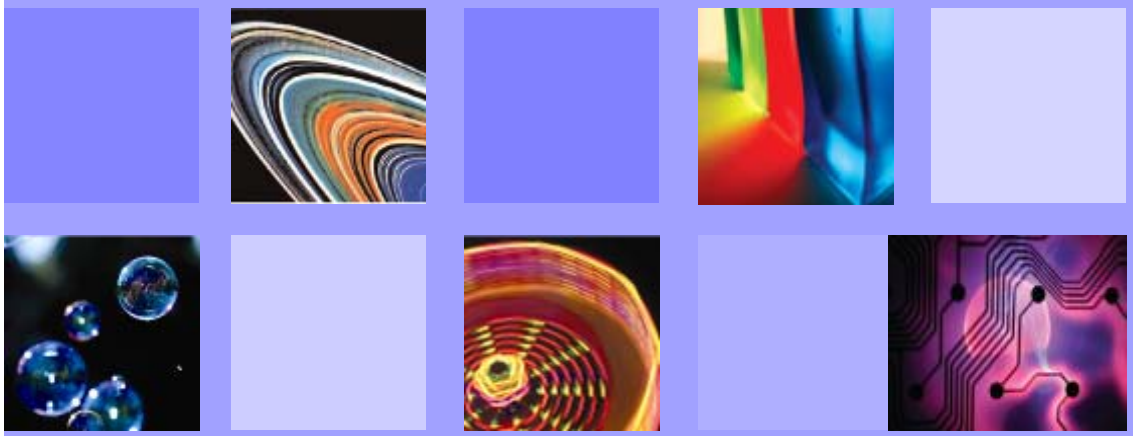
Threshold Concepts and Troublesome Knowledge in Chemistry



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Overview

- Conceptual difficulties in chemistry- *threshold concepts* and *troublesome knowledge?*
- What do ‘A’-level students find difficult – the teacher view
- Student perspective -by questionnaire & test (Yr 1 chemists)
- Effect of prior knowledge on entry
- And…

Thinking like a scientist?

- How can we teach all there is to know?
- Is the science curriculum about content or process?
- When does a student become a practitioner?
- What makes a person begin to think like a chemist, a physicist, or a biologist?
- When did each of you become conscious of the fact that you were a chemist?

What do your students struggle with?

Thinking of your experience of teaching…

What causes your students (and you) most grief?

What is difficult and why? Is it just the 'maths problem'?

"According to Piaget students below the 20th percentile do not often think in an 'abstract' manner and this makes teaching the increasingly broad cohort more challenging, particularly the 35th –50th percentile"

Shayer, M and Adey,P(1981) Towards a Science of Science Teaching, Heinemann

Defining *Threshold Concepts*

From student difficulty to **Threshold Concepts** (Meyer & Land)

- *Core* to understanding the subject;
- *Seismic*: 'getting it' brings about a significant shift in perception of the subject;
- *Irreversible*: change in perspective that comes with understanding;
- *Integrative*: understanding it exposes interrelatedness (previously hidden);
- *Bounded:* has distinct edges and affects other new concept areas.

Meyer, J.H.F. and Land, R. (2006)

Overcoming Barriers to Student Understanding; Threshold concepts and troublesome knowledge, London, UK, Routledge.

Aspects of Threshold Concepts in Science

"When students cannot 'see' particles they cannot really understand chemical reactions and so the fabric of chemistry is lost to them in a haze of impenetrable events completely at odds with their every day experiences of a "continuous" world."

(Barker, 2005)

Chemistry is a conceptual subject and, in order to explain many of these concepts, models are used to describe and explain the microscopic world and relate it to the macroscopic properties of matter. As students progress in chemistry the models they use change and many contradict their everyday experiences and use of language. (Taber, 2002)

Area is complicated by misconceptions – *'Atoms and molecules have macroscopic properties: they expand and lose weight when heated, have uniform densities and well-defined colours, are malleable, change shape under pressure,..* (Talanquer JCE 2006)

Not everything that's difficult is a threshold concept…

Perkins defines *troublesome knowledge* as characterised by a set of student behaviours. Recognise any of these?

- *Ritual knowledge:* students are able to perform superficial tasks and techniques to get a result, yet fail to grasp complexity
- *Inert knowledge* - concepts are understood but not actively used or connected to the 'real world', compartmentalisation
- *Conceptually difficult or Alien* - counter-intuitive, alien or incoherent eg mass & weight, quantum mechanics
- *Troublesome language* – when are "familiar" concepts are rendered strange and subsequently conceptually difficult?
- *Tacit knowledge* – things we now take for granted & use unconsciously i.e. 'ways of thinking'

Perkins, D (1999),*The many faces of constructivism, Educational Leadership. 57 (3)*

The plan -what is the nature of the problem?

- What are the common misconceptions (*Troublesome Knowledge*) from both a staff and student perspective?
- Use diagnostic tests and questionnaires to explore actual understanding of concepts
- Are the problems due to gaps in knowledge?
- Which misconceptions persist from pre-university days?
- Is any of this *Troublesome Knowledge* maths related?
- Are any of these difficult areas actually *Threshold Concepts*?

Misconceptions from school to university?

Survey was done with 18 school teachers

Electron structure; bonding; valency; writing formulae and equations; electrolysis; systematic nomenclature; polymers; fuels; how chemistry relates to the real world; inter-molecular forces; balancing equations and stoichiometry; relating properties to structure; calculations

and academic staff said..

anything that involves a formula; moles, ionic & covalent bonding; rearranging equations.

Why?

"Abstract concepts"; "mathematical formulae phobia"; "lack of prior knowledge"; "difficult for them to conceptualise"; "not well taught at school".

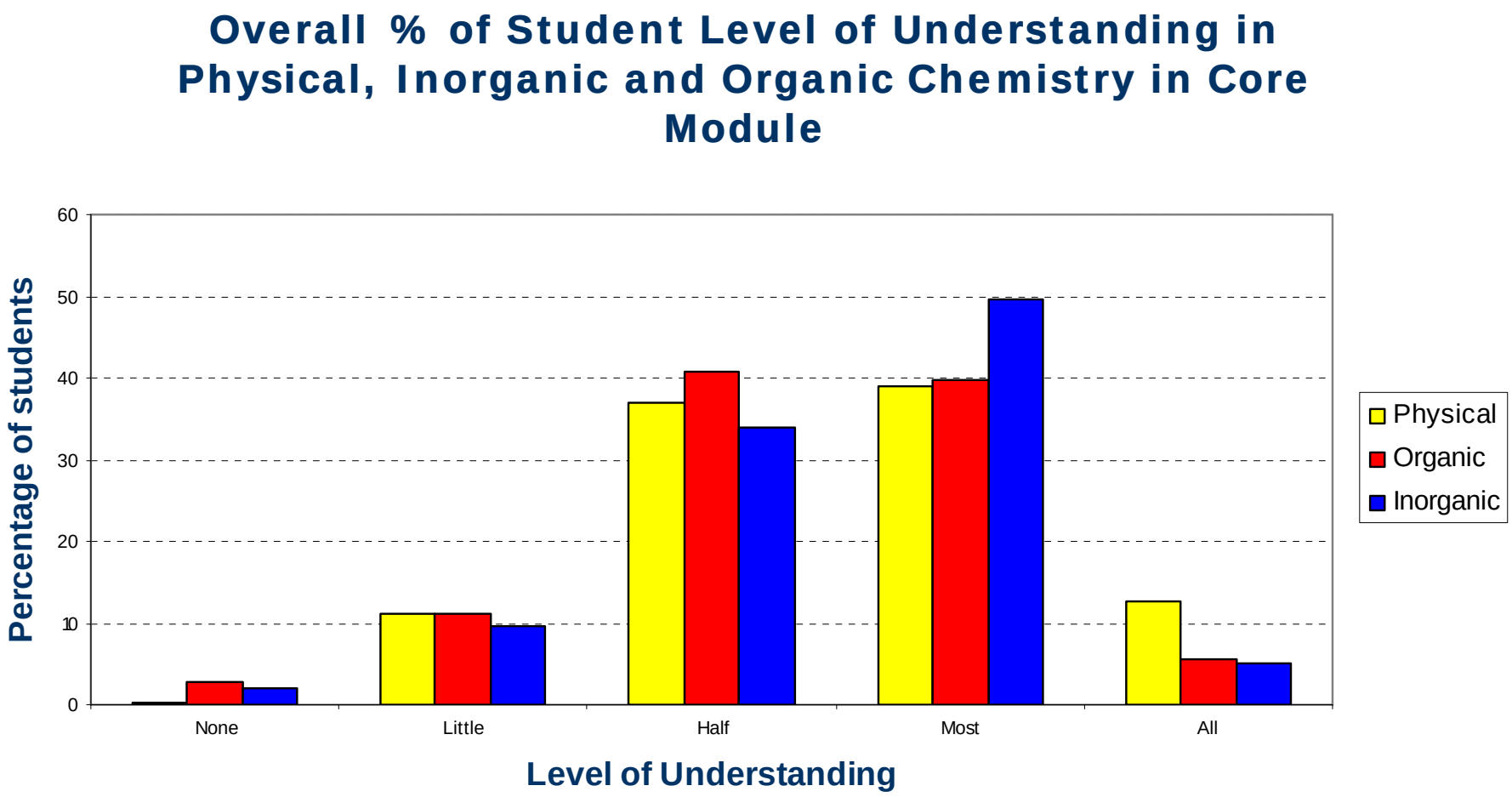
Chemistry level 1 questionnaire

Closed questions one for each of the ‘difficult’ concepts with 5 response categories:

- I understand all facts/theories and can relate them to new problems
- I understand most of the facts/theories and can solve most problems given to me
- I understand some of the facts/theories and can relate them to /solve straightforward problems
- I do not understand many of the facts/theories and I find it difficult to solve problems.
- I do not understand this topic.

- Open follow-on questions to probe why concept is difficult
- Wording chosen so as not to imply a concept was difficult
- Students were asked to identify their entry level qualifications

Students rating of their understanding..



Student self-evaluation - 36 replies

Confident about

- Physical - Moles
- Organic – Alkanes
- Inorganic - Periodicity

Not confident about

- Arrhenius, SI units, Dissociation constants, pH
- Markovnikoff's rule, Alkane isomerism, Inductive effects
- MO theory & VSEPR

Students showed least confidence in organic concepts & most confidence in inorganic topics

Student comments on their difficulties included:

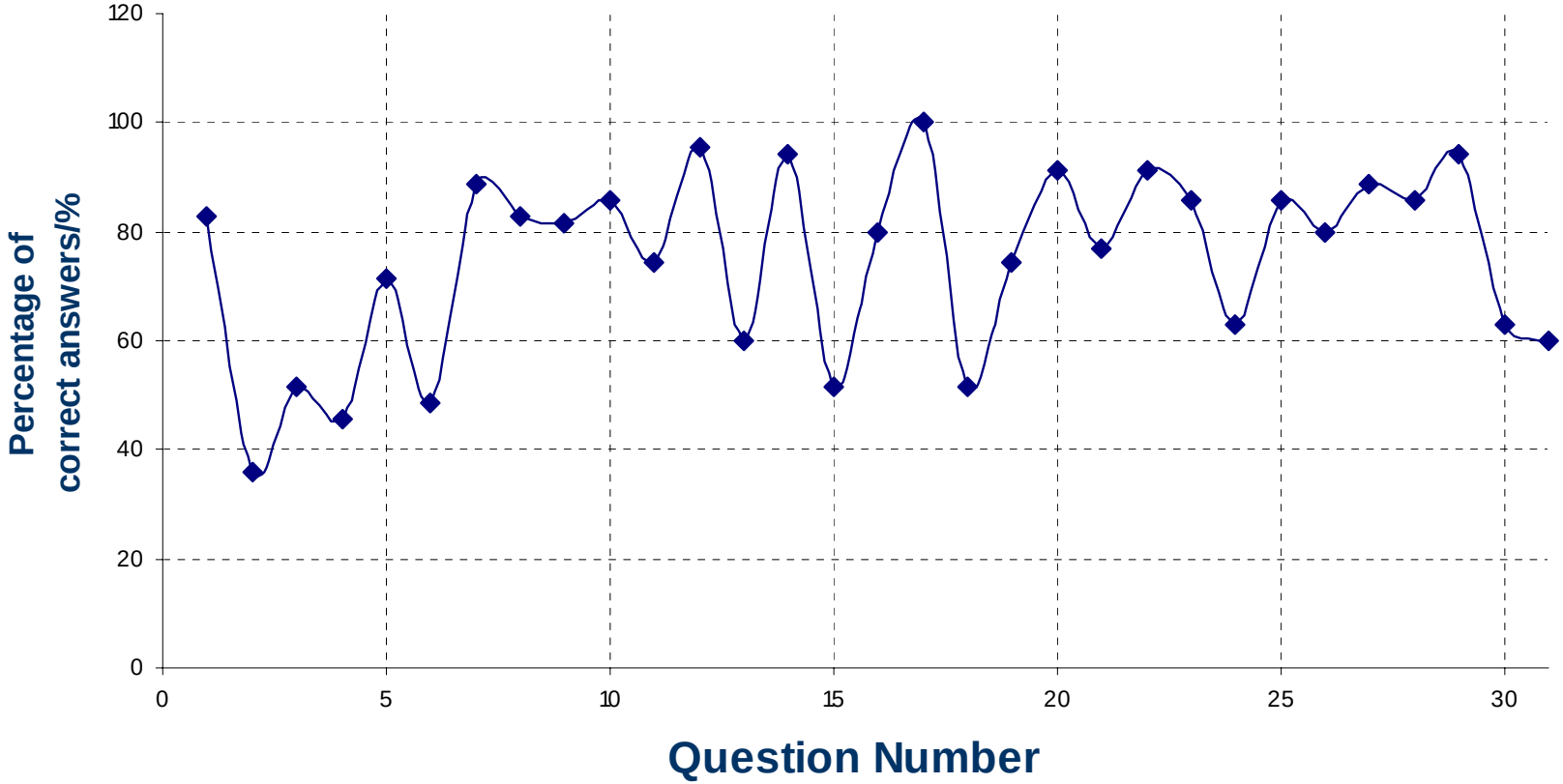
"A lack of prior knowledge of some topics"; "difficulty in understanding"; "uncertainty over meaning of terms"; "books were 'confusing' "; "insufficient examples to demonstrate the purpose of required field of knowledge" i.e. a lack of context.

Knowledge gaps - comparison of Core module & A2 Chem

Physical	Organic	Inorganic
Concept of Moles	Reactions of Alkanes	Trends in the Periodic Table
Stoichiometry	Nomenclature of Alkanes	Basic Properties of elements
pH	Alkane isomerism	Atomic Radius
Dissociation Constants	Addition of Halides to Alkenes	Ionic Radius
Reaction Kinetics	**Markovnikoff's Rule**	VSEPR Theory
Rate constants /orders of reaction	Curly Arrows	**MO Theory**
Arrhenius equation	**+I and –I inductive effects**	
Experimental methods	**Alkyl Halides (S_N1& S_N2)**	
SI units	Nucleophilic Substitution Reactions	

Do they understand what they think they do?

Graph of % of correct answers for Diagnostic Test on 1st year chemists.



Knowledge gaps for Access entrants

Module title	Module content covered at A2 level, but very briefly or not covered at all on science Access Courses
Formulae, equations and amounts of substance	• Calculation of reacting masses, mole concentrations & volumes of gas
Atomic structure	• Use of mass spectrometer in determining relative atomic mass & relative abundance of isotopes
Bonding and structure	• Shapes of molecules & ions up to 4 electron pairs • Interpretation in terms of electron pair repulsion theory • Electronegativity & bond types
Kinetics	• Collision theory; activation energy; effect of temperature on rate • Rate equations ($R=k[A]^m[B]^n$)

Knowledge gaps for Access entrants (cont....)

Equilibria	• Homogeneous reactions; qualitative effect of temperature changes • Effect of temperature, pressure & concentration on equilibrium • Kp, Kc for homogeneous reactions • Equilibrium constants & reacting quantities • Temperature & pressure on magnitude of equilibrium constant
Inorganic chemistry & periodic table	• Trends in terms of structure and bonding • Acid-base character of oxides
Organic chemistry	• Bond polarity & bond enthalpy influencing reactivity • Stereoisomers • Organic synthesis
Modern analytical techniques	• UV/Vis spectrometry • Mass spectrometry • IR spectrometry • NMR

Initial findings- More questions than answers

We know less than we thought we did!

- Staff and students, at both school and university level, identify concepts involving the molecular but invisible, as causing problems: eg structure and bonding
- Mathematical issues, arise at all levels, from the manipulation of equations to statistics
- There is a perceived lack of teaching materials that relate scientific concepts to the real world
- Anything to do with the behaviour of electrons is troublesome
- Prior knowledge does matter – from the students' perspective

Research, indicates that it is not just about what is taught, but how it is taught that matters.

Can materials help support learning of troublesome knowledge?

- moles calculator

- Molecular Geometry web site

The next step….

- Phrasing the right questions
- New approaches to try to collect more data eg concept mapping with chemists
- New resources

My thanks to :

CELS team members -Anne Rockcliffe, Clare Greenall, Mark Crowley, and Alison Mealing;

Sophia Saleem;

The students, teachers and lecturing staff who participated in surveys;

HEFCE for our CETL funding