Scaffolding Students' Argumentation in Science

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Mayflower Secondary School

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Overview

We aim to enable you to:

- appreciate why and how argumentation is critical in Science teaching
- use scaffolds for scientific argumentation
- examine the impact of literacy support for argumentation on students' learning in Science

What is Science Literacy? (PISA, 2015)

A scientifically literate person is willing to engage in reasoned discourse about science and technology which requires the competencies to:

Explain phenomena scientifically:
Recognise, offer and evaluate explanations for a range of natural and technological phenomena.

Evaluate and design scientific enquiry:
Describe and appraise scientific investigations and propose ways of addressing questions scientifically

Interpret data and evidence scientifically:
Analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions.

Focus of Inquiry

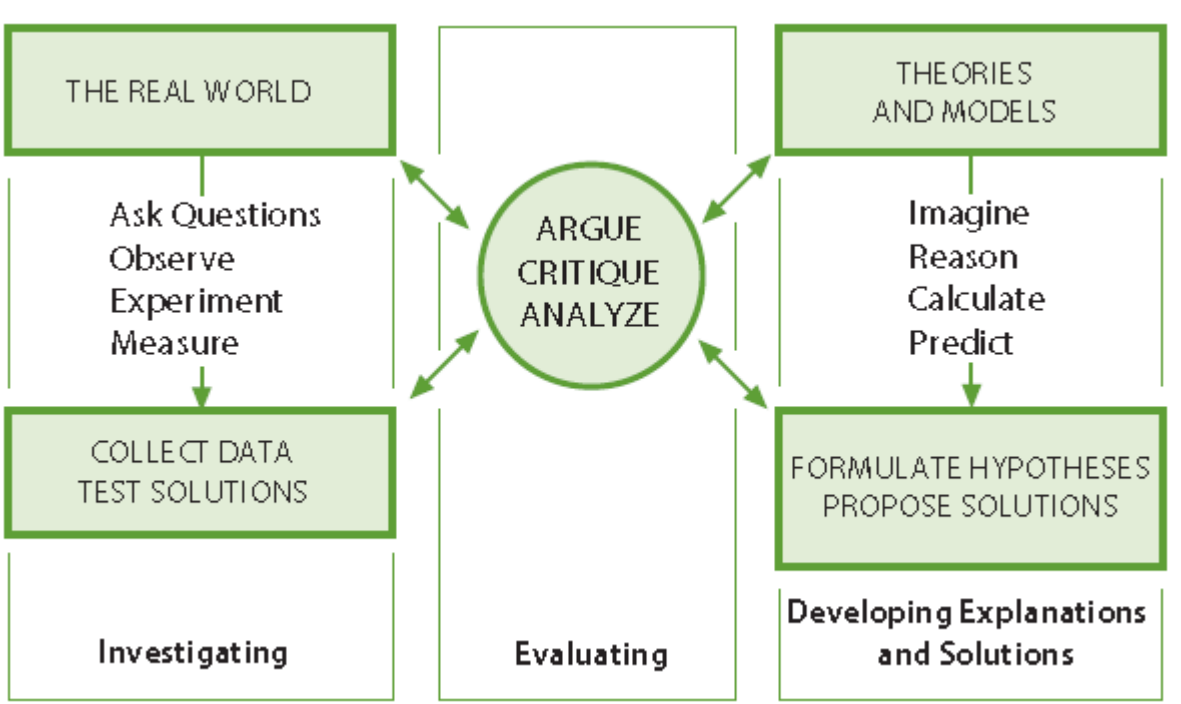
How can teachers support students in scientific argumentation?

Of specific interest:

- how can we scaffold students' construction of scientific arguments to enhance students' learning
- what are the pedagogical implications for classroom practitioners

Theoretical Underpinnings

Language of science



"The history of science is the history of vision and argument..."

Crombie; Tippett, 2009

Value of argumentation

Students who learn through social processes such as argumentation

- retain knowledge longer;
- perform better (Asterhan & Schwarz, 2007);
- learn community practices that promote scientific discourse (Erduran, Simon, & Osborne, 2004)
- use talk more effectively for reasoning

Scaffolding

- Scaffolding is ***assisted performance*** that guides a learner to complete a task and develop the capacity to manage learning independently (Scott,1997).
- It is ***temporary*** help that assists a learner to move toward new concepts, levels of understanding, and new language. (Gibbons, 2009)
- It is ***future oriented****:* in Vygotsky's words, what a learner can do with support today, he or she will be able to do alone tomorrow. (Gibbons, 2009)

Scaffolding Argumentation in Science

Argumentation Framework for Practitioners

Question Formats

Questioning that facilitates argumentative discussion, *e.g. Competing Theories, Concept Cartoons*

Scaffolds

Providing structures that develop students' logical reasoning, *e.g. Graphic Organizers, Framing Statements (PRO, ERC), Writing Frames*

Strategies

Using strategies that promote discourse, *e.g. Evidence Cards, Cooperative Learning*

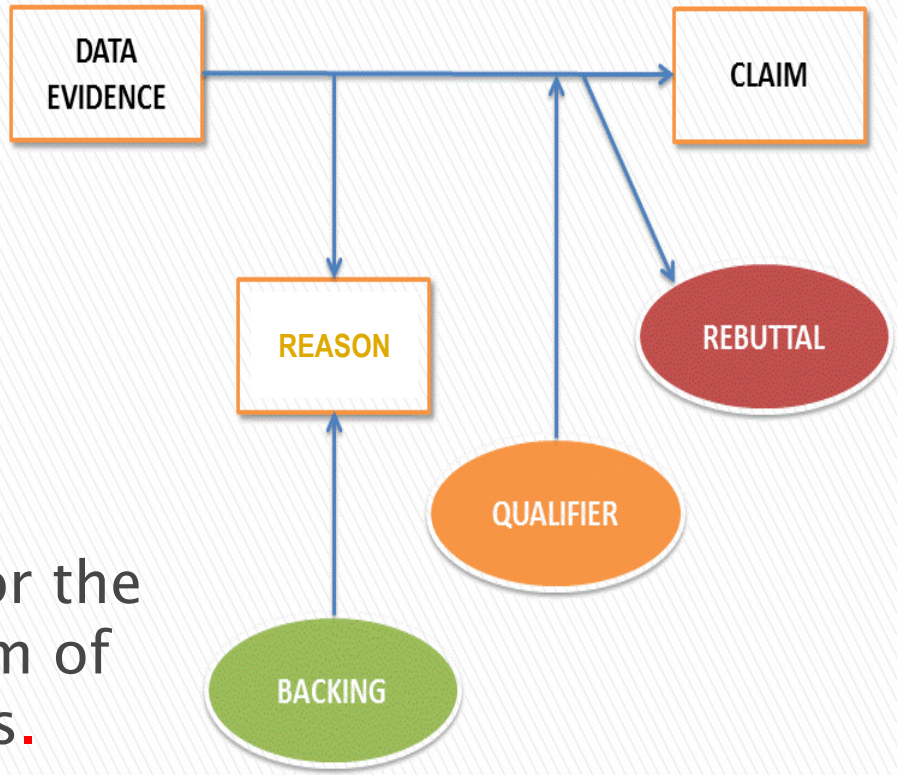
Argumentation for critical thinking

Question Formats

Questioning that facilitates argumentative discussion – *Osborne, Erduran and Simon (2001),* e.g.,

1. **Table of Statements**
2. Concept Map of Student Ideas
3. Report of Science Experiment
4. **Competing Theories—Cartoons**
5. Competing Theories—Story
6. **Competing Theories—Ideas and Evidence**
7. **Constructing an Argument**
8. Predicting, Observing and Explaining
9. Designing an Experiment

Toulmin's Argumentation Pattern (TAP)



A useful structure for the analysis and criticism of rhetorical arguments.

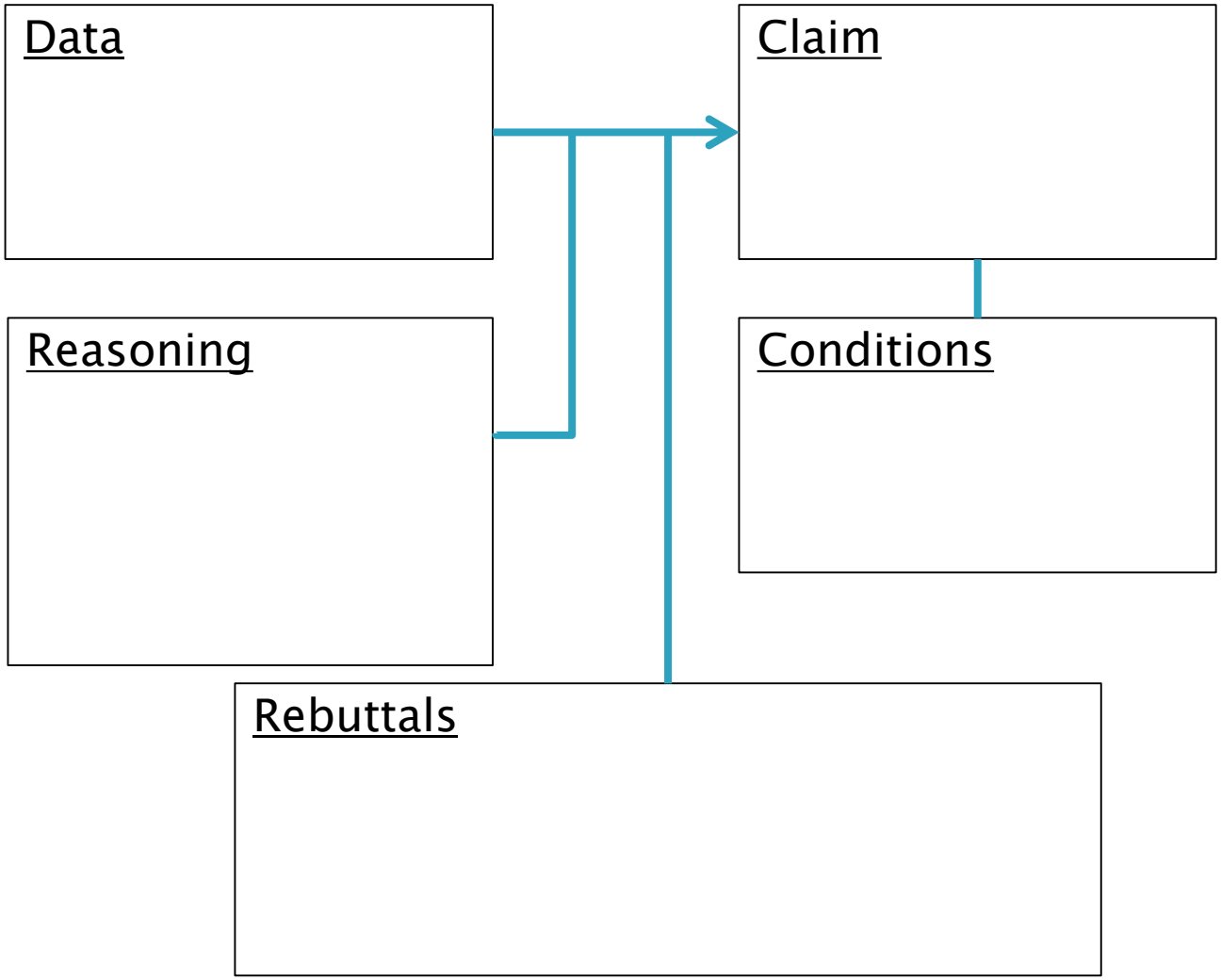
QUALIFIER	Conditions when the claim is considered true.
REBUTTAL	Conditions when the claim is not considered true.

TAP-Plate (Another Example)

Jack and Jill are astronauts on the moon.

They challenged each other and raced each other up a hill.

Will they be able to run faster, the same, or slower, as compared to on earth?



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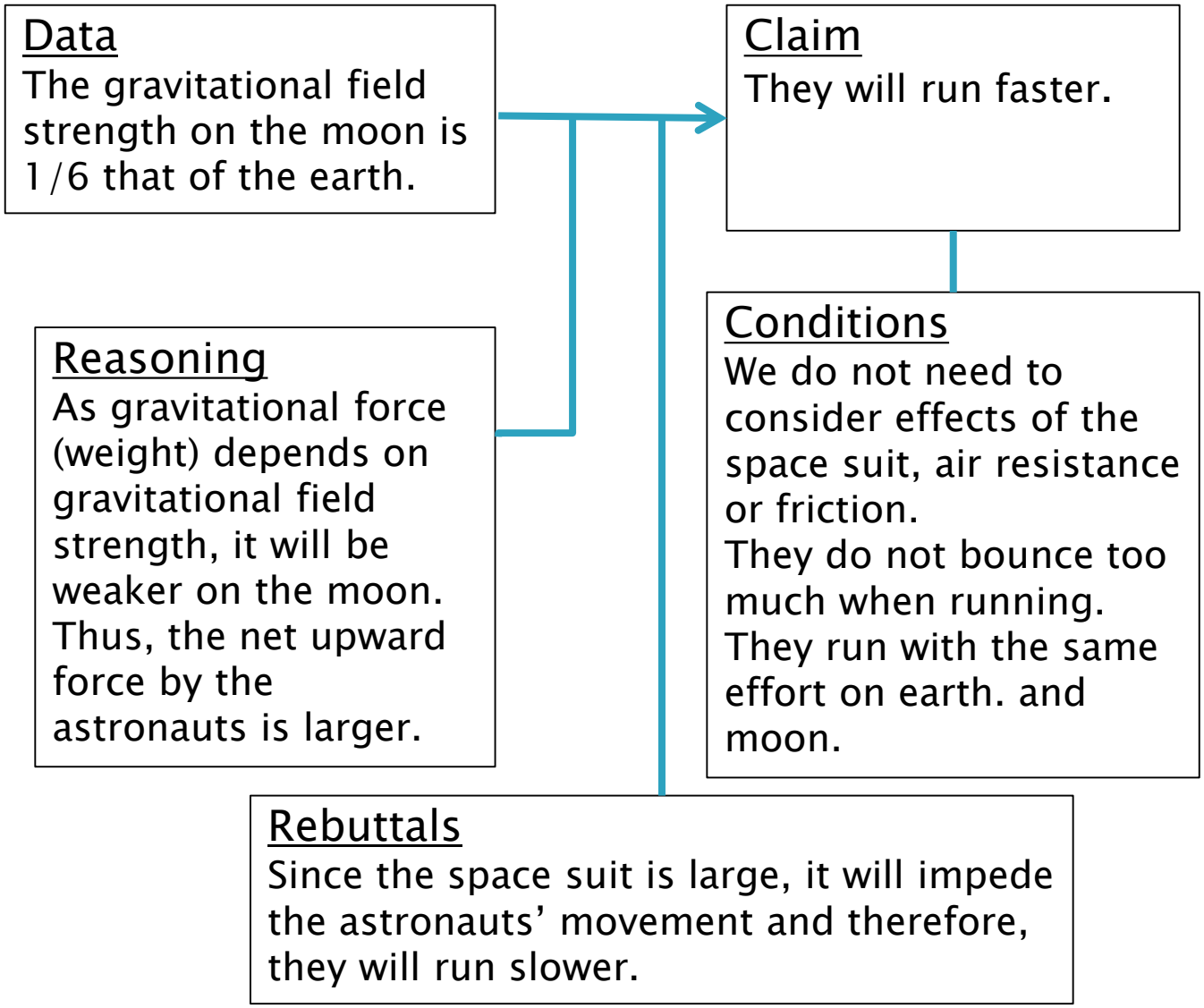


Scaffolding: Framing Statements (PRO)

Premises

Statement or fact held to be true that does not need explanation in the context of the explanation

- E.g. Laws, models, definitions, general facts, initial conditions

Reasoning

- Sequential chain of reasoning (cause-effect, temporal, contrast) that follows from the premises and links *deductively* the premise to the outcome

Outcome

- Phenomenon to be explained

Tang, K. S. (2015). The PRO instructional strategy in the construction of scientific explanations. *Teaching Science, 61*(4), 14-21.

Scaffolding: Framing Statements (ERC)

- **since** **[Evidence] …**
- **because** **[Reason] …**
- **therefore** **[Claim(s)]…**

Examples:

- Since the block was repelled when the magnet was brought close to it, and
- because only magnets can repel magnets,
- therefore, the block must also be a magnet.

Scaffolding: Writing Frames

- My idea is…
- My reasons are that…
- I believe my reasons because…
- Ideas against my idea are…
- I would convince someone who doesn't believe me by…

Evidence Cards: A Scaffolding Strategy

- Why
  - Comfortably examine 10-15 pieces of evidence in groups
  - Engaging cooperative learning pedagogy
- How
  - Teacher pre-prints each piece of evidence on a separate card/slip.
  - In class, argumentation question is first presented.
  - Cards/slips are distributed among group members.
  - Members discuss question based on the evidence assigned to each member.

Our Context

School and Subjects

Mainstream school	**Average to low socio-economic background**
Chemistry	(I): 2 Pure Chemistry Sec. 3 Express classes: 67 students
	(II): 1 Pure Chemistry Sec. 3 Express class: 33 students
	2 teachers (7 and 11 years' experience)
Physics	1 Pure Physics Sec. 3 Exp class: 32 students
	1 Combined Science – Physics Sec. 3 N(A) class:33 students
	2 teachers (5 and 15 years' experience)

Inquiry Process

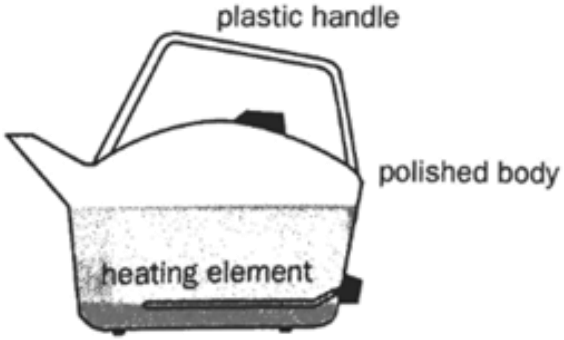
- 2-4 periods of Physics/Chemistry lessons
- Learning Design based on:
  - Pre-lesson Conference (during TTT)
  - Implementation in class (Teacher field notes and observations)
  - Post-lesson conference (Reflection and Consideration of adaptations for future iterations)
- Data sources
  - Teachers' instructional materials
  - Students' written work
  - Teachers' feedback from individual reflections
  - Students' feedback from interviews

Intervention using Toulmin's Model

Physics

- On the topic of Thermal Transfer: Conduction, Convection and Radiation
- Scaffolding argumentation using PRO as Framing Statements
- 1 lesson to explain the PRO scaffold
- 1 lesson to try argumentative explanations using PRO

(1) The figure below shows an electric kettle.



(a) Explain how the polished kettle surface helps to reduce the amount of electrical energy and time required to boil water in an electric kettle.

P: .....

.....

.....

R: .....

.....

.....

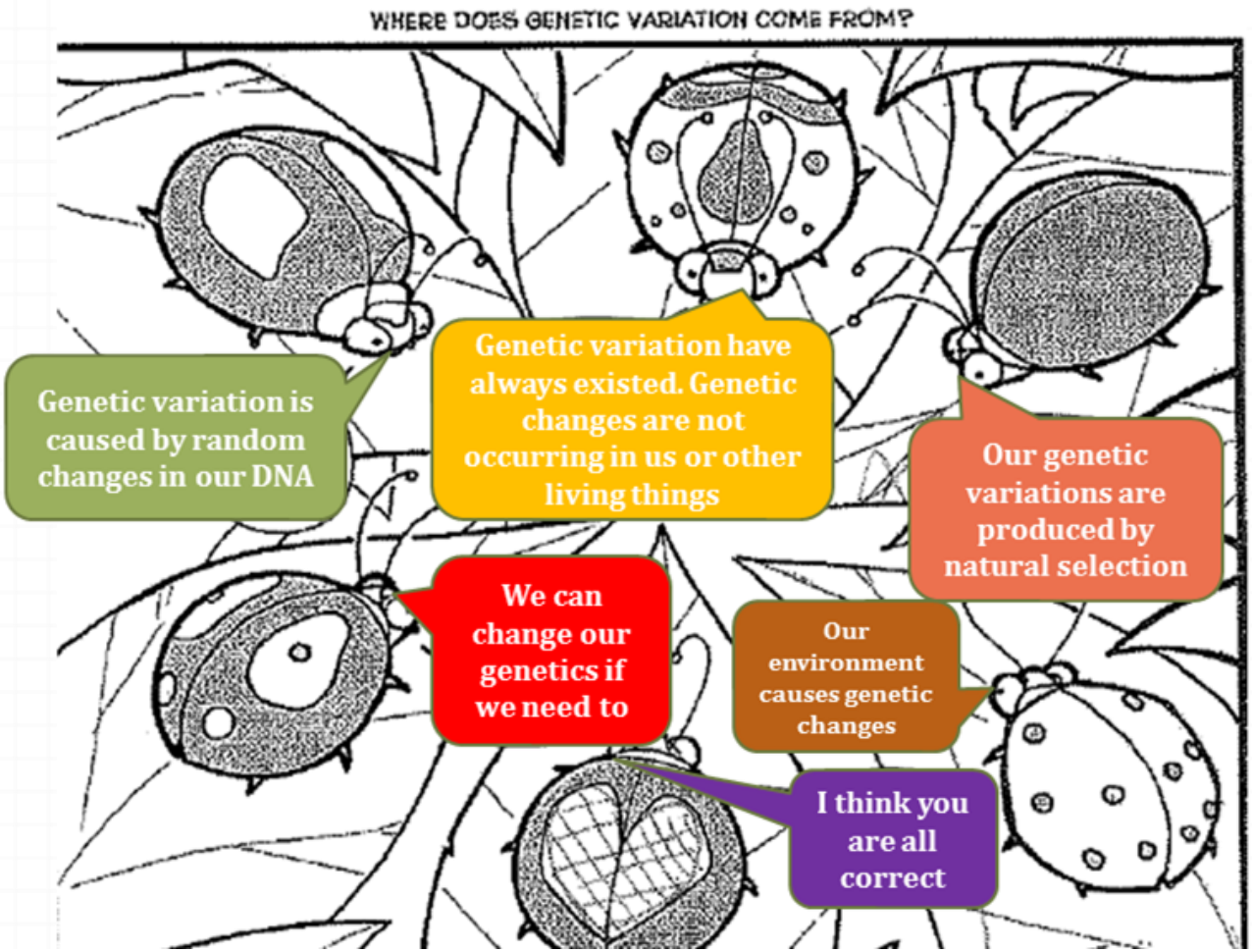
O: .....

.....

Source: Mayflower Secondary School

Biology Example (I)

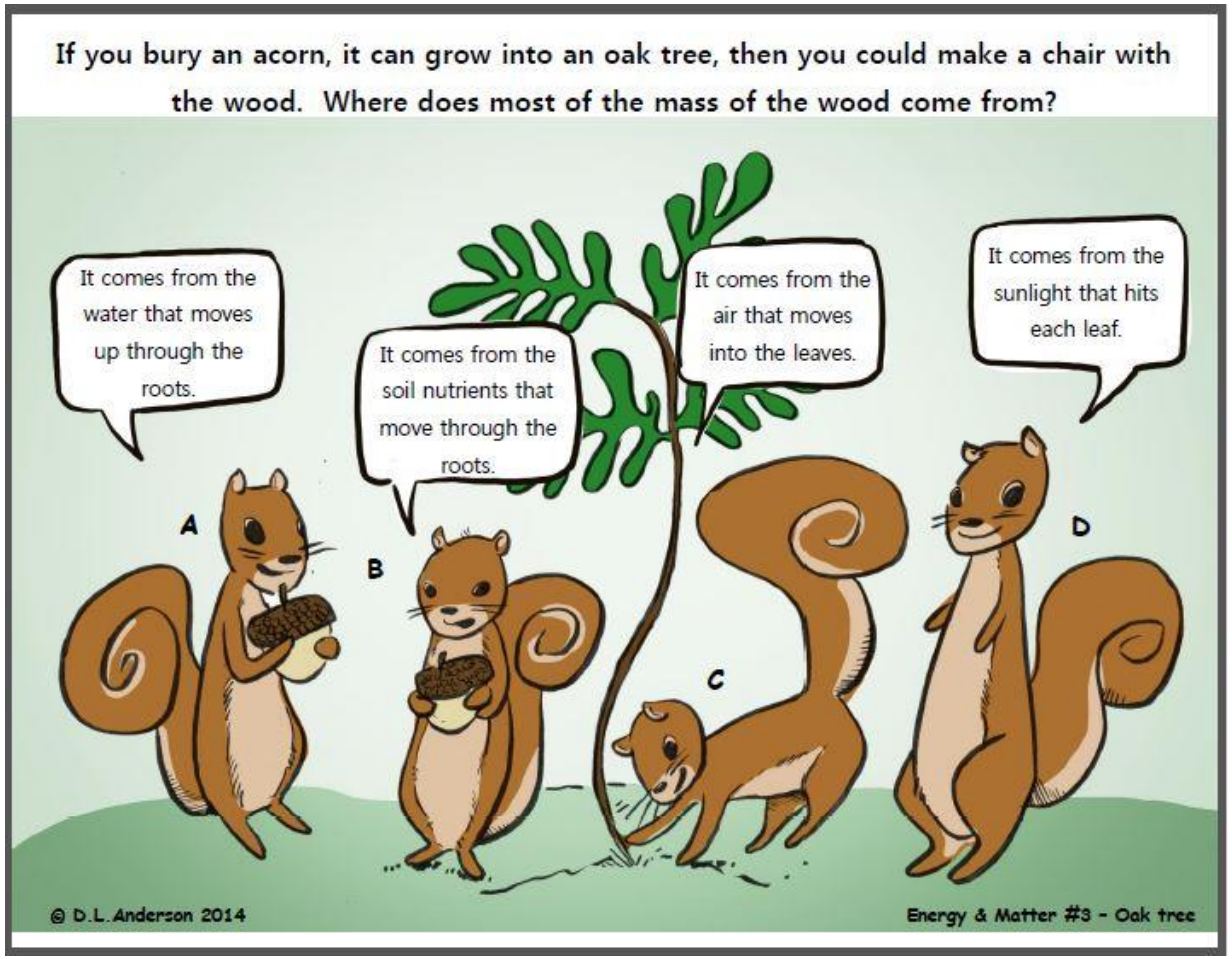
Competing Theories (Cartoon) as Question Format



Source: Point Loma Nazarene University

Biology Example (II)

Competing Theories (Cartoon) as Question Format



Source: Point Loma Nazarene University

Chemistry (I)

- On the topic of Kinetic Particle Theory
- Scaffolding argumentation using ERC as Framing Statement
- 1 period for trigger video, formulate explanation using ERC and discuss

Question:

Why do patterns form on the surface of the ice in the video?

Claims

1) Water vapour from the air is deposited on the ice surface due to the low temperature, forming the patterns.
2) The water beneath the ice froze, causing the pattern to appear.
3) Dust from the air gets too heavy in cold weather and lands on the ice surface, forming the patterns.

I believe that claim _____ is correct. My reason is

_____.

Chemistry (II)

- Topic: Chemistry Calculations
- Scaffolding argumentation using ERC with Evidence Cards as the scaffolding pedagogy
- 1 period for group discussion using Evidence Cards and TAP-Plate;
  2 periods for class discussion

Mole Is Hot

Phosphoric acid is a tribasic acid which means that it has three hydrogen ions to donate to a base in an acid-base reaction. 2 reactions occur in this experiment.

Reaction 1: $2H_3PO_4\,(aq) + 3CaCO_3\,(s) \rightarrow Ca_3(PO_4)_2\,(aq) + 3H_2O\,(l) + 3CO_2\,(g)$

Reaction 2: $H_3PO_4\,(aq) + 3NaOH\,(aq) \rightarrow Na_3PO_4\,(aq) + 3H_2O\,(l)$

Phosphoric acid was used to determine the percentage purity of a sample of chalk.

Procedure:

1. **Weigh an empty conical flask. Grind up some chalk and add a small amount of the powdered chalk into the conical flask. Reweigh the flask.**
2. **Add 25.0 cm^3 of 1.0 mol/dm^3 phosphoric acid to the flask.**
3. **Titrate the excess acid with 2.0 mol/dm^3 sodium hydroxide, using thymol blue as an indicator.**

Results:
Mass of empty conical flask = 76.18 g
Mass of conical flask + chalk = 77.37 g
Volume of 2.0 mol/dm^3 sodium hydroxide added = 28.50 cm^3

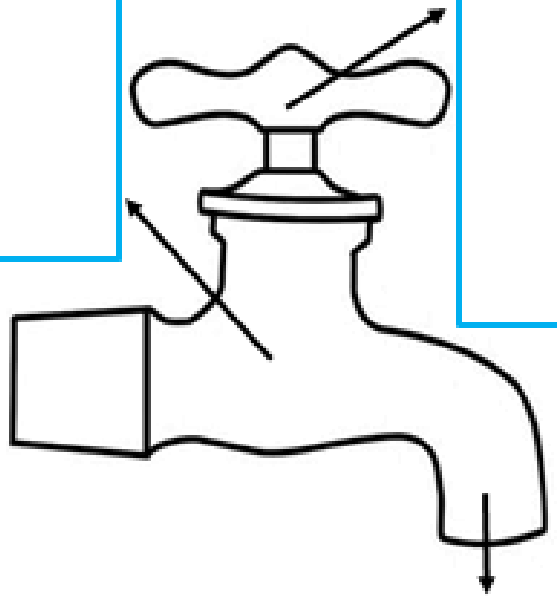
Determine the percentage purity of the sample of chalk. [7]

Source: Mayflower Secondary School

TAP-Template

2) Because…(reason/s)

1) Since …… (your evidence)



3) Therefore…(your argument / claim)

Source: Mayflower Secondary School

Our Reflections

Teachers' perspectives

- **Personal takeaways**
  - Helps in engaging students in class
  - Helps students apply what they have learnt in authentic situations
  - Helps teachers to detect misconceptions by students
  - Can be used as scaffolding for scientific explanations
- **Designing of task sheets / learning resources**
  - Teachers have to set questions that are more authentic
    - E.g. Sources from media sites and news
  - Worksheets may have to be scaffolded further to enable weaker students to participate
  - Students have to know their theory well beforehand to benefit fully from the lesson

Teachers' perspectives

- **Supporting classroom interaction during a lesson with argumentation**
  - Greater wait time to allow students to structure their answers
  - Students reminded to keep answers short due to time constraints
  - Students to value the answers given by their classmates instead of putting down answers that challenge theirs
- **To develop and pursue further**
  - Introduce elements such as rebuttal and qualifiers in TAP-Plate for students who show greater aptitude
  - More questioning resources to help students use the argumentation framework

Students' perspectives

- **How students benefitted from argumentation**
  - Students were able, through the TAP-plate, to deconstruct complex questions
  - Helped to structure students' thinking and responses, particularly with higher order questions
  - Helped students to be more self-aware of parts of the theory that they are strong / lacking in
  - Helped students to retain knowledge when they used the theory to answer questions through the TAP-Plate

Students' perspectives

- **Students' concerns regarding argumentation**
  - Students may not be comfortable in using argumentation framework. More practice and feedback from the teachers needed.
  - Some students found it initially hard to apply the framework:
    - 'Not my studying pattern'
    - 'My answers come naturally'

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» Thank you!

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