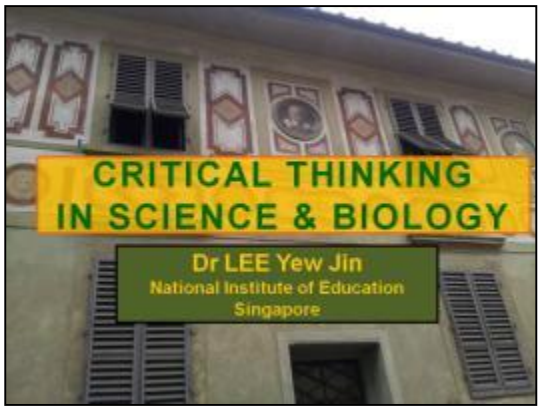


OUTLINE

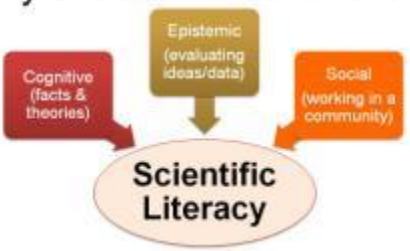
- Science teaching then & now
- What lies at the heart of science?
- Critical thinking & argumentation:
  1) Structural/formal methods
  2) Organic communication
  3) Problem-based triggers
- Various classroom HOT strategies

Science Learning (formerly?)

Textbook
Teacher talk
Hands-on activities

QUESTION:
What do we know?

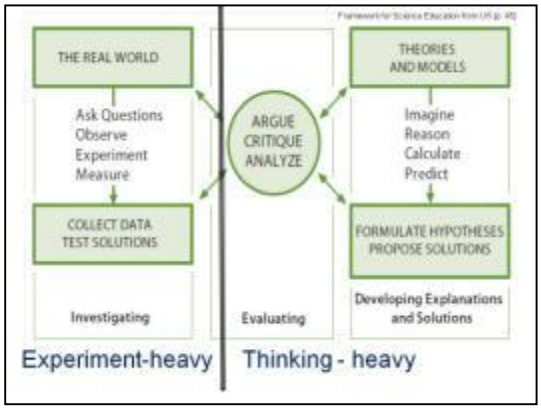
QUESTIONS:
How do we know?
Why should we believe it?

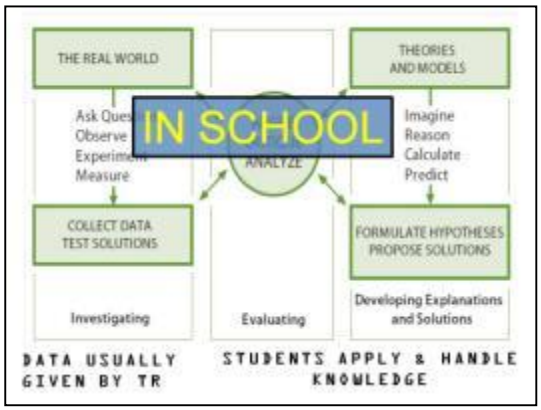


Literacy defined:

- 1st sense of being literate i.e. to read, write, communicate in science
- 2nd deeper idea of knowing how to ask right questions, collect data, make or apply theories/models, & persuade with evidence

→ overlaps a lot with "reasoning" or "inquiry"





Argumentation is great way to demonstrate & handle knowledge

- When lawyers argue, only one will eventually win
- When scientists argue, they use shared scientific data & language, but both want to find the truth about nature → both "**win**" because they achieve a better or new understanding of the world

Argumentation benefits

- Learn content & processes
- Fosters scientific literacy
- Participate in scientific practices e.g. vocabulary & debates
- Develops critical thinking & communication skills
- Scientists argue **ALL** the time because peer review/critique is perhaps even more crucial than making new discoveries!

Contd.

- Explanations are therefore central to science
- Theories, models and concepts that make up explanations were often hard-won; sometimes through centuries of debate others through accumulated or new data
- But school science sometimes gives the impression that "facts" are obvious or natural, appeared without argumentation in peer-review

Anderson et al (2001, p. 84)

'CRITIQUING LIES AT THE CORE OF WHAT HAS BEEN CALLED CRITICAL THINKING'

However

- Students find it very hard to participate in argumentation, why?
  - Unable to handle content & process
  - Unable to mount good reasons, don't make use of evidence, biased etc
  - Syllabus doesn't have enough compelling topics
  - Don't have enough time to learn & rehearse
  - In Asian contexts, Trs & Ss fear "arguing" & conflict, respect & discipline concerns

Not at all: advance organizers, concept mapping, wait time, collaborative group work, questioning, classroom climate etc

IS ARGUMENTATION THE "BEST"?

Ways to enhance scientific reasoning aka argumentation

1. **Fixed structure method/templates** eg teaching language grammar rules or soccer via weekly skill sets
2. **Immersion method** eg "just speak/spell the language" or soccer via mini-games
3. **Problem-based** eg students learn about science and practices by being challenged by an authentic issue

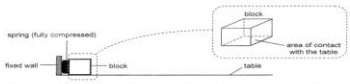
Which is better?

- All have pros & cons and depends on how explicit/implicit you want to be, Tr & student readiness, your school contexts etc

EXAMPLES OF ARGUMENTATION IN TEACHING

1) C-R-E applied as answering technique

Minghao conducted an experiment using the set-up shown below



He measured the distance the block moved after releasing the spring. He repeated the experiment using blocks made of the same material, but with various mass and area of contact with the table.

His results are shown below.

block	mass (g)	area of contact with the table (cm^2)	distance moved (cm)
F	30	100	12
G	40	100	9
H	40	150	9

(a) Based on Minghao's results , what is the relationship between the mass and the friction on the block? [1]

CLAIMS

(b) Based on Minghao's results, did the area of contact with the table affect the friction on the block? Explain how you came to your conclusion. [1]

REASONS

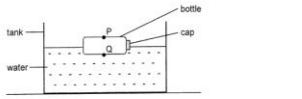
(c) Minghao repeated the same experiment using another block W. Block W is made of the same material as F, G and H. The mass of W is 30g and its area of contact with the table is 150 cm^2.

What is the distance moved by W? [1]

EVIDENCE

(2014/(B)/42)

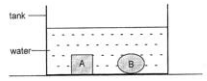
(a) Minghan placed an empty bottle with two holes at point P and Q into a tank of water as shown.



Give a reason why the bottle sank after a while. [1]

REASONS

(b) Minghan put objects A and B into a tank of water. He observed that both objects sank to the bottom of the tank as shown.

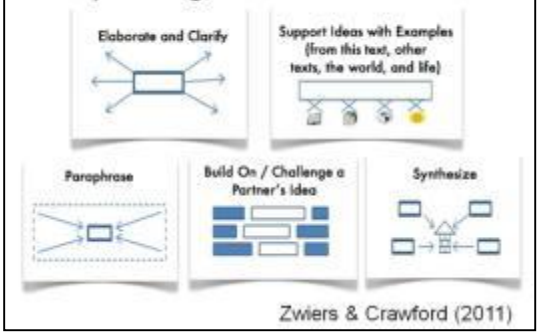


Can Minghan conclude that objects A and B were made of the same material? Give a reason for your answer. [1]

REASONS // REBUTTAL

(2013/(B)/38)

2) Dialogic Skills



Zwiers & Crawford (2011)

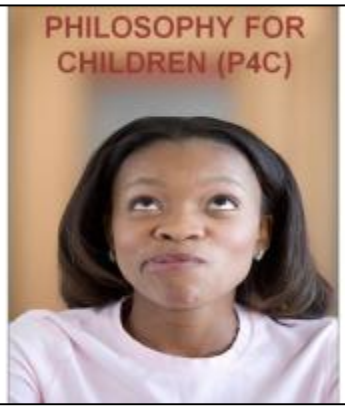
Robin Alexander's Dialogic Teaching

- **Supportive**: Opinions without fear, supporting each other to reach common understandings.
- **Reciprocal**: Listening to each other, sharing ideas, consider alternatives.
- **Collective**: Addressing learning tasks together.
- **Purposeful**: Planning and steering talk with specific educational objectives in mind.
- **Cumulative**: Building on each other's ideas, chaining coherent lines of thinking.

A f L?

Epistemic discourse activities (Ohlsson, 1996)

Discourse Activity	Description
Describe	Obtain an accurate conception of an object or event
Explain	Understand why an event happened
Predict	Being convinced that an event will happen (under certain circumstances)
Argue	State reasons for or against a position on an issue
Evaluate	Be aware of good & bad points
Clarify	Acquire a clearer understanding of meaning
Define	Propose a usage for something (overlaps with clarify)



3) Socioscientific Issues (SSI)

- No distinctive pedagogy, more like a collection of strategies eg project work, PBL, debates and student-led research
- Flexible, powerful, applicable to daily life yet can be very challenging for Trs & Ss:
  - Should we eat less meat to help save the planet?
  - Should Sg consider using nuclear power?
  - Kids build, curate, & sustain an insectarium…

Ways to begin in school?

- Discuss CRE framework with Ss
- Model & critique examples
- Connect to everyday issues
- Provide Ss with feedback
- Ss engage in peer critique
- Debate arguments as whole class

McNeill (2011)

Note that:

- Quality of arguments will be uneven when Ss don't have enough practice, the issue is not compelling/interesting/appropriate, and the classroom climate doesn't welcome failure or extended Ss talk
- Also, it depends on the cultural resources Ss bring, Tr scaffolds, & assessment demands

1. HOT QNS

Revised Bloom's taxonomy (2001)

	Verbs of Cognitive Processes					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual						
Procedural						
Metacognitive						
Nouns of Knowledge						

Invert the questions

- Instead of asking LOT eg is this flower insect- or wind-pollinated, we move up in the Taxonomy to ask which is "better"?
- Instead of asking what is the optimum temperature for this enzyme, we might ask "What are the implications of wide/narrow optima for a class of enzymes?"

2. Translation

- Music lyrics, song, rap, dance
- Poetry, art, drawing, metaphor
- Taking pictures, collections, journalism
- Telling stories ← → graphs, through science fiction, movies
- Prove me wrong, find what's incorrect
- Cheat sheets?

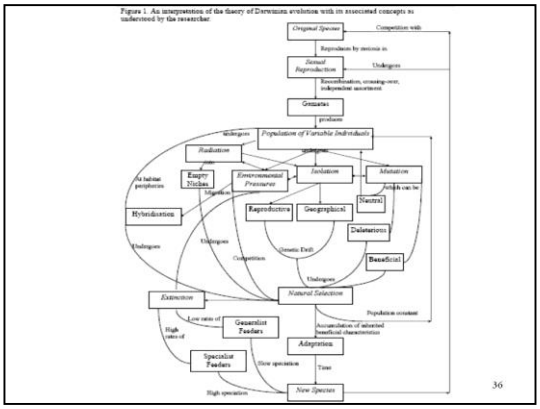
→ Much processing of ideas, not just memorization when Ss do translation work!

3. CONCEPT MAPS

Score table: Concept maps

	Points
Valid cross-link	10
Valid hierarchy	5
Valid concept link	2
Valid example	1

35



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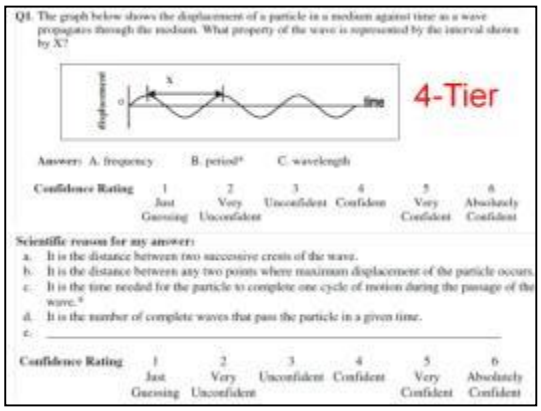
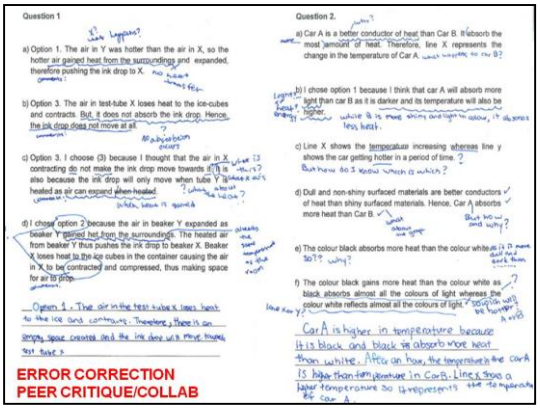
4. Tiered MCQ



WHICH LEVEL DO YOU THINK THIS CAME FROM?


Question 1

a) Option 1. The air in Y was hotter than the air in X, so the hotter air gained heat from the surroundings and expanded, therefore pushing the ink drop to X.

b) Option 3. The air in test-tube X loses heat to the ice-cubes and contracts. But, it does not absorb the ink drop. Hence, the ink drop does not move at all.

c) Option 3. I choose (3) because I thought that the air in X contracting do not make the ink drop move towards it. It is also because the ink drop will only move when tube Y is heated as air can expand when heated.

d) I chose option 2 because the air in beaker Y expanded as beaker Y gained hot from the surrounding. The heated air from beaker Y thus pushes the ink drop to beaker X. Beaker X loses heat to the ice cubes in the container causing the air in X to be contracted and compressed, thus making space for air to drop.

Option 1 - The air in the test-tube X loses heat to the ice and contracts. Therefore, there is an empty space created and the ink drop will move towards test tube X

Question 2.

a) Car A is a better conductor of heat than Car B. It absorb the most amount of heat. Therefore, line X represents the change in the temperature of Car A.

b) I chose option 1 because I think that car A will absorb more light than car B as it is darker and its temperature will also be higher.

c) Line X shows the temperature increasing whereas line y shows the car getting hotter in a period of time.

d) Dull and non-shiny surfaced materials are better conductors of heat than shiny surfaced materials. Hence, Car A absorbs more heat than Car B.

e) The colour black absorbs more heat than the colour white as

f) The colour black gains more heat than the colour white as black absorbs almost all the colours of light whereas the colour white reflects almost all the colours of light.

Car A is higher in temperature because it is black and black is absorb more heat than white. Also on how, the temperature the car is higher than temperature in Car B. Line X shows a higher temperature so it represents the temperature for car A.

ERROR CORRECTION
PEER CRITIQUE/COLLAB

5. Assertion-Reason

Assertion:
Tony Blair is the best leader the Labour Party has ever had

Reason:
His policies on Europe have been the most carefully thought out

Put a tick in each line, then give reasons for your choice

	Right	Wrong
Assertion	√	
Reason		√

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- The reasons for my decision is because Mr Blair is indeed an excellent leader for the Labour party by winning the elections twice but this is due to his economic policies rather than his handling of foreign affairs.

45

- Both statements written as complete sentences in their own right
- May or may not be a connection between them but a connection is implied
- Students decide whether the statements themselves are true or false and if they are linked as implied

46

Assertion:
Natural selection is the main mechanism of biological evolution

Reason:
NS ensures survival of the fittest in nature

Put a tick in each line, then give reasons for your choice

	Right	Wrong
Assertion		√
Reason	√	

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Assertion:
Mammals are warm blooded as their body temperature is 37°C

Reason:
Enzymes work best near an optimal temperature of 37°C

Advantages

- Students give own critical viewpoints
- No blind copying or guessing
- Active learning as students have to *solve* something i.e. they have to make a decision based on reasoned argument

50

Marking

- Rather rapid and easy to set
- Be prepared for novel arguments (i.e. claims, reasons, & evidence)

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Learners have to

- Coordinate & verify [high-order skills]:
  Claims (Assertions)
  Reasons
  Evidence

6. Guided Arguments

I. "ERROR CORRECTION" WITH SAMPLES OF GOOD/BAD C, R, E

II. UNDERSTANDING EVIDENCE

Is *Eulgena* a plant or animal?

- Use four different colouring pencils to shade in each of the boxes below. Use this key to show what the colours mean:

☐ Evidence that suggests *Euglena* is a plant
☐ Evidence that suggests *Euglena* is an animal
☐ Evidence that suggests *Euglena* is **either** a plant or animal
☐ Evidence that suggests *Euglena* is **neither** a plant nor an animal

From King's College London

Euglena does not have a cell wall	*Euglena* contains chloroplasts
Euglena has a nucleus	*Euglena* is a single cell organism
Euglena can absorb food from its surrounding	*Euglena* confused early scientists
Euglena is normally green	The nucleus contains DNA and controls the cell.
Chroloplasts enable a cell to photosynthesise	A vacuole controls the amount of liquid in a cell
Euglena swims through water	*Euglena* can make its own food
Euglena has a vacuole	*Euglena* is light sensitive
Euglena contains cytoplasm	*Euglena* can change its shape
Euglena live in ponds and puddles	*Euglena* is temperature sensitive
Euglena can reproduce	There are more than two classification groups

Conclusion sheet

1. Having considered the arguments, do you think *Euglena* is a plant or animal?
2. Explain below how you came to your decision. Identify the evidence you used and explain why it may have been difficult to decide.

III. SIMPLE TRAINING IN FORMING ARGUMENTS

Heavier things do not always fall faster

Look at the following statements of evidence. Discuss them with the others in your group and put them in a logical order to justify the statement above.

- A penny and a brick reach the ground at the same time when dropped from the same height.
- Air resistance is a force which opposes motion.
- All things fall at the same rate if you ignore air resistance.
- A piece of paper falls much more slowly than a brick.

Osborne, Erduran, Simon & Monk (2001)

7. Refutation Texts

COMPLEX TRAINING

Refutational Writing

- Trigger = common idea/misconception & Ss then attempt to refute it
- Trs should outline all info a learner needs to write e.g. topic, audience, purpose, format, # words, & due dates for drafts & final etc
- Ss will present both sides, but then proceeds to argue how one view is better supported logically
- Textbooks usually one-sided representations, although not good research reviews for eg
- Lots of practice definitely required!

8. Structural Communication Grids

Johnstone, Bahar & Hansell (2000) in Journal of Biological Education

[1]Activation of embryo	[2]Synthesis of amylase	[3]Breakdown of starch
[4]Release of gibberelins	[5]Synthesis of protease	[6]Diffusion of glucose or amino acid to embryo
[7]Stimulation of aleurone layer	[8]Water absorption by seed	[9]Breakdown of protein to amino acids

Above are the metabolic reactions which happen during mobilisation of food stores in seed germination. Use the numbers from the boxes to answer the following questions. Each number can be used more than once.

65

Q1. Which boxes contain the reactions which happen during metabolism of carbohydrate reserves in seed germination?

- A) Select the relevant boxes …….
- B) Put your selection into a logical sequence……

- Ans: 8, 1, 4, 7, 2, 3, 6

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SCG

- Data presented in numbered grid
- Student select appropriate boxes and place them in logical sequence in response to a set of questions
- Gives insight into sub-concepts & linkages between ideas held by students
- Deep level of understanding can be assessed & diagnosed

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How to make SCG?

- Ask a question
- Write a fair answer
- Break answer down into component parts
- Scatter *randomly* across grid
- Ask a second related question and follow the same method
- Continue if necessary

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- Can add distractors
- Students select and put in sequence (a mini-essay)
- As student imposes order, s/he communicates ideas from the random grid hence the name SCG
- 9 boxes for secondary school, or 12 for higher levels

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[1] **radiated into new habitats**	[2] **lack of predators**	[3] **evolved into different species**
[4] **different reproductive patterns**	[5] **lack of food**	[6] **isolated from other populations**
[7] **different weather patterns**	[8] **Finches arrived by chance**	[9] **unable to recognize conspecifics**

Q1 Describe the evolution of Darwin's finches.

a) Which are the relevant boxes?

b) put your answers in a logical sequence

Q2 What prevented the newly evolved species from mating with the ancestral ones?

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Scoring

$$\frac{\text{Number of relevant pieces chosen}}{\text{Number of relevant pieces available}} - \frac{\text{Number of irrelevant pieces chosen}}{\text{Number of irrelevant pieces available}}$$

73

Scoring

- Scores range from –1 to +1
- E.g. There are 7 correct boxes out of 9 in total in a SCG
- A student chooses 5 of these 7 and 1 from the 2 irrelevant boxes
- Score = 5/7 – ½ = 0.21
- To convert to upon 10
  - Add 1, multiply by 5 = 6.06 = 6/10

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Advantages

- Contents can be in words, pictures, numbers etc
- No guessing as pupil does not know how many boxes needed and its sequence
- No guessing by elimination
- Objective scoring
- Partial credit given
- Good revision tool as it checks concepts in related areas

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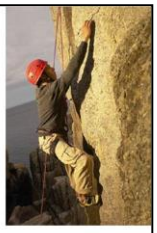
Learners have to

- Coordinate & verify [high-order skills]:
  - Claims
  - Reasons
  - Evidence

Hard Decisions

Time, Effort, Context

Ss Learning



ENCOURAGING MEMORIZATION
OR *MEANINGFUL LEARNING*?
PREPARING FOR A LIFE OF TESTS
OR *THE TEST OF LIFE*?

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Everyday HOT

- Bloom's Taxonomy
- Translation work
- Concept Maps

Everyday CRE

- Sorting Ranking Sequencing
- Tiered MCQ
- Assertion Reasons
- Guided Arguments
- Refutation Texts
- SCG

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Penanya : Ibu Wahyuni, IKIP PGRI Madiun.
Pertanyaan : Apa sebenarnya yang dimaksud *claims* pada pembelajaran? Apakah sama dengan *problem* dalam pembelajaran? Lalu apakah C-R-E hampir sama dengan diskusi?
Jawaban : *claims* lebih seperti suatu pernyataan atau ungkapan yang dibuktikan dengan *evidence*. C-R-E berbeda dengan diskusi, karena C-R-E merupakan cara yang digunakan untuk membuat suatu argumentasi siswa, sedangkan untuk melakukan suatu diskusi dibutuhkan *skill* yang lebih kompleks lagi yaitu kemampuan untuk berdialog atau *dialog skills* seperti yang dikemukakan oleh Alexander Robin bahwa kemampuan berdialog terdiri dari lima aspek yaitu: dukungan, timbal-balik, penuh tujuan, kumulatif, dan bersama-sama.

Penanya : Universitas Palangkaraya
Pertanyaan : Apa indikator atau parameter dari berpikir kritis siswa?
Jawaban : berpikir kritis siswa dapat dilihat dari jawaban atau *reasoning* yang diberikan oleh siswa itu sendiri. Siswa yang mampu berpikir kritis juga mampu didiagnosa dari hasil belajarnya, apakah siswa tersebut mendapatkan good poin atau bad poin. Siswa yang berpikir kritis dapat berargumentasi dengan menggunakan C-R-E, bukan masalah benar atau salah argumentasi yang diberikan namun bagaimana cara siswa menghubungkan argumentasinya dengan alasan dan bukti yang diberikan.