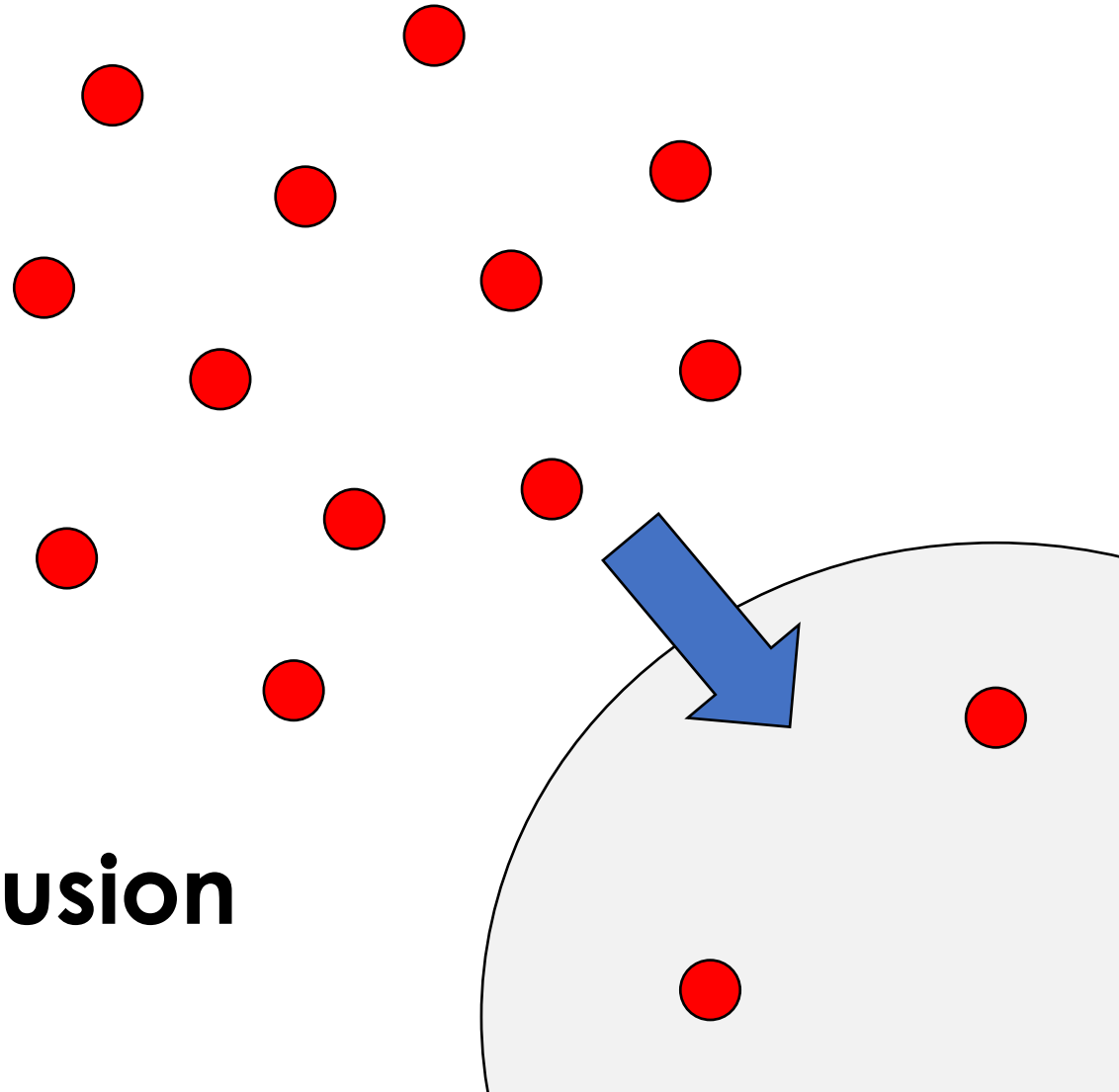
Diffusion
Active transport

Scaffold

Recall

DOWN gradient



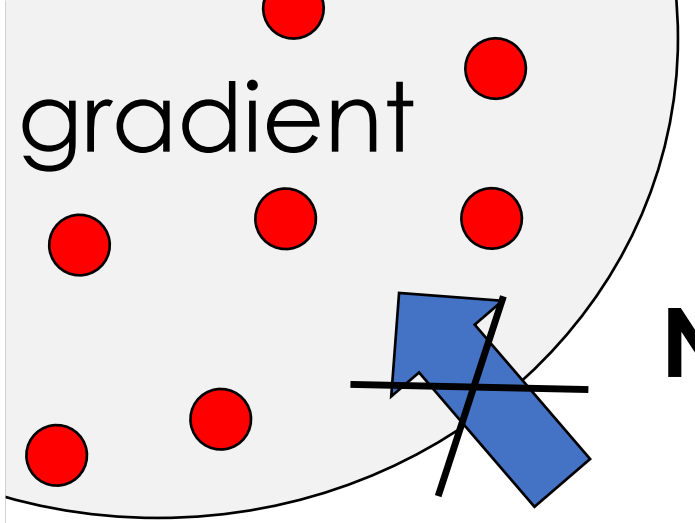


Diffusion

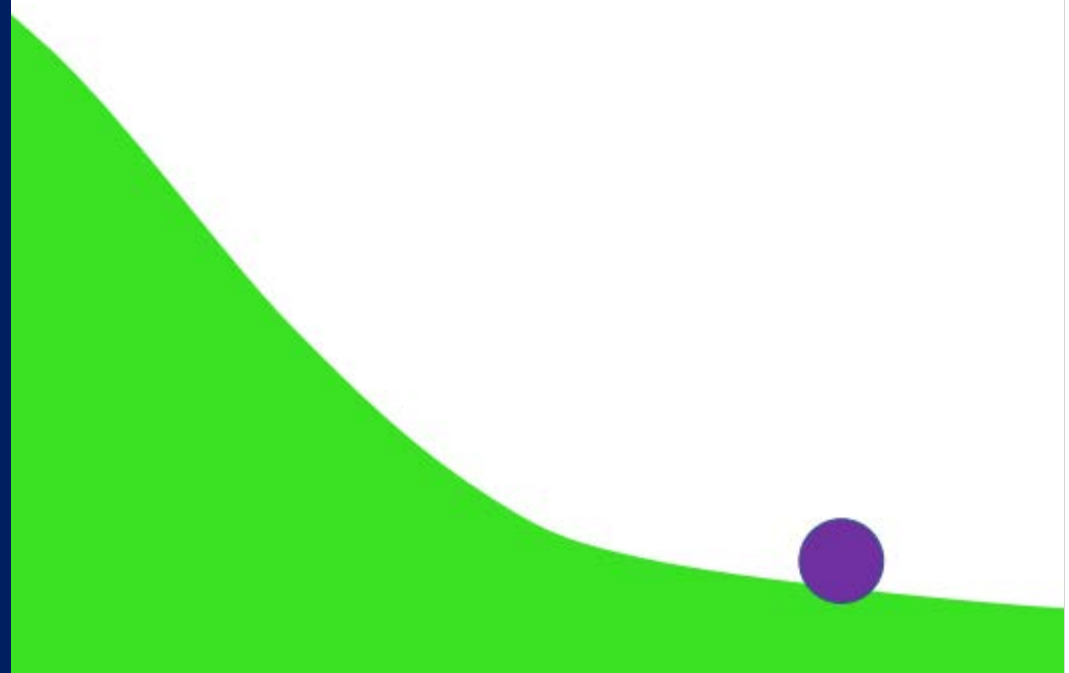
Scaffold

Recall

UP gradient

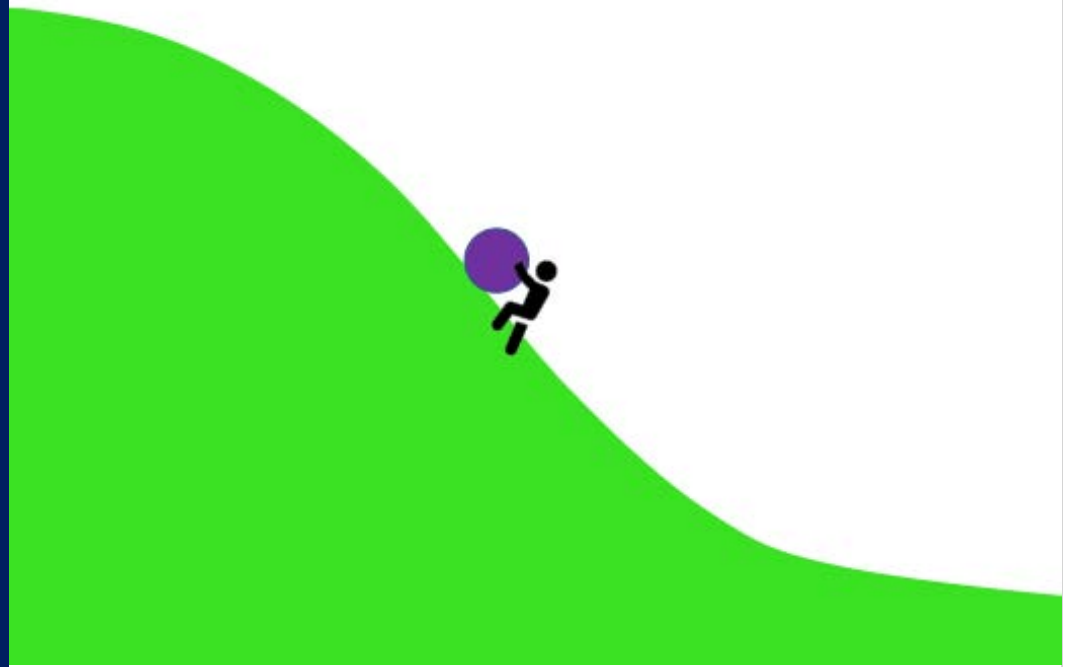


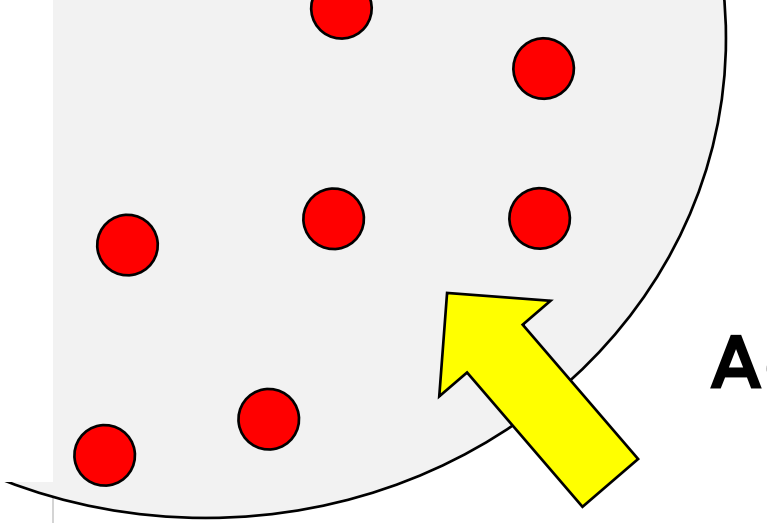
No diffusion



Scaffold

Recall





Active transport

Scaffold

Solve

How to structure an explanation

- **Claim** A simple statement that answers the question
- **Evidence** Data or observations that supports the claim.
- **Reasoning** Scientific ideas that show how the evidence supports the claim

Scaffold

active transport →

Mineral	Concentration in plant root cells in mol/dm^3	Concentration in surrounding soil in mol/dm^3
A	0.7	0.5
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Solve

- ✔ Claim
- ✔ Evidence
- ✔ Reasoning

Mineral A: its movement will be affected by a reduction in oxygen.

Scaffold

active transport →

Mineral	Concentration in plant root cells in mol/dm^3	Concentration in surrounding soil in mol/dm^3
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C	0.8	1.0

Solve

- ✔ Claim
- ✔ Evidence
- ✔ Reasoning

Mineral A: its movement will be affected by a reduction in oxygen.

The concentration of A inside the root cells is higher than the soil.

Scaffold

Solve

ctive transport →

Mineral	Concentration in plant root cells in mol/dm³	Concentration in surrounding soil in mol/dm³
A	0.7	0.5
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Solve

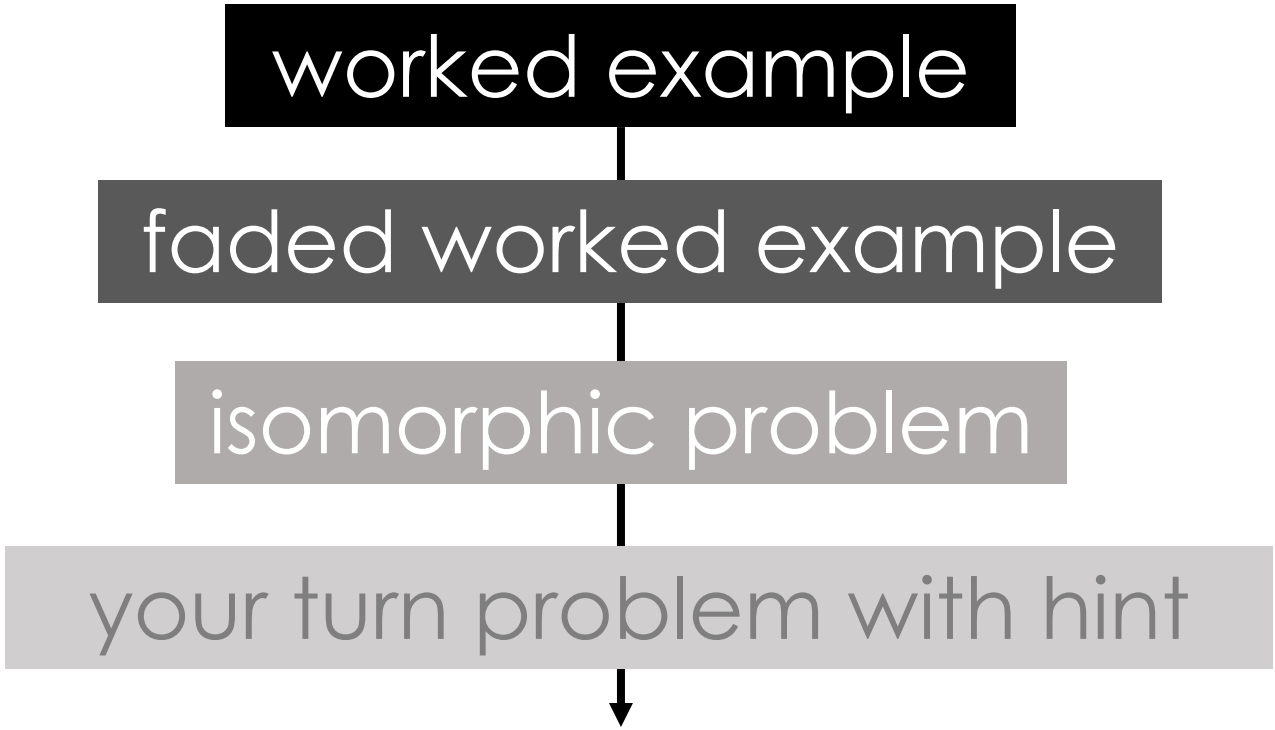
- ✔ Claim
- ✔ Evidence
- ✔ Reasoning

Mineral A: its movement will be affected by a reduction in oxygen.

The concentration of A inside the root cells is higher than the soil.
So it cannot move in by diffusion, but must move by active transport.
Active transport require energy which comes from respiration. Aerobic respiration provides the most energy but requires oxygen.
If the cell receives less oxygen, it will start switch to anaerobic respiration, which produces less energy. So the active transport of A is reduced.

Scaffold

Scaffold from example to independence



Scaffold

worked example

faded worked example

isomorphic problem

your turn problem with hint

Your turn problem – no hint

Mineral	Concentration in mmol/dm^3	
	Outside cells	Inside cells
Calcium	120	5
Chloride	3	28
Potassium	6	135
Sodium	139	11

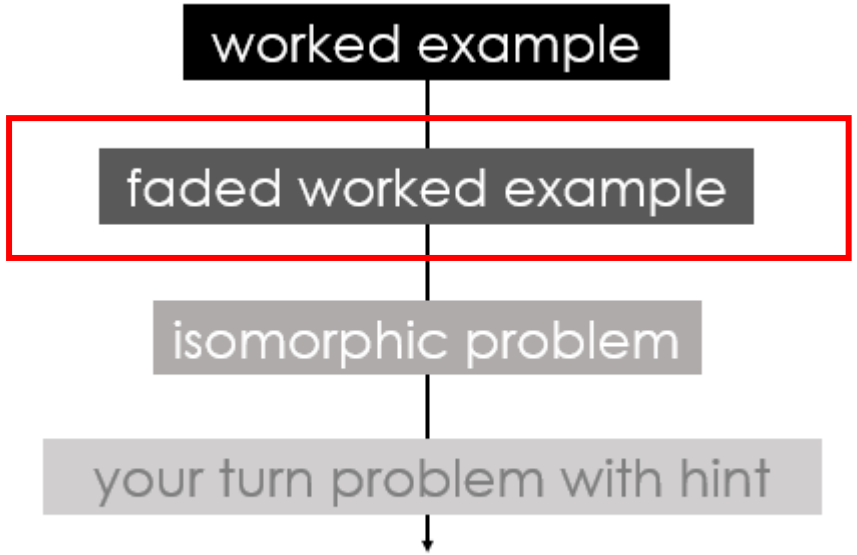
Scientists studied the movement of minerals that normally flow into human cells.

They measured the initial concentrations of ions outside and inside the cells.

Then they added cyanide, a poison that stops respiration.

Explain the effect of stopping respiration on the movement of each mineral.

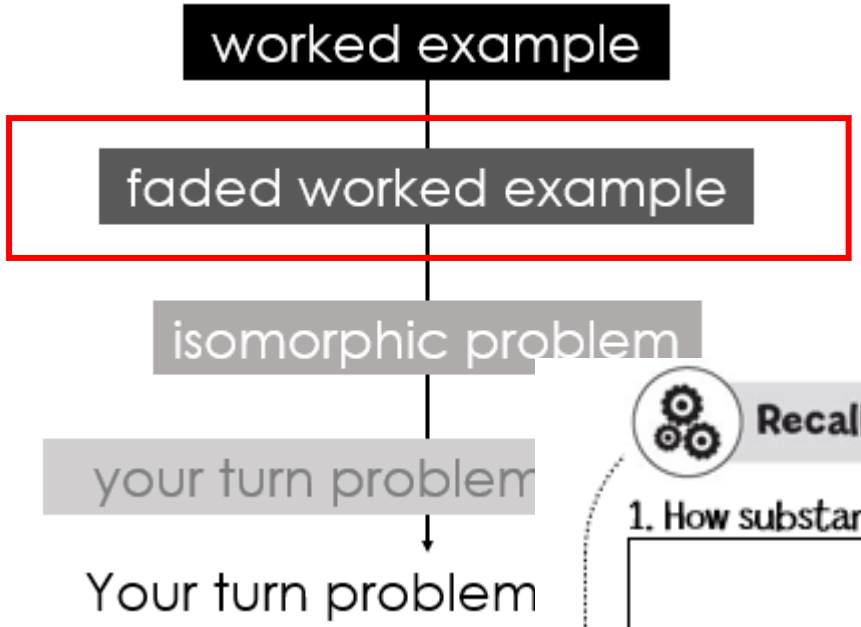
Scaffold



Detect

✔ Values	The table shows the concentration of four different minerals outside and inside cells. The minerals normally flow into cells. The concentration is higher outside cells for calcium and sodium. It is higher inside cells for chloride and potassium.
✔ Unknown	I need to explain the effect of stopping respiration on the movement of each mineral.
✔ Concept	The concept I need to use is cell transport.

Scaffold



Recall

1. How substances move in/out of cells by diffusion.

2. How substances move in/out of cells by active transport.

3. How substances get their energy from respiration.

Scaffold

worked example

faded worked example

isomorphic problem

your turn problem with hint

Your turn

Solve

Claim

The movement of and into cells will be affected by stopping respiration. The movement of and will not be affected.

Evidence

Before respiration was stopped, the concentration of chloride and potassium were in the inside of the cells compared to the outside. The concentration of calcium and sodium were inside the cells compared to the outside.

Reasoning

Chloride and potassium move into cells by . This requires , which is released by respiration. Calcium and sodium move into cells by , which does not require .

Scaffold

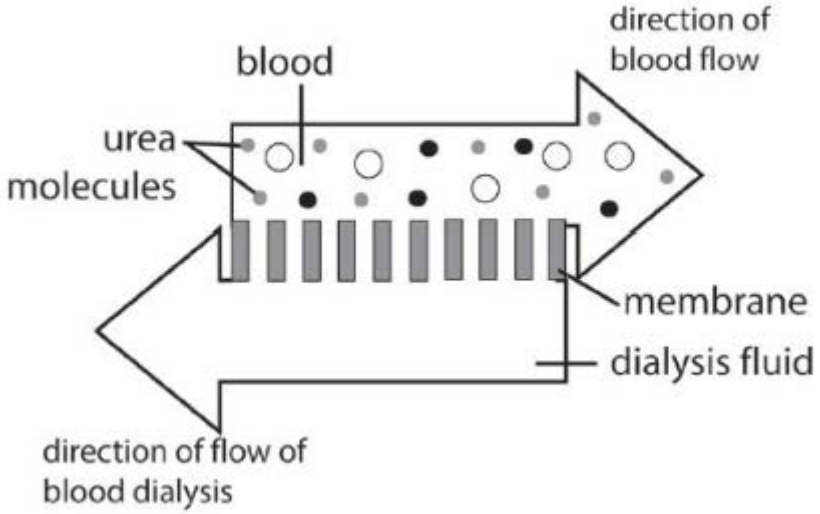
worked example

faded worked example

isomorphic problem

your turn problem with hint

Your turn problem – no hint



In kidney disease urea builds up in the blood. The diagram shows how a treatment works.

Explain how a moving stream of dialysis fluid can help the patient.

lint: Urea only diffuses if there is a concentration difference.

Hug

Use increasingly complex problems

Tony

Hug

Goal of education : transfer

From osmosis in potatoes

To a variety of contexts

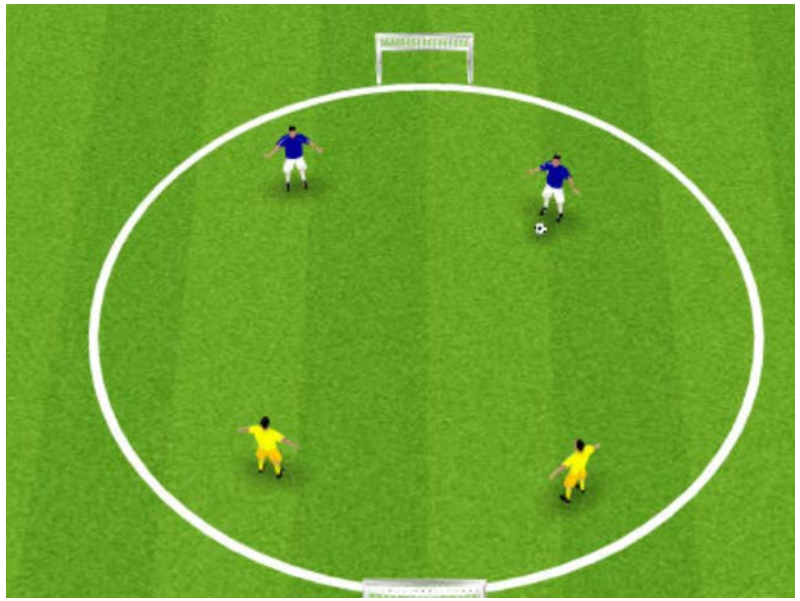
When skills and knowledge learned in one situation help you learn or perform better on something else.

Hug

Low-road transfer

- Similar conditions e.g. right -> left hand drive
- Fairly automatic and unconscious
- Transfer happens easily

‘Hugging’ the eventual goal



Small-side games

Are the best preparation for big games

Stay as close as possible to the eventual performance: start with small, simple version and add complexity.

Put hugging into practice

Hug

7KC-Heat & temperature

Temperature difference

Temperature difference: When two objects are at different temperatures, energy moves from the warmer to the cooler until they are at the same temperature. The bigger the difference, the faster energy moves.

Gemma

Hug

Blueprint performances

Simpler

More complex

Acquire

Goal To determine what variables affects the rate at which a substance cools, using a graph.

Apply

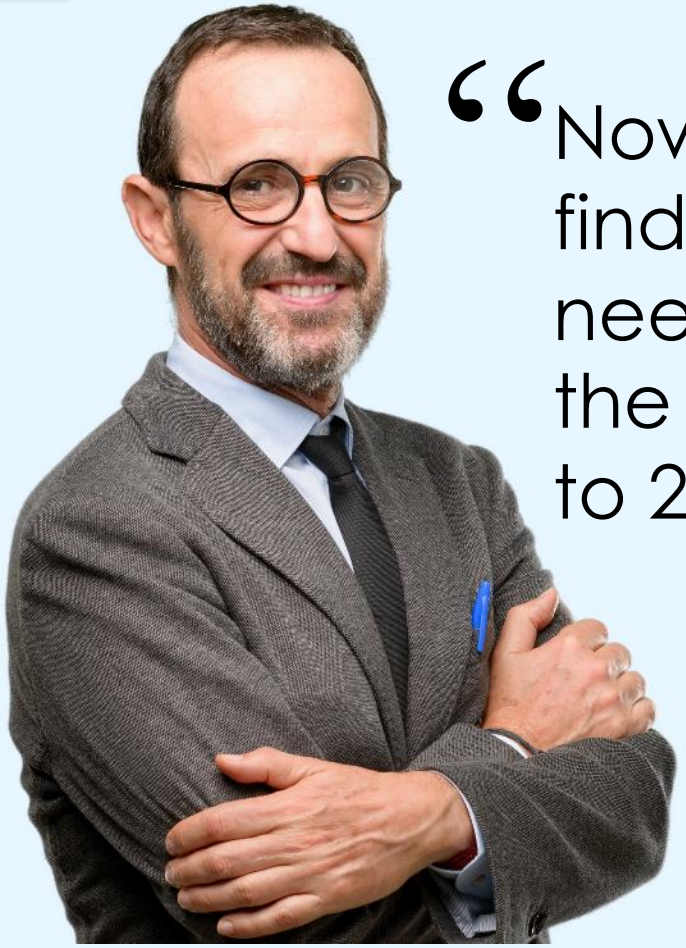
Goal To determine how a variable affects the rate of temperature change from a graph.

Analyse

Goal To draw conclusions from graphs about the affect of several variables on rate of temperature change.

EXPLORE

What determines how quickly an object cools?



"Now for the real puzzle. To find the time of death, you need to work out how long the dead body took to cool to 29.5°C. Let's investigate!"

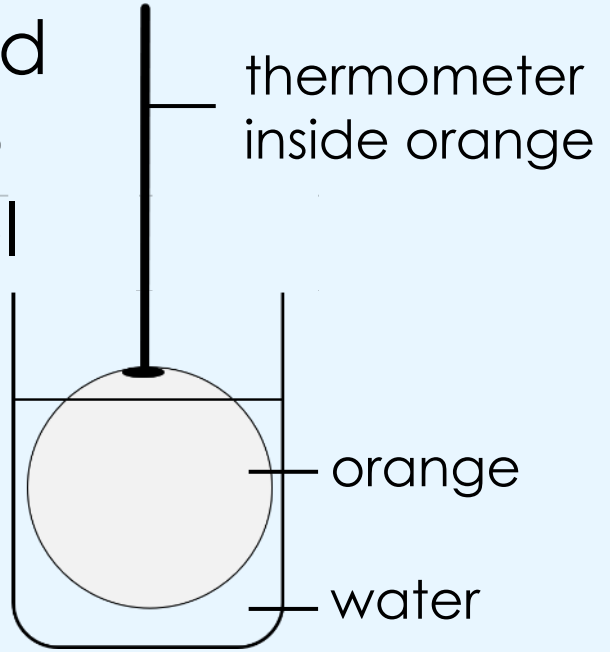
What variables could affect how quickly an object cools down?

Hug

EXPLORE

What determines how quickly an object cools?

"I don't have dead bodies for you to test! Use a model – an orange"

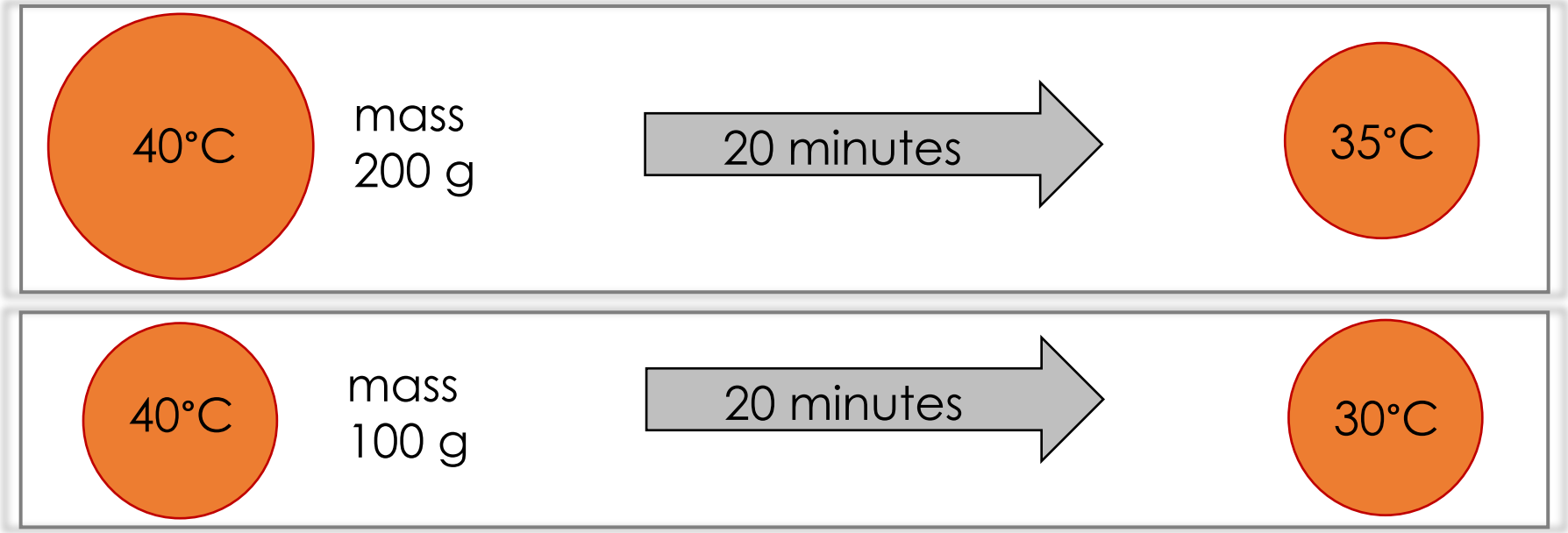


Activity: What affects the rate of cooling?

- Work in pairs to investigate one independent variable.
- Put the orange in the water and measure the temperature of the orange every 2 mins for 20 mins.
- Record your results
- Draw a line graph and write a conclusion.

EXPLAIN

Mass affects rate of cooling



The smaller the mass, the greater the temperature drop.

How does mass affect how much heat is transferred?

Acquire

Hug

EPILOGUE Could Lee be guilty of murder?

"Lee's lawyer used a cooling curve to estimate the time of death as 7pm. That means Lee wasn't home to kill her...but is this estimate correct?"

Activity: Study the evidence **SS4**

- Study the graph Lee's lawyer used. How did he use it to conclude that Clare was killed at 7pm?
- Use what you have learnt about cooling to decide if she could have been killed after 10pm.

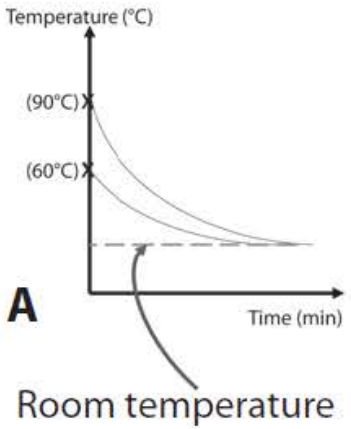
Hug

3.5 Temperature Graphs

1 Two beakers of hot water are left to cool.

Which set of graphs shows how the temperatures change with time?

A



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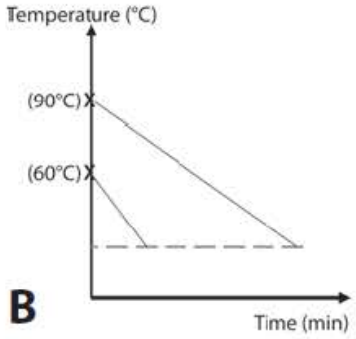
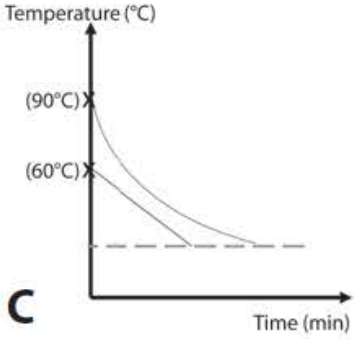


C



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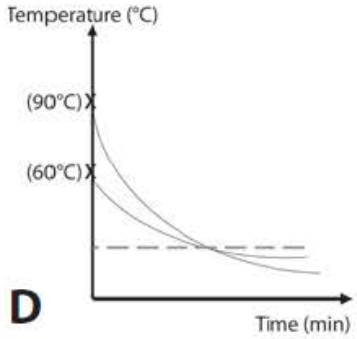

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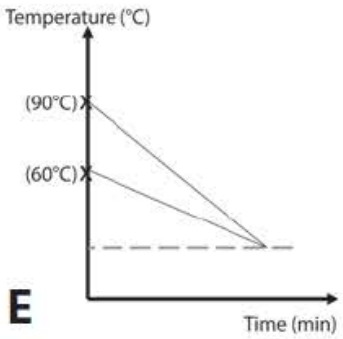
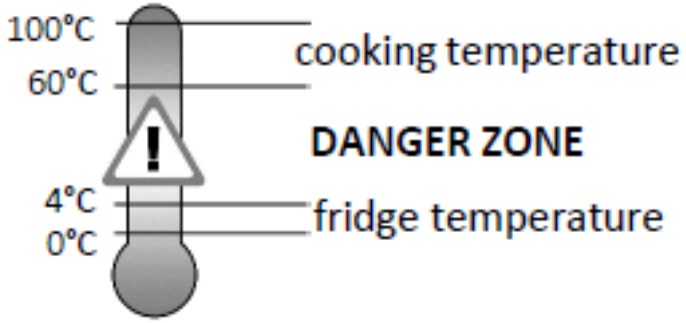


Hug

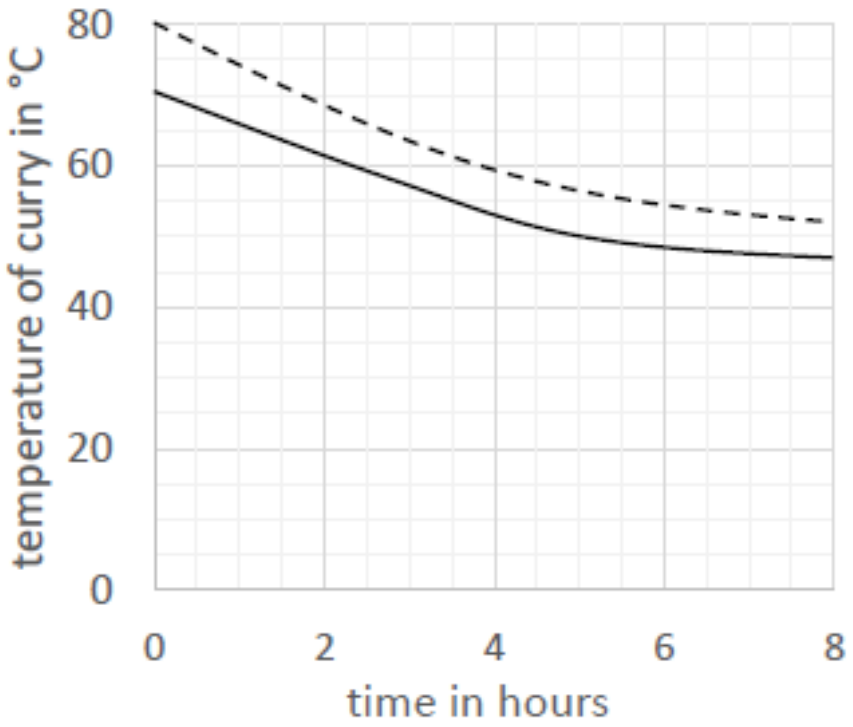
Analyse

The danger zone! When food is between the temperature of 4 and 60°C bacteria start to multiply rapidly. Leave the food for too long in this danger zone and it will not be safe to eat.

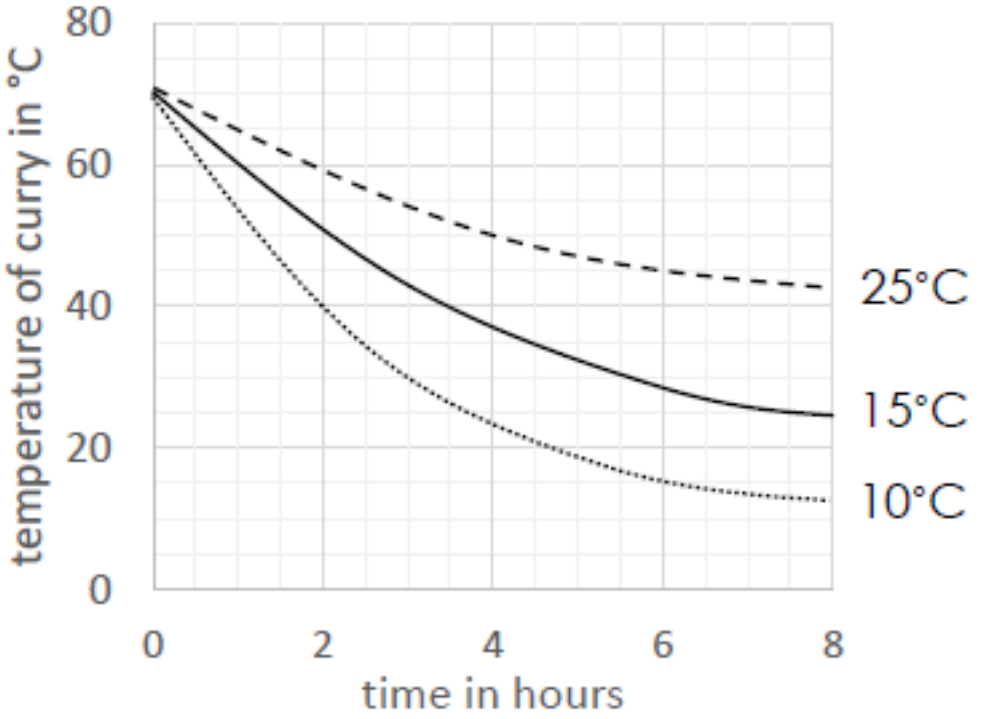


Luca wants to work out how to avoid his curry being too long in the danger zone. He investigated 4 different factors and plotted the results below

1. Initial temperature of the curry



2. Temperature of the surroundings



Bridge

Learn the deep structure

Tony

Hug

High-road transfer

- Different conditions e.g. chess to politics
- Transfer not easy - takes effort
- Requires search for patterns and principles

Bridge

‘Bridging’ between situations

- Build an abstract idea from concrete experience
- Use bodily and visual analogies – how people think
- Help students ‘bridge’ (generalise) across contexts

Bridge

Beyond tell and practice 1

Practicing Versus Inventing With Contrasting Cases: The Effects of Telling First on Learning and Transfer

Daniel L. Schwartz, Catherine C. Chase, Marily A. Oppezzo, and Doris B. Chin
Stanford University

Being told procedures and concepts before problem solving can inadvertently undermine the learning of deep structures in physics. If students do not learn the underlying structure of physical phenomena, they will exhibit poor transfer. Two studies on teaching physics to adolescents compared the effects of "telling" students before and after problem solving. In Experiment 1 ($N = 128$), students in a tell-and-practice condition were told the relevant concepts and formulas (e.g., density) before practicing on a set of contrasting cases for each lesson. Students in an invent-with-contrasting-cases (ICC) condition had to invent formulas using the same cases and were told only afterward. Both groups exhibited equal proficiency at using the formulas on word problems. However, ICC students better learned the ratio structure of the physical phenomena and transferred more frequently to semantically unrelated topics that also had a ratio structure (e.g., spring constant). Experiment 2 ($N = 120$) clarified the sources of the effects while showing that ICC benefited both low- and high-achieving students.

Bridge

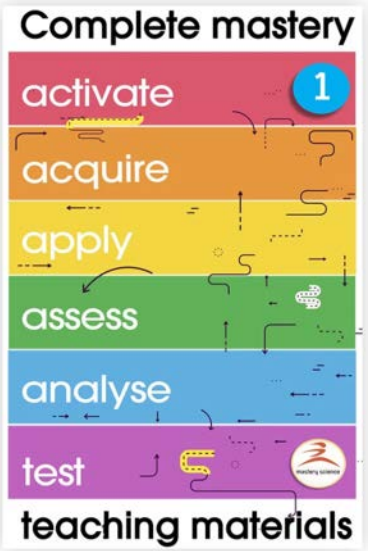
Example: density, a difficult concept

$$\text{Density} = \frac{\text{mass (g)}}{\text{volume (cm}^3\text{)}}$$

- It's a derived quantity (mass / volume)
- It involves proportional thinking
- Students equate density with weight

Bridge

Concrete analogy



EXPLORE Why are some materials heavier than others?

Let's use an analogy: crowded clowns

Companies send clowns to parties in buses. Unfortunately some clowns are unhappy because their companies make the buses too crowded. Your job is to calculate the crowdedness of each company's bus.

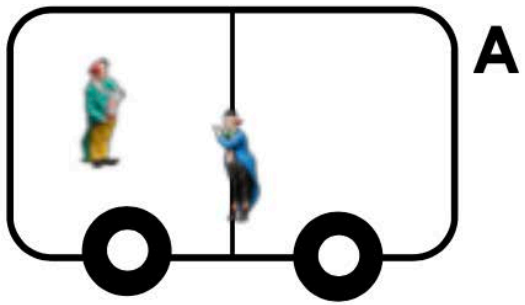
Activity: Calculate crowdedness **SS2**

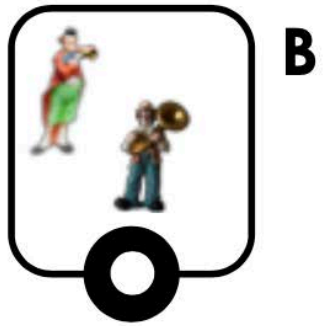
- Invent a way of comparing each company's crowdedness.

Bridge

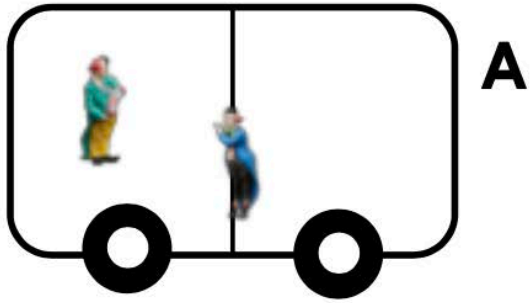
Contrasting cases

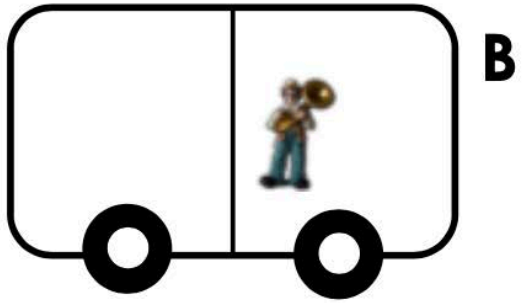
1. Which bus is more crowded: A, B or the same? Why?





2. Which bus is more crowded: A, B or the same? Why?





Bridge

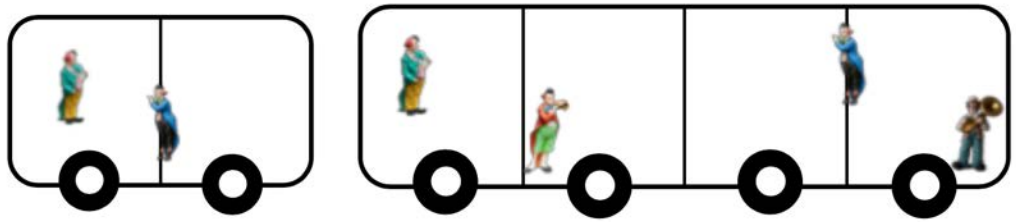
Invention

5. Now use your rule. Calculate a number for the crowdedness of each bus.

SS2

Clowns for U bus Crowdedness = _____

Rent-a-clown bus Crowdedness = _____



Fun clowns bus Crowdedness = _____

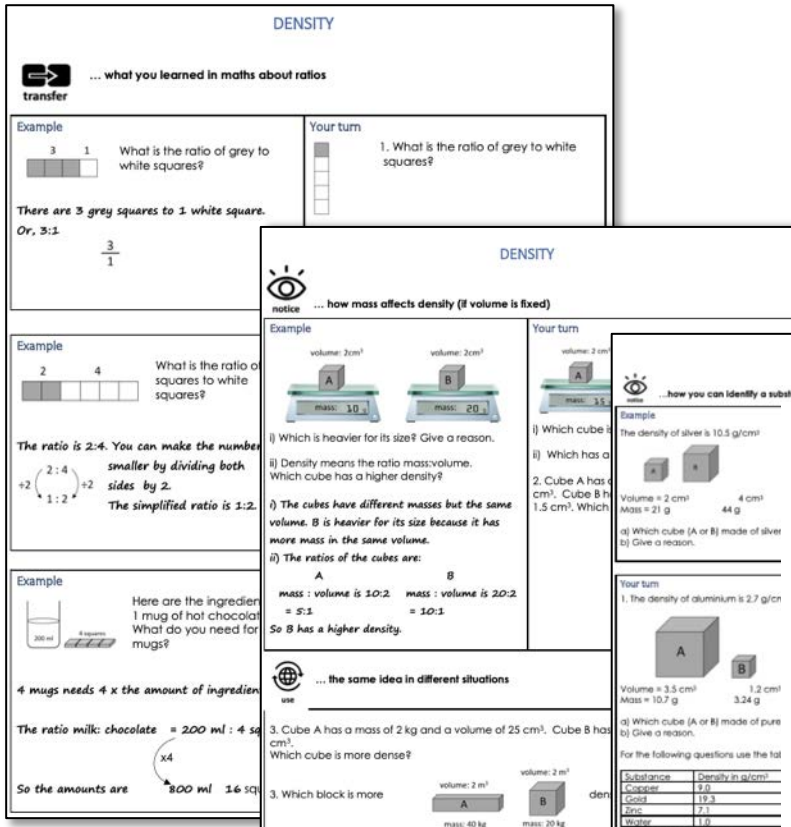
Bridge

Beyond tell and practice 2

Standard T&P instruction is important because it delivers the explanations and solutions invented by experts, and students need opportunities to hear and practice these ideas. For students to gain this benefit without undermining transfer, the current studies suggest that expositions should happen after students have explored novel deep structures. The inventing activity can serve as "preparation for future learning" by readying students to appreciate more fully the expert solutions and deep structures when they are explained (Bransford & Schwartz, 1999). Giving students the end-product of expertise too soon short-cuts the need to find the deep structure that the expertise describes. Students in the T&P condition focused on what they had been told, and they applied the formulas sequentially to the problems, which reduced their chances of finding the deep structure. Without an appreciation of deep structure, students are less likely to see the structure in new situations that differ on the surface, and they will fail to transfer.

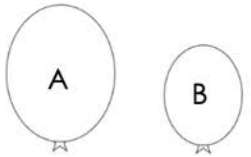
Bridge

Do you need 'Question Sets'?



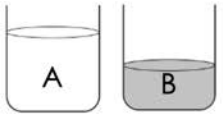
1. Cube A has a volume of 10 cm³ and a mass of 1 kg. Cube B has a volume of 20 cm³ and a mass of 1 kg. Which cube is more dense? Give a reason.

2. Cube A has a volume of 5 cm³ and a mass of 10 g. Cube B has a volume of 4 cm³ and a mass of 10 g. Which cube has a lower density?



3. Whitney fills balloons with 10 g of two different gases. She then measures the volume of the balloons.

Balloon A has a volume of 15 cm³.
Balloon B has a volume of 9 cm³.
Which gas has the lowest density?



4. Here are two different liquids. Each has a mass of 50 g.

Liquid A has volume of 48 cm³
Liquid B has a volume of 30 cm³
Which liquid has the higher density?

Next steps

Next steps

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