Chemed research - where do we go from here?

A summary of the presentation by: Prof. Alex H Johnstone (Centre for Science Education, University of Glasgow) To Chemical Education Research Group RSC 7th September 1999.

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Unpalatable observations over the past forty years:

1. Student numbers coming into chemistry have fallen, and continue to fall
2. It is increasingly difficult to recruit good chemistry teachers
3. Since the early 60s we have been inundated with chemistry schemes and courses full of promise (e.g. Chem.Study; Chem.Bond; Nuffield; Salters'; Science for 70s) most of which have come and gone leaving the promise unfulfilled
4. Research has unearthed a plethora of problems and solved almost none of them. Research literature has been dominated by work on pupils' misconceptions
5. The general public are still not keen to understand chemistry
6. A sure way to kill conversation at a party is to confess that you are a chemist!

There have been a number of fashionable developments, including:

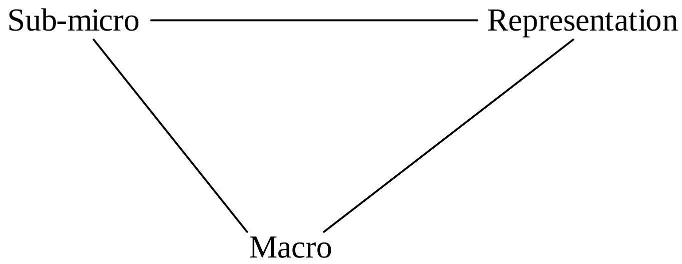
- microchemistry
- demonstrations
- textbooks
- computer-assisted learning
- CD ROMs
- societal issues

However, by and large, these have addressed ways of transmitting chemical knowledge and understanding rather than critically examining course content (i.e. emphasis has been on 'how', rather than on 'what'). There are problems with Chemed research. The Journal of Chemical Education largely ignores it - less than 2.5% of articles over a six month period in 1996-97 related to it. The International Journal of Science Education is dominated by research into 'alternative frameworks' (36%). This encourages negative research practice and it seems that the editors are controlling the orientation of research.

The need to introduce 'modern ideas' into chemistry courses was signalled at the 'Greystones' conference' (1961) which led, in part, to Nuffield developments with its logical view of modern chemistry. It is ironic that this seems to coincide with the start of the drift away from chemistry.

The more I have studied chemistry, chemical education and the psychology of learning, the more I have become aware that we are trying to share our beautiful subject with young people in an apparently logical way, but one which conflicts with what we know about how people learn (psychological). The remainder of this lecture attempts to harmonise a logical approach with the psychological so that young people in the next century can catch our enthusiasm and enjoy the intellectual stimulus that our subject can, and should, offer.

The ‘logical’ structure of chemistry can be seen as progressing within the space mapped by the following triangle:



In our teaching we tend to use the central areas of the triangle thus involving an intimate mixture of macro, sub-micro and representational and making it <u>very</u> difficult for beginners. Learning begins with the senses. Thus, we should start with ‘things’ and ‘materials’ (macro) and carefully move towards the interpretation in terms of atoms, molecules, ions and structures (sub micro). Experienced chemists can move freely around and inside the triangle but to make ‘sense’ and to avoid overloading the ‘information processing system’ the learner needs to work along one side only.

The crucial aspects of the information-processing model (the psychological) are

- What the learner already knows and believes controls PERCEPTION.
- Perception is what we use to filter out some stimuli for special attention and to ignore others. We look for things that are familiar or ‘make sense’ and if the stimulus does not accord with this, we see it as a surprise and may ignore it.
- If the filtered material can be processed into a form which ‘makes sense; then it can be attached to our existing interconnecting network of knowledge, experience, beliefs, preferences in the Long Term Memory. This extended network then is the ‘controller’ of our next perceptual experience.

Two factors, at least, limit this process.

a. Too many pieces of information in the ‘Working Space’ overload the system. This then shuts down, preventing learning taking place.
b. If we try to store material in the Long Term Memory and cannot find existing knowledge with which to link it, we either ‘bend’ it to fit or try to store it unattached. Unattached (rote) learning is easily lost and the bending process leads to ‘alternative conceptions’.

<u>Some specific examples</u>

<u>The dreaded ‘Mole’.</u> As an EXTENSIVE property of substance - a chemist’s counting device (allows a mass to be converted to a number of particles) it is very straightforward. It can readily be made tangible:

- 100 small balls take up less space than 100 large ones
- The size of one mole of ‘CH_2’ can be estimated (19cm^3) by comparing molar volumes of the homologous series of straight chain primary alcohols.
- Anion volumes can be compared by comparing volumes of gram formula weight of sodium halides

- Molar volumes of gases (of widely differing density) turn out to be similar at room temperature (ca 24 dm^3)
- Molar heat capacity of different metals (Dulong and Petit's Law).

These are relatively straightforward and useful, as an EXTENSIVE property of materials, to understanding chemistry at appropriate levels. Problems arise when we move to MOLARITIES (an INTENSIVE property). Do we need moles in solution? Are we victims of our analytical past? This move much too early to an INTENSIVE property of a solution causes confusion (c.f. heat and temperature in physics).

Equilibrium Confusion

Most of the alternative conceptions regarding chemical equilibrium can be traced to the physics concept of equilibrium, which is generally learned much earlier. The following table highlights major points of comparison.

Physicists' Equilibrium	Chemists' Equilibrium
a. Masses/Moments equal on both sides	a. Numbers of moles need not be the same on both sides
b. Addition to one side makes balance tip to that side	b. Adding more reactants tilts the balance towards products
c. Balance has sides	c. No sides
d. Can do something to one side only	d. T and P changes affect both sides
e. Static	e. Dynamic

Practical work

This frequently is undertaken as mindless recipe following since any other approach simply overloads the working memory of the learner.

In most situations the learner needs to attend to:
- Instructions (from board, worksheet, text book)
- Theoretical aspects of problem
- Names and quantities of apparatus/materials
- The recall of existing skills
- The learning of new skills
- New vocabulary
- Inputs from the experiment itself.

These almost by definition lead to an unstable overload. If this is to be avoided VERY CAREFUL preparation and follow-up to practical work are essential (and rare!)

Overall: Research needs to emphasise WHAT as well as HOW to teach and to look for ways of developing harmony between Chemistry and Chemistry Education. This should encourage a logical approach to chemistry, which takes cognisance of the nature of learning.