Rethinking the Introduction of Particle Theory for the Learning of Gifted/More Able Students in Regular Classrooms

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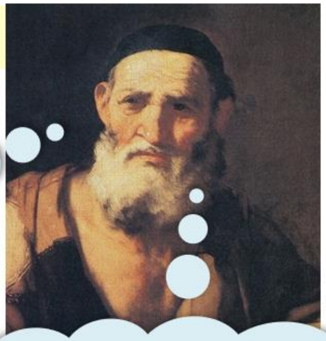
Overview

- Discussing how particle theory is taught with the textbook approach
- What to consider when rethinking the unit design?
- Sharing of two lesson examples
- Some tips on redesigning the whole unit based on lesson try-outs from the GE School Network

B Particle theory

About 2500 years ago

Matter should be made up of tiny **particles** (粒子).



Greek thinker

But I could not find evidence to support this...

The particle theory:

1. All matter is made up of particles.
2. The particles are tiny.
3. Different substances are made up of different particles.
4. The particles are moving randomly all the time.
5. There are empty spaces between the particles.

B Particle theory

In the 18th century

Scientists found more and more evidence

↓ support

Matter is made up of tiny particles

↓ develop

particle theory
(粒子理論)

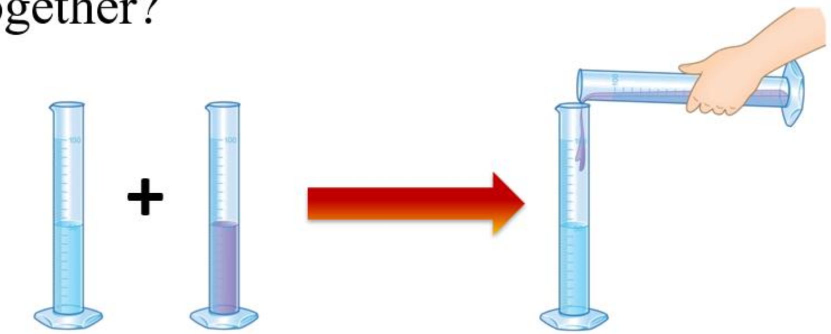
C Evidence for particle theory

Particles are too small to be seen even under microscopes.

Is there any evidence that supports the particle theory?

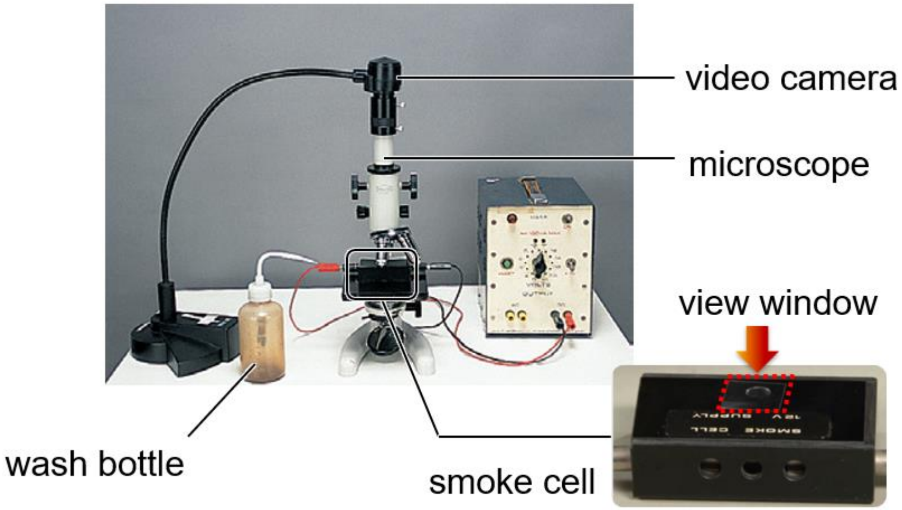
Practical 6.1

6 Based on the results in part II, can you give a possible explanation for the changes in volume when water and alcohol are mixed together?



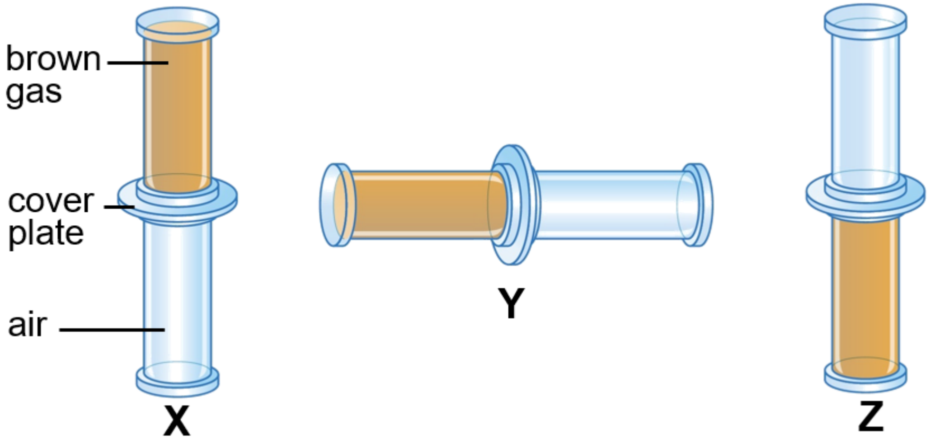
Practical 6.3

2 Fill the cell with smoke using a wash bottle.



Practical 6.2

2 What will happen to the brown gas when the cover plates are removed?



Which statement(s) of the particle theory does each practical supports?

Statement in the particle theory	Practical 6.1	Practical 6.2	Practical 6.3
1 All matter is made up of particles.	✓	✓	✓
2 The particles are tiny.	✓		✓
3 Different substances are made up of different particles.	✓		
4 The particles are moving randomly all the time.		✓	✓
5 There are empty spaces between the particles.	✓		

Textbook approach

- State the five strands of particle theory at the beginning
- Collect ‘evidence’ to confirm the five strands through different practical works, such as
  - Solid feels hard; liquid takes the shape of containers
  - A drop of concentrated Ribena spreads out in the water
  - Brown gas in each set-up fills both jars eventually
  - The volume of the water and alcohol mixture is smaller than the sum of the volumes of the two liquids
  - Smelling perfume in the balloon
  - Movement of particles in a smoke cell under a microscope

Textbook approach (students' perspectives)

- Particle theory is told at the beginning, the role of the practical works is just to confirm what the teacher said.
- Problems of the textbook approach
  - No connection to students' prior knowledge and experience
  - Some has too low cognitive demand
  - Some has too high cognitive demand
  - Students need to connect the series of practical work to the each of the strands of particle theory (cognitive overload)
  - Hard to assess student understanding during their learning

What to consider when rethinking the unit design

- Gifted/more able students need more challenges which enhance their conceptual understanding and mirror the epistemic aspect in scientific inquiry
- Start with puzzling phenomena (unfamiliar experimental set-ups) but not to disclose the five strands of particle theory
- Elicit student pre-conceptions of what might happen with intuitive reasoning
- Support student on-going changes of ideas through (e.g. classroom dialogue, intense discussion and scientific argumentation)

What to consider when rethinking the unit design

Rethinking the sequence of the practical work

Cycle	Contents	Practical tasks
	FIRST TERM *effective learning and teaching of micro-macro relationship*	
	UNIT 2 WATER *[MACROSCOPIC PHENOMENON]*	
4	**2.1 Change in states of water**	Practical 2.2
4	**2.3 Dissolving** *(Reverse experiment: Salting out of alcohol)*	Practical 2.5
	UNIT 6 MATTER AS PARTICLES *[SUBMICROSCOPIC EXPLANATION] (supported with educational technology)*	
5 – 6	Particle view at liquid state (A puzzle of mixing water and alcohol)	(Appendix 4: Experimental designs and teachers' guidelines for introducing particle theory) Practical 6.1 modified Practical 6.8 modified
5 – 6	Particle view at solid state (The solidification of candle wax)	
6 – 7	**6.3 Dissolving** Particle view at solid and liquid state (Dissolving table salt in water)	
6 – 7	Particle view at gaseous state (Predicting with particle model: injecting a drop of water into a hot syringe)	
8	**6.2 Particle model**	
9	**6.1 Matter and particle theory**	

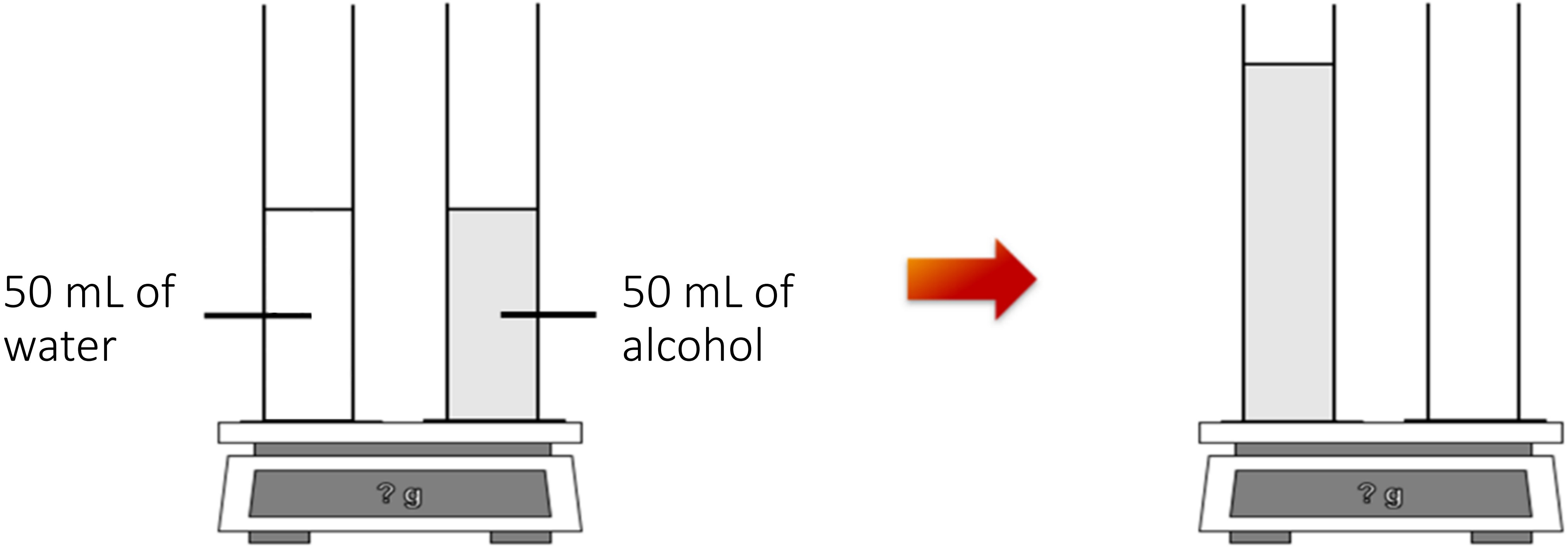
LESSON EXAMPLE 1

Mixing water and alcohol

via P-E-O-E approach

Reframing the puzzling phenomenon of mixing water and alcohol

- Reduction in volume; <u>conservation of mass</u>



P-E-O-E

- The lesson begins by asking students to predict what would happen to the total mass and total volume when 50 mL water and 50 mL alcohol are mixed.

Volume	Mass
Larger than 100 mL	Greater than the sum of both
Equal to 100 mL	Equal to the sum of both
Lower than 100 mL	Smaller than the sum of both

- The teacher then invites students to explain for their predictions.

P-E-O-E

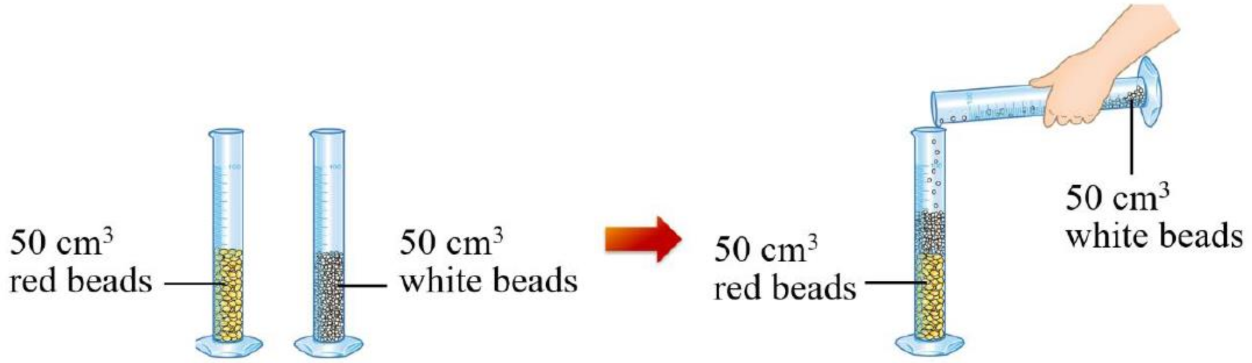
- Students observe teacher's demonstration and record their observations (i.e. mass is conserved but volume is reduced).
- Students propose explanation to explain the result, such as
  - some alcohol is evaporated
  - measurement error
  - some liquid remained in the cylinder

If you were the teacher, how would you respond to them?

P-E-O-E

- The teacher guides students to mix beads with different colours and sizes (analogous to mixing water and alcohol)

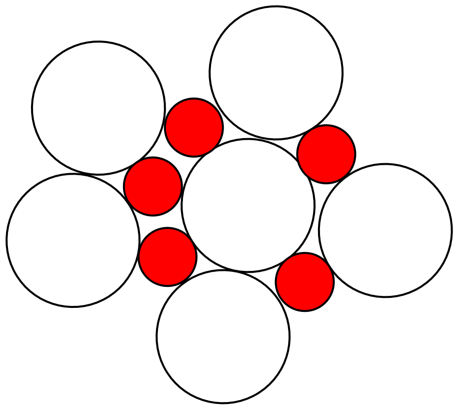
❖ The observable analogy for the particle view – mixing beads of different sizes



	Before mixing		After mixing	
	Volume	Mass	Volume	Mass
Red beads	50 cm^3	g	cm^3	g
White beads	50 cm^3			

P-E-O-E

- Students then construct models to explain the puzzling phenomenon rather than the teacher preaching the ‘correct’ explanation.
- It offers a meaningful way to introduce that matters are made up of discrete particles (as compared to the continuous model).



Highlight of this lesson design

- With conservation of mass highlighted, phenomenon reframed.
- Teachers need to be open-minded to support students on-going changes of scientific ideas.
- Prediction and observation phase in P-E-O-E have to be in contrast to create students’ cognitive dissonance / a need to know
- In the explanation phase in P-E-O-E, the teacher provides scaffolds (not to tell the answers) to facilitates students’ thinking, e.g.
  - use of analogy with concrete model
  - classroom dialogue to support students’ deep thinking

LESSON EXAMPLE 2

The solidification of wax

via P-E-O-E approach

Engaging students with the puzzling phenomenon of the solidification of candle wax

- Volume remains unchanged; conservation of mass

P-E-O-E

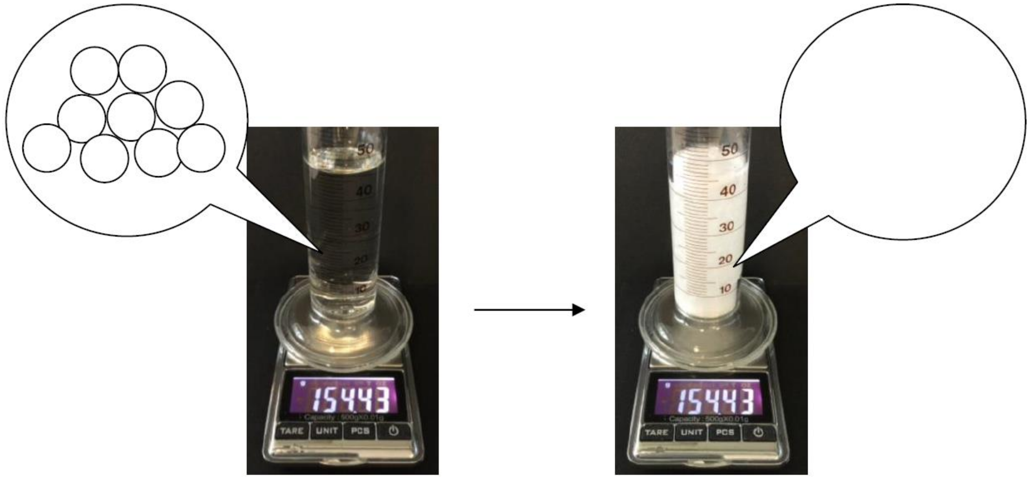
- The lesson begins by asking students to predict what would happen to the total mass and total volume when the molten candle wax is cooled down.

Volume of solid wax (30 mL)	Mass of solid wax
Larger than 30 mL	Greater than the liquid wax
Equal to 30 mL	Equal to the liquid wax
Lower than 30 mL	Smaller than the liquid wax

- The teacher then invites students to explain for their predictions.

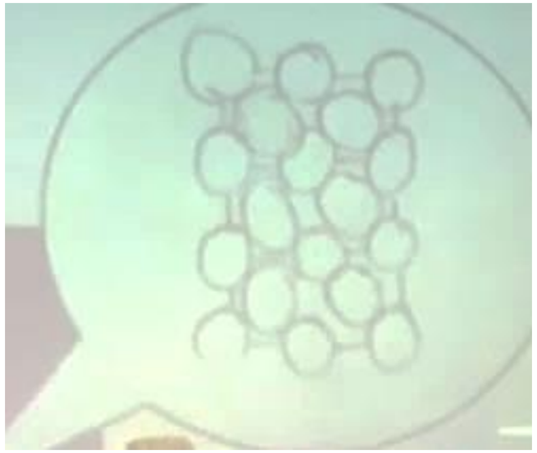
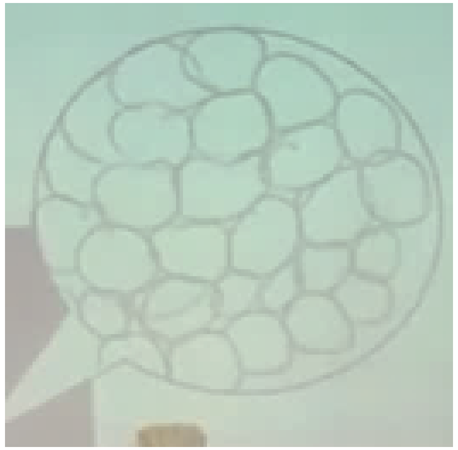
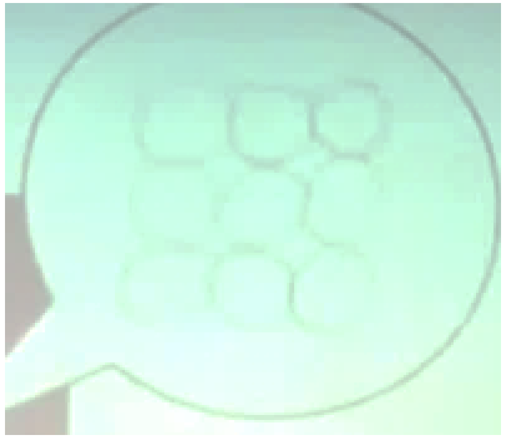
P-E-O-E

- Students observe teacher's demonstration and record their observations (i.e. both mass and volume remain unchanged).
- Students propose explanation by arranging of the wax particles. They draw individually first, followed by group discussion.
- The teacher collects interesting students' ideas (teacher's noticing) and then invites them for whole class sharing.



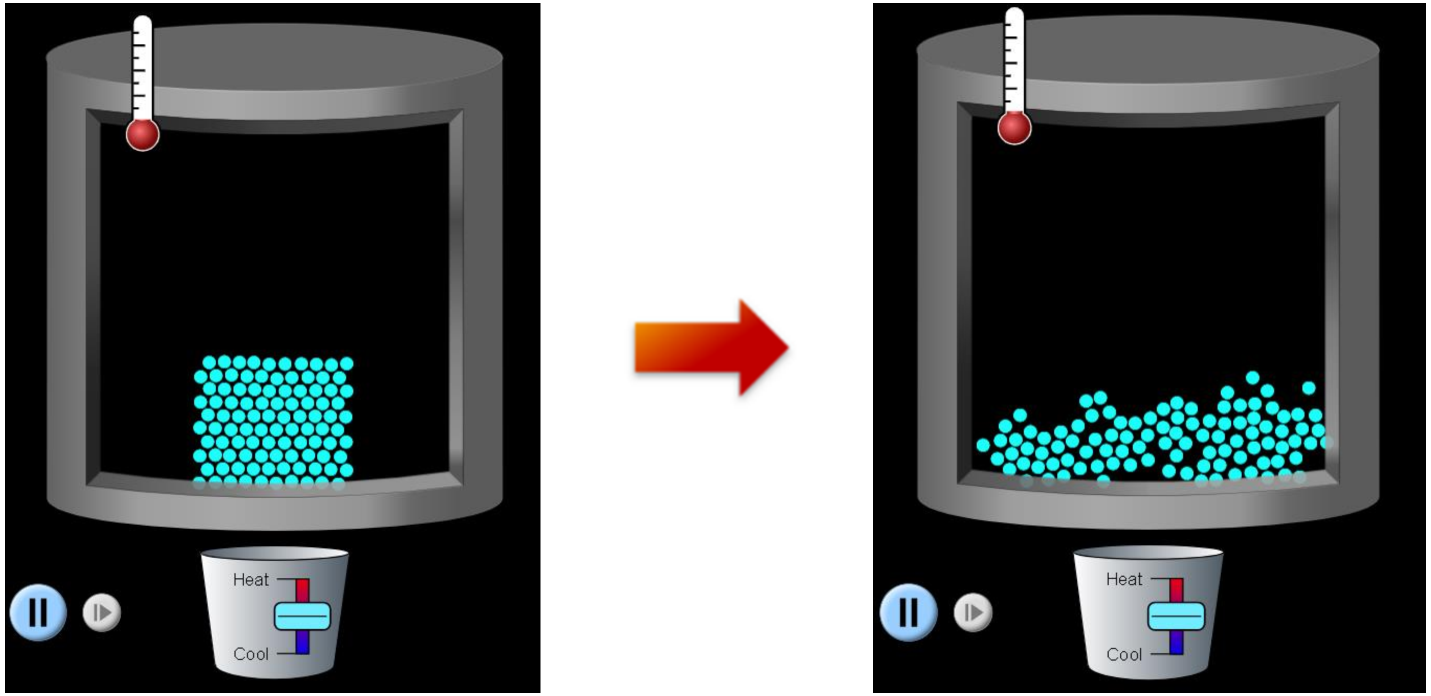
P-E-O-E

- Students compare their arrangement of the wax particles in groups. The teacher facilitates students' scientific reasoning and argumentation.
- Students debate among each other and evaluate possible particle diagrams. Then they reconstruction their best explanation towards the macroscopic phenomenon.

P-E-O-E

- The teacher uses a simulation about melting for students to figure out the best model that represent solidification.



Highlight of this lesson design

- Arouse students' curiosity, motivate student learning.
- In the explanation phase in P-E-O-E, the teacher uses classroom dialogue and discursive moves to support students' deep thinking
  - press for reasoning
  - clarification
- Teachers need to be open-minded to support students on-going changes of scientific ideas.
- Students draw connections between the macroscopic phenomenon and the submicroscopic level of explanation (student-centred approach).

Redesigning the whole unit

- P-E-O-E approach
  - Mixing water and alcohol (liquid)
  - Solidification of candle wax (liquid → solid)
  - Dissolving table salt in water (liquid + solid → solution)
  - Injecting a drop of water into a hot syringe (liquid → gas, thermal expansion and contraction)
  - Watermelon and grape, which will sink? (Density)
- Purposeful design to support deep thinking
  - Classroom dialogue (to clarify and press for elaboration)
  - Student-centred (use of analogy and simulation) to facilitate student thinking (not to confer teacher's idea)
  - Students' ideas visualised through model construction and classroom talk
- Students' learning motivation
  - unfamiliar scenario
  - intuitive reasoning and cognitive conflicts

Science is fun, and is often counter-intuitive

More puzzling phenomena

- What would happen if 1 mL water is added into a very hot syringe?
- What would happen to the total mass and volume after dissolving?
- When a grape and watermelon is dropped in water, which one will float and which one will sink?

Even more puzzling phenomena are to be reframed by us and used in teaching.