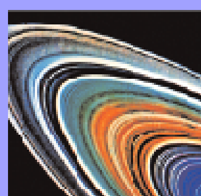
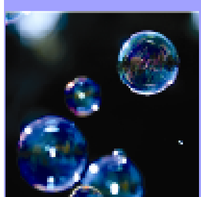
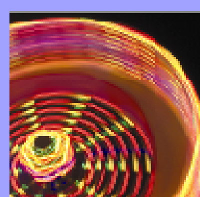
Threshold Concepts, misconceptions and common issues



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Outline

- Thresholds portals & transformations
- Journey
- Answer to life the universe and everything?

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 an ecologist, a physicist, a chemist, a statistician?
- When did each of you become conscious of the fact that you were now a scientist?

Did the earth move for you?

Can you describe a moment in your life when you *got-it*?

When grasping an idea changed the way you thought about a subject?

- on a post-it please – anonymously

What do your students struggle to get?

Thinking of your own disciplines and experience of teaching

What causes your students (and you) most grief?

Add it to your post-it

"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;

Not everything that's difficult is a threshold concept

Troublesome knowledge -characterised student behaviour:

- *Ritual knowledge:* students are able to perform superficial tasks and techniques to get a result, & 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
- *Troublesome language* – when are "familiar" concepts are rendered strange and subsequently conceptually difficult?
- *Tacit knowledge* – things we now take for granted & use unconsciously 'ways of thinking'

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)

Threshold concepts in biosciences can arise from problems with both *process* concepts and *abstract* concepts and situations where students develop '*islands of knowledge*' that are not integrated into the bigger picture eg photosynthesis. (Taylor, 2006)

Newtonian mechanics – '*heavier objects fall faster*', '*for an object to move it must be subject to impetus*' (Hestenes, 1992)

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 2006)

The plan -what is the nature of the problem?

- What are the common misconceptions from both a staff and student perspective?
- Use focus groups to explore students' understanding
- Use diagnostic tests, questionnaires to explore actual understanding of concepts
- Are problems due to gaps in knowledge?
- Which misconceptions persist from pre-university days?
- Is any of the 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

DNA and protein synthesis; 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; photoelectric effect; nuclear particle families; calculations

and 18 academic staff

Genetics; differences between viruses, bacteria & fungi; biomechanics; statistics in final year projects; anything that involves a formula; biochemical pathways (eg Kreb's cycle); molecular biochemistry (DNA); moles, ionic & covalent bonding; cellular respiration; rearranging equations.

Forensic Science

- New area in science education research
- Interdisciplinary programme -concepts from biological sciences, chemistry, physics and forensic science itself.
- Mixed entry profiles of A2 and AS-levels in different subjects.

This will affect their prior knowledge, and hence is likely to affect their ability to acquire both knowledge and understanding of concepts.

Focus Group of year 1 students

Topics they identified as causing problems included:

In chemistry:

- *Electrochemistry; chromatography; bonding; functional groups; spectroscopy, radiochemistry; Arrhenius equation; chemical equations, analytical science; crystal field theory; formulas and equations; dilution factors; structural formulas;*

In biology:

- *Energy chains; electrophoresis of proteins & nucleic acid immunodetection; many types of chromatography*

In physics:

- *Microscopy; waves; photography and image processing; ballistics; complexities caused by different theories, equations and functions*

In general:

- *Equation manipulation*;

Their voice…

On the perils of oversimplification and its consequences

"… they teach you one thing and then you get to the next level and they say forget everything you learned in GCSE, it's not like that, it's like this and it's the same when you get to the degree, they say forget everything you learned at 'A' level, this is how it is and you have to keep resorting back to what you learned in the first place and it just confuses you".

On the value of contextualising

"… why do you need to know that? If you are using a microscope you don't need to know that the light is behaving as a particle, all you need to know is that you have to adjust the thing to get it into focus and that's the thing I would rather have learned, rather than looking how the light bends this way?"

On the use of language..

"I find a lot of the technical words are difficult to grasp, ... it's like anything that you are working with, if you use it all the time, they become part of your everyday language and you don't realise that people don't understand it. I worked with the police force for eight years and they use loads of acronyms etc."

Forensic Chemistry – level 1

Follow-on questionnaire from Focus Group work

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

- I understand it well and could explain it to someone else
- I have a fairly good understanding of it
- I could probably pass an exam questions on it but I don’t completely understand it.
- I don’t understand it well enough to pass an exam question on it.
- I don’t understand it at all.

- 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

Initial findings

The 3 most difficult topics for students with A2 chemistry were

- **Arrhenius equation,**
- **Difference between π- and σ- bonding**
- **Spectroscopy**

The topic posing most problems for those with AS chemistry was **functional groups ->** *a knowledge gap*

In many areas >50% students indicated a level of difficulty with the topics especially mathematical formulae

40% said not knowing what all parts meant,

40% didn't know which formula to use.

Behaviour patterns are typical for Troublesome Knowledge

And also.. VSEPR, Hybridisation, Moles.

Digging deeper with diagnostic tests

8 years of Physics tests and Flexible Learning Approach to Physics (FLAP)

Test is peer-marked, anonymously

Sections on *Waves* and *DC Electricity* persistently have poorer scores

WHY??

Topic	3 or more correct answers*
Scientific notation, graphs and units	75-80%
Motion	60-76%
DC electricity	13-21%
Atoms and radioactive decay	60-64%
Waves.	0-24%

* 3 year sample

Conclusions

We know less than we thought we did!

Some common themes are beginning to emerge:

- Staff and students, at both school and university level, identify concepts involving the molecular but invisible, as causing problems: whether in biochemistry, molecular biology, or chemistry (eg DNA, structure and bonding)
- Mathematical issues, at all levels, from the manipulation of equations to statistics
- A perceived lack of teaching materials that relate scientific concepts to the real world
- Anything to do with the behaviour of electrons – from electrolysis, to DC electricity to electrophoresis, is troublesome

The next step….

- Phrasing the right questions
- New approaches to try to collect more data eg concept mapping with physics
- New resources e-stats, protein-purification learning package, moles
- Extension into Sport Science eg psychology, biomechanics

This is tough – any suggestions welcome

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