Deploying differentiated inquiry-based learning activities to foster higher-order thinking skills and creativity

Ka Yeung POON

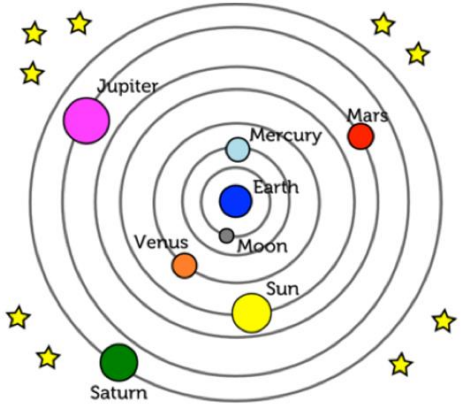
St. Paul’s School (Lam Tin)

Overview

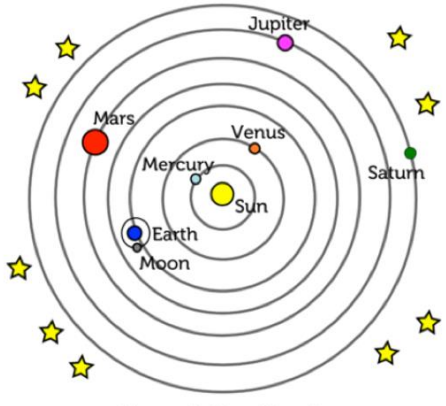
- Discussing how NOS is taught with the traditional approach
- Reflecting on problems associated with our usual practice and what to consider when rethinking the introduction of NOS
- Sharing of two lesson examples adopting differentiated inquiry-based learning activities

How do we teach NOS in S1 Introducing Science?

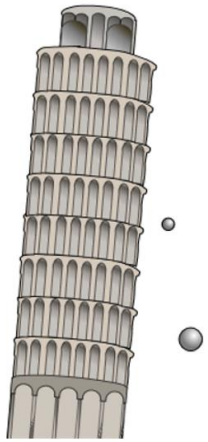
- Copernicus' proposal on heliocentric view opposing geocentric view?
- Galileo's experiment opposing Aristotle's idea?
- Barry Marshall's discovery on *H. pylori* causing gastric ulcer?

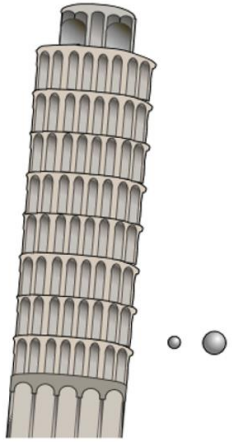


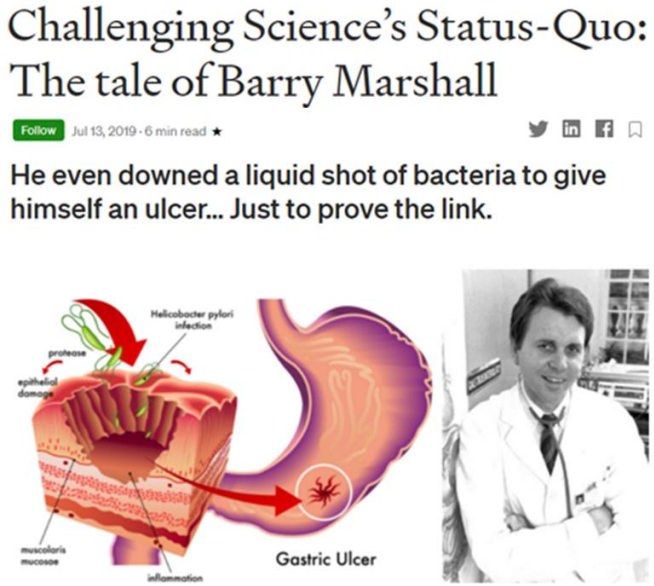
Earth at the Center



Sun at the Center


Aristotle


Galileo



Traditional approach

- Introduce tenets of nature of science
- Illustrate with ‘authentic’ examples

Problems associated with our usual practice

- Tenets of NOS were told at the beginning, the role of the ‘authentic’ examples is just to confirm what the teacher said.
- They are like pieces of fact to memorise.
- No connection to students’ prior knowledge and experience.

Black box investigation – the mystery tube

- Inquiry-based, hands-on activity used to explore the tenets of nature of science (NOS) through experiencing the process of authentic scientific inquiry (SI)

Stage 1: Engaging prior ideas

1 In the beginning of the lesson, each group of students were provided with a mystery tube.

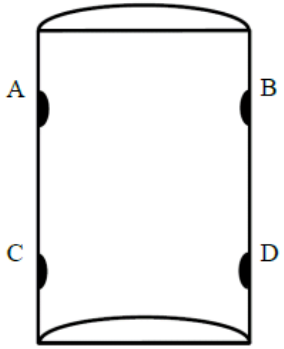
Stage 2: Constructing evidence-based claim

2 Students were asked to record their observation and propose the inner structure individually.

Task 2(a):

1. Complete the following table individually

Evidence	
If I pull A:	If I pull B:
If I pull C:	If I pull D:
Hypothesis	
I think the inside of the Mystery Tube like:	

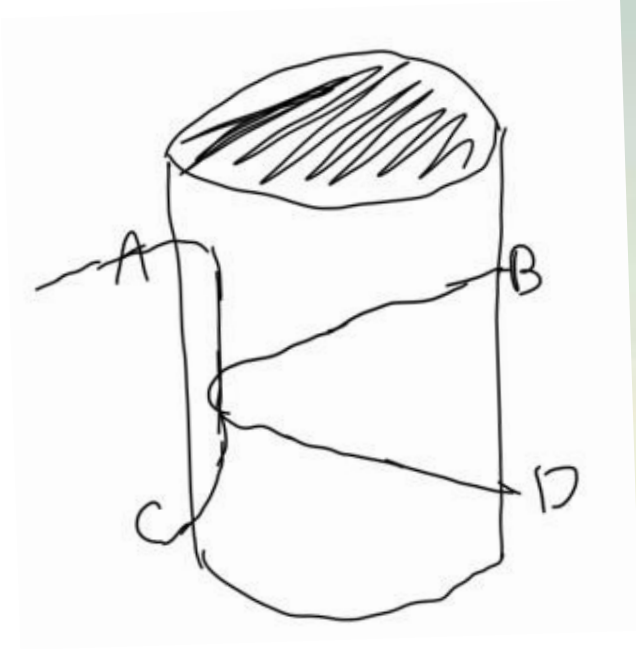


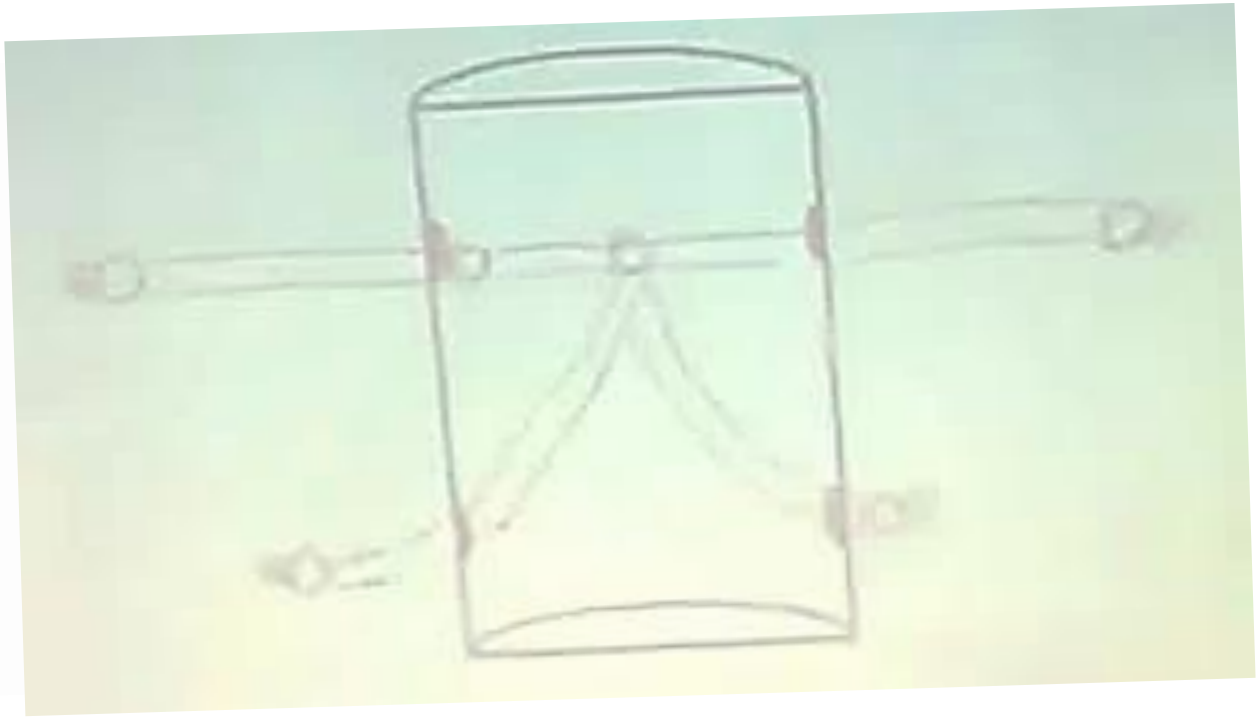
Stage 2: Constructing evidence-based claim

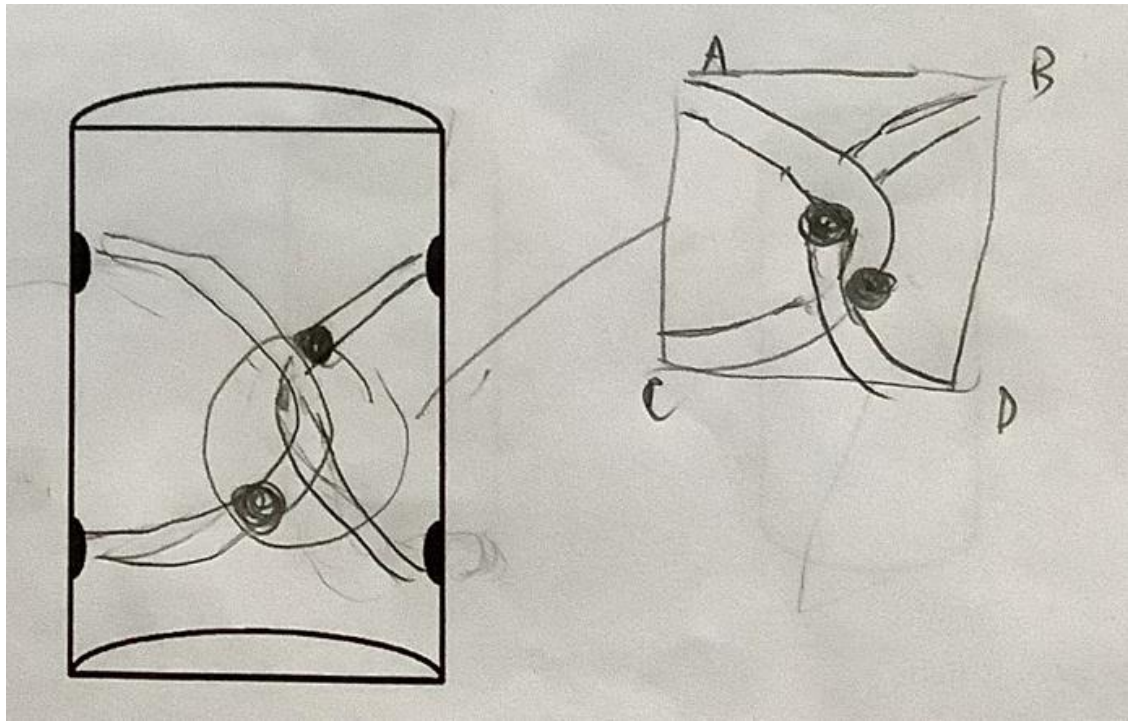
3 Students were asked to work in group and revise their initial thoughts after discussion.

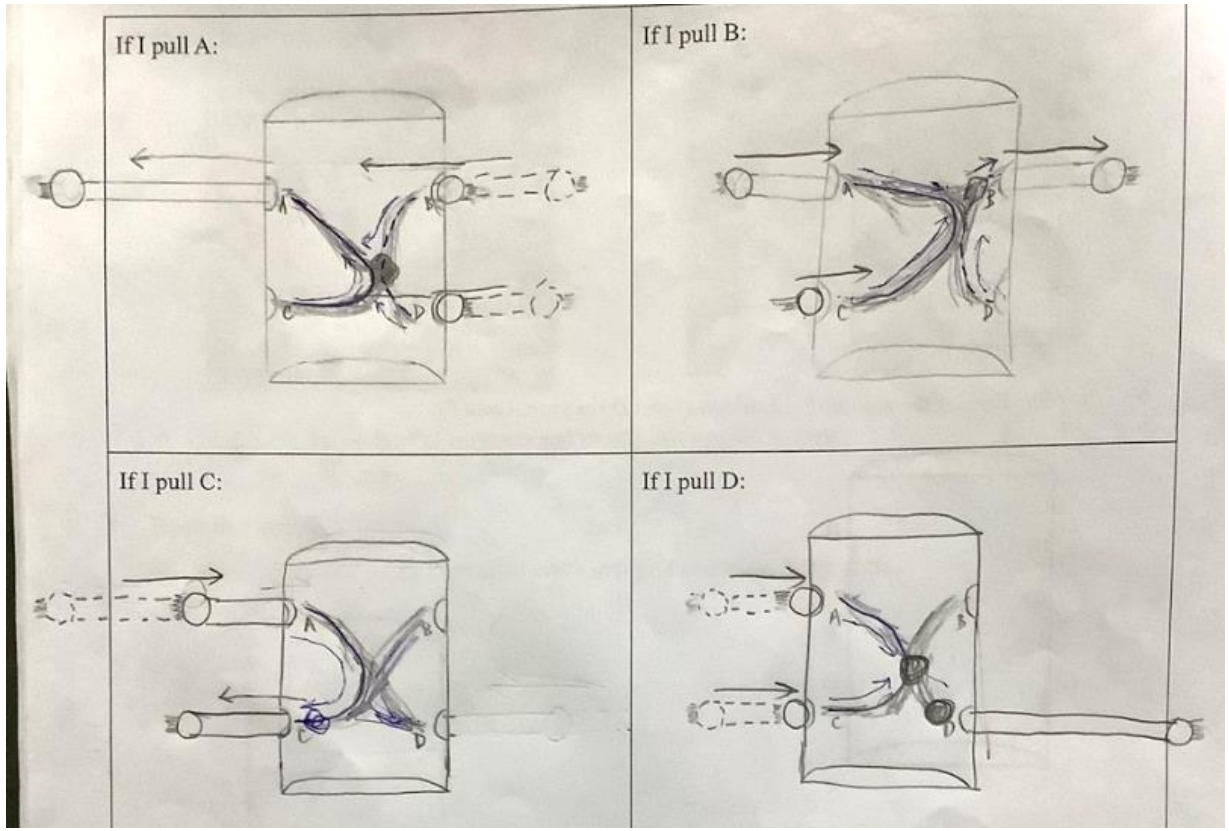
Stage 2: Constructing evidence-based claim

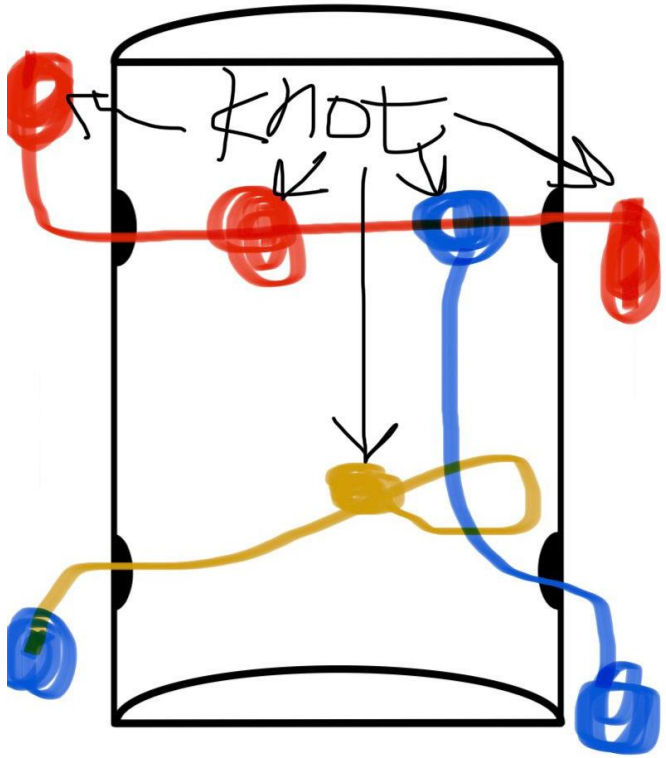
4 Students were invited to share their proposed model.

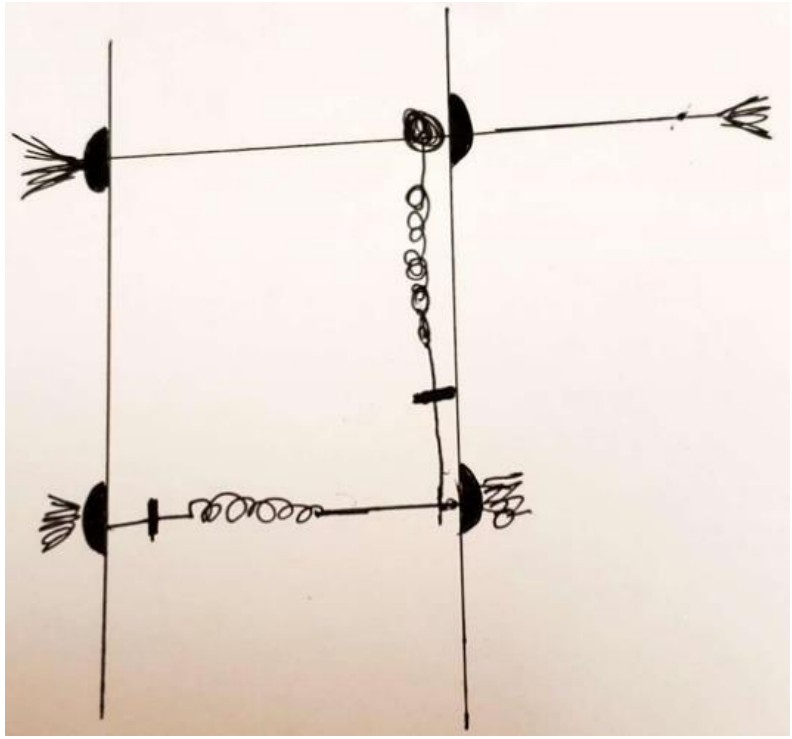

A
B
C
D




A
B
C
D


If I pull A:
If I pull B:
If I pull C:
If I pull D:


knot

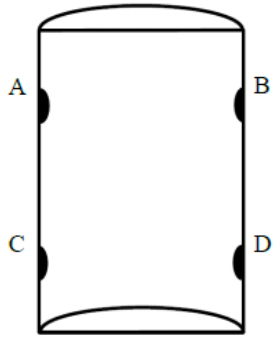


Stage 2: Constructing evidence-based claim

5 Students in each group were asked to consider alternative possible models that works and to share the model to the class.

Task 2(b):

1. Share your evidence and hypothesis with your classmates. Come to a consensus on your group's evidence and hypothesis.

Evidence	
If I pull A:	If I pull B:
If I pull C:	If I pull D:
Hypothesis	
I think the inside of the Mystery Tube like: 	

Stage 3: Explaining the underlying scientific principles

6 Guided reflection on the experience of the activity

Assignment

Compose a reflective writing journal about your learning experiences and views about the nature of science (NOS) and authentic scientific inquiry (SI).

Consider the following questions in your reflective journal:

- Did the mystery tube activity reinforce what you have known about scientific inquiry and NOS? How?
- Did the lab activity reveal any aspects of scientific inquiry and NOS that you have not noticed before? If so, what are those aspects?
- Is there any other things you would like to share with us?

Post-lesson assignment which Ss enjoyed

Ideas conveyed through the mystery tube

- tenets of nature of science (NOS)
  - science is a blend of logic and imagination based on evidence
  - science is empirical and inferential
  - scientific ideas are tentative to change
  - scientific knowledge has limitations
- authentic scientific inquiry (SI)
  - scientific inquiry is an iterative process
  - scientists use different ways to study the nature
  - scientists collaborative with each other

Questions which prompt Ss' reflection on NOS

- science is a blend of logic and imagination based on evidence
  - *You were never able to directly observe the inner structure of the tube. However you claimed to understand what is going on inside. Is your model valid even if you can never directly verify it?*
  - *In what ways were you creative during the activity? When might scientists have to be creative?*
  - *Is it possible to have more than one model that accurately predicts the observations? If so, how do you know which one is correct?*

Questions which prompt Ss' reflection on NOS

- science is empirical and inferential
  - *How often are scientists able to directly open their 'tube' when they study things that do not lend themselves to being 'opened'?*
  - *Do scientists always have someone to ask for the 'correct' answers? If not, how do scientists know their results are valid?*

Questions which prompt Ss' reflection on NOS

- scientific ideas are tentative to change
  - *I noticed you have changed your idea. What have driven you to make such a change?*
  - *Why is it okay for you to change your idea? When would scientists change their mind?*

Questions which prompt Ss' reflection on SI

- scientists use different ways to study the nature
  - *Why is it okay when different groups did different things during the activity?*
  - *Why might it be good that scientists try to solve problems in different ways?*

Questions which prompt Ss' reflection on SI

- scientists collaborative with each other
  - *I noticed all of you worked together during the activity. Why is working together useful?*
  - *Why do you think scientists often work together?*

How to succeed and how to fail?

- tell the ‘correct’ answer?
- direct students to a single correct answer?
- open the tube?
- give hints?
- establish an open and a non-judgmental environment?
- prompt students to think further?
- encourage students to build models?
- distinguish between observation and inference?

A way forward

- Pre/Post test
  - Before the activity, students' pre-instructional idea are elicited through mapping out their view of SI (e.g. show some cards)
  - After the activity, students' original map will be returned and they are asked to revise their view on SI.

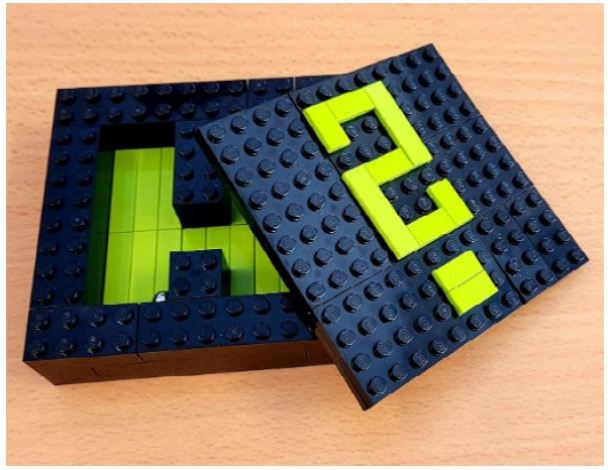
Task 1 – Mapping out scientific inquiry

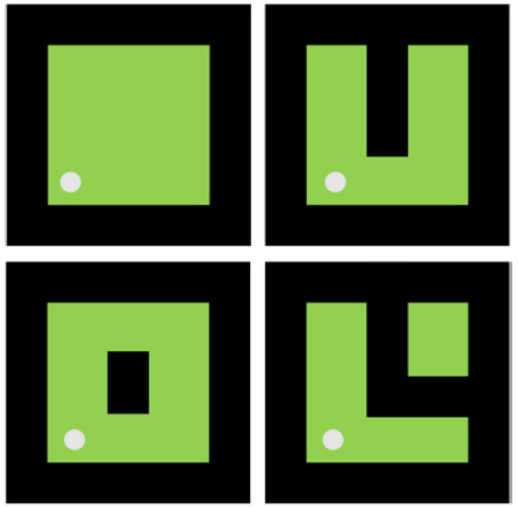
(Print out the inquiry slips below for students to arrange the sequence and present what the authentic scientific inquiry should be like.)

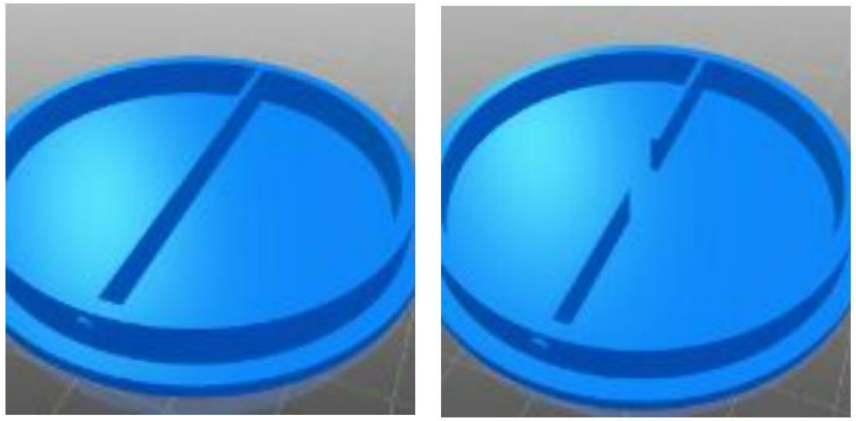
Carry out an experiment
Observe
Form the question
Design an experiment
Conduct background research
Define the problem
Articulate the prediction
Reflect on the findings
Communicate the findings
Propose hypotheses
Analyse the data
Interpret the results

A way forward

- lego-based mystery box / a 3D-printed mystery box
    - students use instrument to collect data (e.g. a magnet) mirroring scientific practice
    - students can build their prototype to test the model
    - easy to prepare







Summary of using mystery box to introduce NOS

Engaging prior ideas

- Construct initial model of the inner structure of the mystery tube.

Constructing evidence-based claim

- Make observation, collect data and infer the inner structure
- Discuss in group and revise their own model
- Consider alternative models that work

Explaining the underlying scientific principles

- Guided reflection with questioning prompts which linked to NOS
- Build model similar to the provided one

Introducing particle theory: solidification of wax

- Volume remains unchanged; conservation of mass

Stage 1: Engaging prior ideas

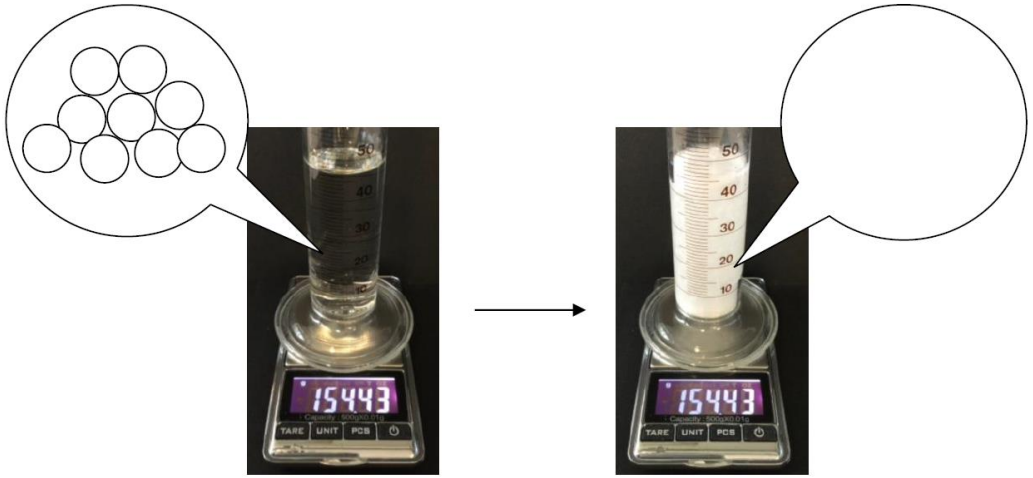
- The lesson begins by asking students to predict what would happen to the total mass and total volume when the molten candle wax is cooled down.

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.

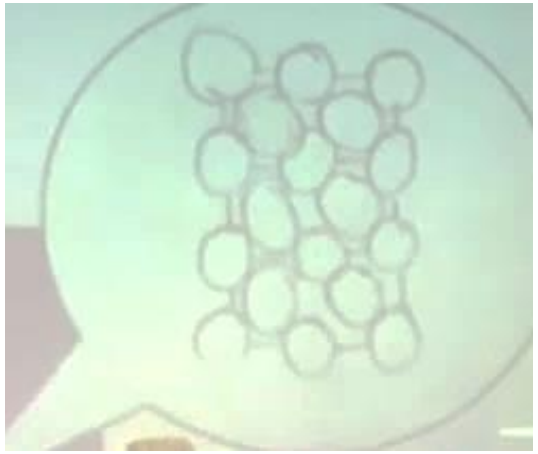
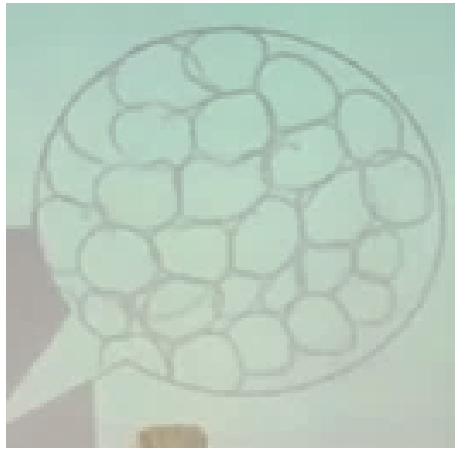
Stage 2: Constructing evidence-based claim

- 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 circulates to different groups and record interesting students ideas and then invite them for whole class sharing.



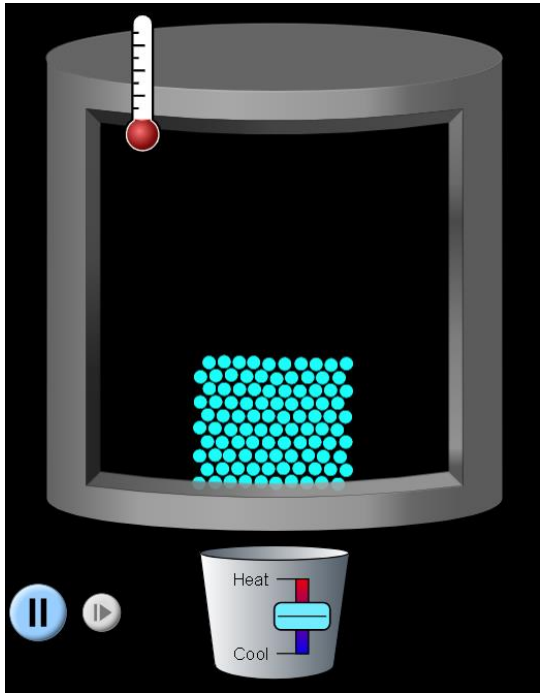
Stage 2: Constructing evidence-based claim

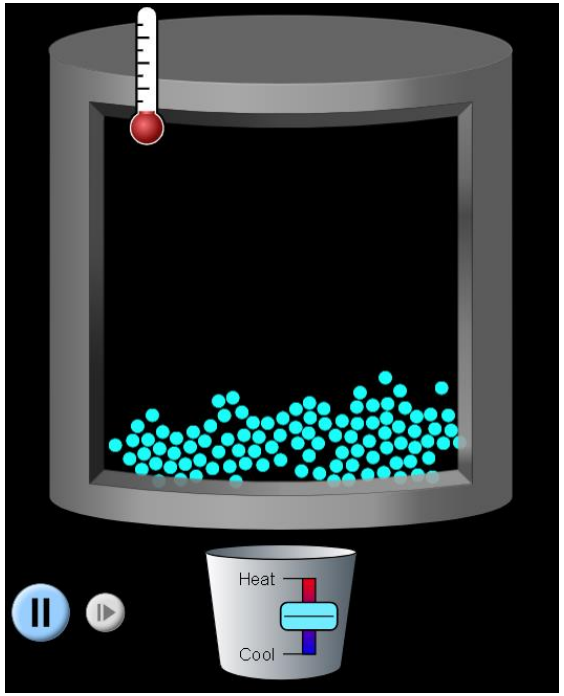
- Students compare their arrangement of the wax particles in groups. The teacher facilitates students' scientific reasoning and argumentation.
- Students debate among each other and evaluate possible particle diagrams. Then they reconstruction their best explanation towards the macroscopic phenomenon.

Stage 3: Explaining the underlying scientific principles

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





Highlight of this lesson design

- unfamiliar scenario used to arouse students' curiosity
- use of model
- classroom dialogue and discursive moves used to support students' deep thinking and on-going changes of scientific ideas (e.g. press for reasoning, clarification)
- evaluation and selection of the best model done by students
- simulation of melting helping students to figure out the best model that represent solidification

Summary of using solidification of wax to introduce particle theory

Engaging prior ideas

- Make prediction on the change in mass and volume of wax

Constructing evidence-based claim

- Formulate explanation by arranging of the wax particles
- Observe the experiment and collect data to revise their arguments
- Discuss in group and revise their own model

Explaining the underlying scientific principles

- Use simulation of melting to provoke students' thinking in figuring out the best model that represent solidification

Thank you

Contact info:

2347 2991 (Mr. K Y Poon) / 9097 3048

kypoon@spslt.edu.hk / kayeungpoon@gmail.com