

Teaching Undergraduates to Think- from Parrots to Professionals



Tina Overton

University of Hull

and

Higher Education Academy

Physical Sciences Centre



From Parrots.....

- Rote learning and good memory is well rewarded
- Lower order cognitive skills required to succeed
- Factual subject, right or wrong
- No opportunity for discussion or opinion
- Unrelated to practice



The problem

- lectures - didactic, passive
- laboratories - recipe driven, closed
- problem solving - exercises, routine
- lack of creativity
- little discussion & opinion



The result

- Passive students who want to be told what to think



To Professionals.....

Higher order cognitive skills

- critical thinking
- analytical approach
- data interpretation
- tackling unfamiliar, open-ended problems
- application of chemical knowledge etc, etc



And incidentally.....

- Communication
- team working
- time management
- negotiation skills
- information retrieval
- independent learning
- enthusiasm, etc, etc



What's needed?

- The opportunity for students to learn how to reason, question, evaluate, use judgement, tackle unfamiliar problems, form opinions
- Learning opportunities that integrate application of knowledge, independent learning and problem solving with the development of professional skills and generate enthusiasm



Using problem solving to develop professional skills

- not exercises
- related to applications/contexts
- incomplete/excessive data
- require cooperation
- require interpretation/evaluation of outcomes
- not necessarily single answer/goal
- gives something to discuss



Problem Types

Classification of Problems (Johnstone, 1993)

Type	Data	Methods	Outcomes/Goals	Skills Bonus
1	Given	Familiar	Given	Recall of algorithms.
2	Given	Unfamiliar	Given	Looking for parallels to known methods.
3	Incomplete	Familiar	Given	Analysis of problem to decide what further data are required.
4	Incomplete	Unfamiliar	Given	Weighing up possible methods and then deciding on data required.
5	Given	Familiar	Open	Decision making about appropriate goals. Exploration of knowledge networks.
6	Given	Unfamiliar	Open	Decisions about goals and choices of appropriate methods. Exploration of knowledge and technique networks.
7	Incomplete	Familiar	Open	Once goals have been specified by the student, these data are seen to be incomplete.
8	Incomplete	Unfamiliar	Open	Suggestion of goals and methods to get there; consequent need for additional data. All of the above skills.



What is critical thinking?

- Essential graduate attribute
- Higher order cognitive skill
- ‘The intellectual process of actively conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from observation, experience, reflection, reasoning, or communication.’



Can critical thinking be taught?

- **The Critical Thinking Community**
 - > Definitions, guides, conferences, etc
 - > <http://www.criticalthinking.org/>
- **Austhink: Critical Thinking at Work**
 - > Good list of weblinks
 - > <http://www.austhink.org>
- **Mission:Critical**
 - > an interactive tutorial for critical thinking, lots of exercises
 - > <http://www2.sjsu.edu/depts/itl/index.html>



Mission:Critical

Causal arguments

Five people became sick at the company picnic. Which might be considered the most significant commonality of their illness?

- A. They all work in marketing
- B. They all ate potato salad
- C. They all went home early
- D. They all ran in the three legged race



Thinking Skills Assessment

- Used for admissions at Cambridge and Oxford
- Developed to differentiate between very good applicants
- Context free
- Used to test, not developmental
- <http://tsa.ucles.org.uk/index.html>



Understanding argument

- Every year there are 25000 car fires in the UK, yet it is estimated that only 5% of motorists carry a fire extinguisher. If more motorists could be encouraged to carry fire extinguishers then the number of car fires could be considerably reduced.



Which of the following is the best statement of the flaw in the argument?

- A. It ignores the fact that millions of motorists have never experienced a fire.
- B. It assumes that carrying a fire extinguisher will enable fires to be put out.
- C. It implies that the occurrence of car fires is related to the lack of an extinguisher.
- D. It overlooks the possibility that fires might not be put out by an extinguisher.
- E. It ignores the fact that there are different types of extinguisher for different kinds of fires.



Subject specific exercises

- Can we explicitly develop critical thinking skills within science?
- Are there exercises available?
- Can we use context free exercises as a model?
- Development vs assessment?



A Question of Chemistry

- Used the Cambridge TSA model to develop chemistry versions
- Understanding argument
- Constructing argument
- Critical reading
- Using judgement
- Reference trails



Understanding argument

A Mo atom has six valence electrons. Carbon monoxide may act as a two electron donor when coordinated to a transition metal atom as a ligand. Hence the total number of valence electrons on the Mo atom in $\text{Mo}(\text{CO})_7$ would be $6 + (7 \times 2) = 20$. $\text{Mo}(\text{CO})_7$ is therefore unlikely to be stable.

Which one of the following is an underlying assumption of the argument above?

- A. The compound $\text{Mo}(\text{CO})_6$, with exactly 18 valence electrons, is very stable.
- B. Organometallic compounds of transition metals with more than 18 valence electrons on the central metal are rarely stable.
- C. CO ligands are π acids.
- D. 6-coordinate compounds are more stable than 7-coordinate compounds.
- E. $\text{Mo}(\text{CO})_7$ cannot be an octahedral compound.



Constructing an argument

- A. A solution containing thiocyanate gives a red colour with the Fe^{3+} ion.
- B. Solution X gives a red colour with Fe^{3+} .
- C. Solution X contains thiocyanate.



Critical reading

In the vapor phase, alkali metal halides are present mainly as ion pairs, but measurements of bond lengths and dipole moments suggest that under these conditions electron-sharing is also involved to a considerable extent, especially for the lithium halides.

Sharpe A G, Inorganic Chemistry (3rd edition), Longmans, 1992.

Which one of the following statements best represents the key point of the passage?

- A. Alkali metal halides are predominantly ionic.
- B. Measurement of bond lengths and dipole moments are effective methods for estimating electron-sharing.
- C. Alkali halides exhibit some covalent character.



Literature trails

A paper by Woodward and Schwartz entitled 'In Situ Observation of Self-Assembled Monolayer Growth'. (*J. Am Chem Soc* 1996,118, 7861) presents the first in situ images of SAM growth proving molecules aggregate into dense 2 dimensional islands as monolayers from solution.

- a) What are SAMs?
- b) SAMs of dialkyl ammonium salts monolayers on mica have previously been studied. What method was used to obtain the images? What did these images show?
- c) According to Woodward and Schwartz what formation process do the SAMs demonstrate?
- d) What factors are the extent of monolayer island growth proportional to?



Choose from the list below the type of water which, if any, would be acceptable for use in each of the following cases?

- (a) drinking
- (b) keeping fish
- (c) making up standards for trace metal analysis
- (d) cooling water in a power station
- (e) turbine water in a power station
- (f) water for injectable pharmaceuticals

sea water

river water

tap water

deionised water

distilled water



Using judgement - Estimations

We shed our outer skin completely approximately every three weeks.

(a) What weight of skin do we lose during this time?

(b) What does this imply in terms of molecules of amino acid incorporation into the skin per second?



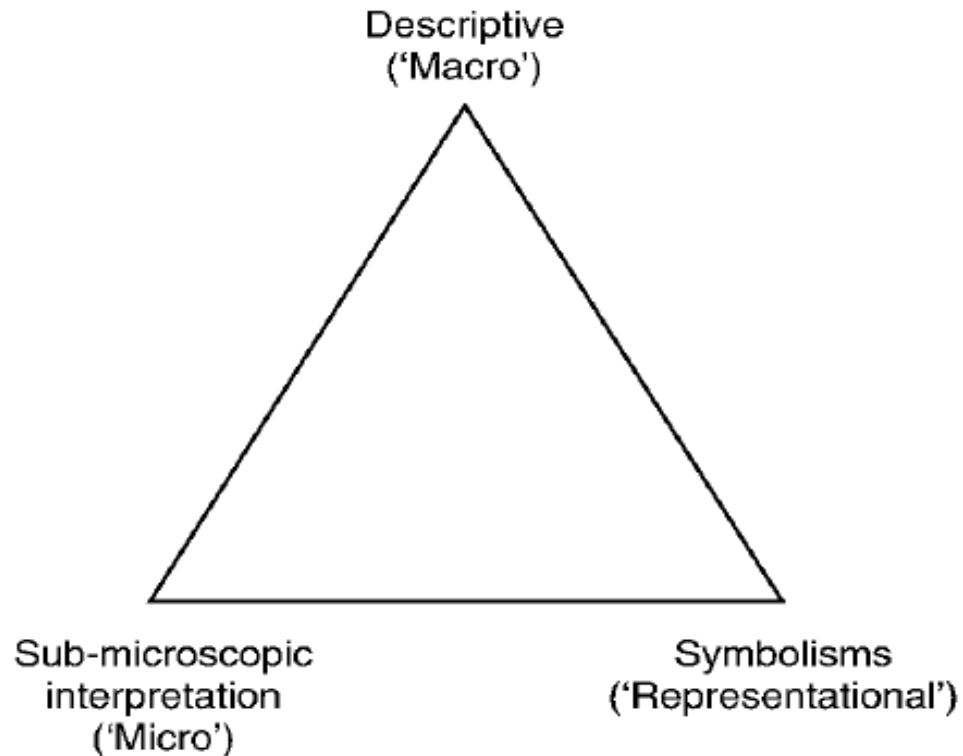
CBL Case Studies

- problem scenarios
- involve the learning of chemistry
- are active in style
- involve a work-related context
- involve personal skills development
- encourage reflective learning
- have clear learning objectives for students



Use of context

Johnstone 1991



Outcomes

- A deeper understanding of the subject
- Motivation
- Engage with complexity and ambiguity that exists in real life
- Independent and collaborative learning
- Skills
 - Critical skills, Problem solving, Group working, Critical analysis, Communication, Presentation, Information retrieval



Contexts for Chemistry

- environmental
- industrial
- forensic
- analytical
- pharmaceutical
- materials



Silicon chemistry

- Some undergraduates in the literature department are taking a module on science fiction. A theme that they come across time and time again is silicon-based life forms. Some of these students are also taking a module in film studies and this same theme has arisen in some films that they have been researching. From their limited knowledge of chemistry they do not understand why such life forms could not theoretically exist. Their tutor has invited you to speak to them and to explain why nature is carbon-based and silicon-based life is best left to fiction.



The Titan Project

- Based around industrial production of titanium dioxide pigment
- 2 processes
- Millennium Inorganic Chemicals, Tioxide
- Consider industrial production in context of economics, environment, safety, politics, social issues
- Part time vs full time students



What do they have to do?

- Justify keeping the site
- consider pros and cons of each process in a wide context
- develop 5 year plan
- make recommendations to the Board - fully justified
- plan new environmental monitoring lab
- compare methods of analysis
- evaluate statistical data
- make recommendations



Evening Herald

Volume 17 Issue 25

Serving the County of Midshire.

Local Elections Loom

Local MP for Beauport East, Simon Ford officially opened his election campaign on Tuesday to a packed hall. As he put it 'the two biggest issues facing the town today' are unemployment and the environment. A representative of the nearby nature reserve said later that he was encouraged but remained yet to be convinced.

'Industry must clean up act'

After a lengthy investigation, the Midshire Water Authority has condemned local industry for its poor pollution record.

A report issued this week highlights the need to clean up the Coley River and Estuary. Local environmental groups (supported by MP Simon Ford) have called for a dramatic reduction in

Local Success Stories

This week our weekly feature highlights two different stories of recovery in the local area.

Workers Save Mill

Two months ago, the Paperpak Ltd. paper mill, west of Beauport faced almost certain closure. Today, however, managers are discussing expansion plans after securing a new contract with the government. Paperpak Ltd. will supply high quality paper for use in official documents in a 10 year deal of undisclosed value.

A spokesman on behalf of owner John Tate said 'The credit must go to our workers who have put in a great deal of extra work over the last year.' Paperpak is hoping to employ 100 more staff on the completion of the expansion work which is necessary to equip the mill to supply the

Next week

"I was given 3 months to live....in 1957", a local farmer's battle to prove the doctors wrong.

Political Row over Water Treatment Plant

At a recent dinner, MP Simon Ford claimed the soon to be opened water treatment plant as part of his 'Environment and Employment' campaign. However the opposition claim that the Beauport East MP has had little to do with the development until recently.

The plant should be operational within 12 months and should have a major effect on the state of the estuary.

Titan to Send in Top Management Team



THE UNIVERSITY OF HULL



S.Summerfield 2002



THE UNIVERSITY OF HULL

Assessment

- Strategy vs solution
- Presentations, reports, reviews
- Individual vs group assessment
- Peer assessment of group contribution



Observations...

- Motivation
- Context must not alienate students
- Part-time vs full-time student performance
- Online versions
- Collaborate and re-purpose existing resources
- Positive feedback - students, external examiners



The best thing about this course was.....

Group problem solving

Preparing me for employment

Got me doing things I'm not very good at

Developing communication skills

Interacting in a group

Not just some bloke at the front talking chemistry



And finally.....

'The long years of education are mostly concerned with knowledge. Fact is piled upon fact and little if any time is spent thinking'

'On the whole it must be more important to be skilled in thinking than to be stuffed with facts'

De Bono, The 5 Day Course in Thinking, 1967



Acknowledgements

- John Garratt
- Simon Belt
- Stephen Summerfield
- RSC Analytical Trust Fund
- RSC Cutter Bequest
- Undergraduates at Hull

