Core Concept Science: a holistic approach to teaching and learning

Abstract for the 3rd International Conference Integrating for Excellence. Sheffield Hallam University 27 and 28 June 2007

(Additional Slides post conference from September 2007)
Why Change the way we teach Science?

• In 2001 only 49% of Students obtained a grade C GCSE in Year 11
  • The number for boys was lower in the UK

• After many new initiatives and 80% increase in spending per pupil results only increased Nationally to 54% by 2007
  • Again the figure was lower for boys  [Figures DFES website]
Background

• Nationally there is growing evidence that teaching in secondary schools is not producing the level of understanding and success desired from the Educational process / system for many students. This is despite:
  
  – Changes by QCA and the government.
  – The introduction of the National Curriculum (1989)
  – Successive government and ministerial attempts to change both content, context and assessment.

• Science is of particular concern with standards of HE students questioned, numbers of centres and students falling and percentage pass rate at C and above, relatively lower to other subjects.

• New developments by QCA have tried to address these issues with restructuring of content, pathways, new course and context (How Science Works).
Our School

This slide was to recap the history, background and development of the school.

The purpose of this was to tie in the ethos and values of what we were doing to the values of the school.
Introduction

An audit was conducted within our science department aimed at highlighting particular concerns. (Common to any/most schools)

- Higher ability students were not achieving levels of A and A* expected and often underachieving.

- Those that achieved A* – B grade GCSE struggled with science A levels. Many dropped out early in the course or opted for other subjects.

- Numbers of students from “lower ability” sets expected to gain grade C passes did not achieve expectations.

- Often earlier ability shown at KS3 (Yr 7-9) was not reciprocated at KS4.
Understanding. A Case Study

Despite a strong department of highly qualified, experienced and specialised teachers providing a strong subject specialist framework understanding of science seemed to be a key failing amongst students.

- **Higher group students** possessed a good ‘Knowledge’ of Science in terms of detail, content and application. Understanding of deeper principles seemed to be too often absent.

- **Lower ability groups** seemed to struggle with the abstract nature of the subject and lack confidence.

- **Quick learners at KS3** would quickly forget areas that needed to be re-introduced at KS4.

- What often exposed many students depth of understanding was the simple question. Why? And following a “line of questioning” in a specific way.
Asking the Questions

• Do we have a content and assessment driven curriculum?

• Is learning at the heart of what we now value and is there a void in understanding within the science curriculum and teaching methodology?

• Do we now value what we measure rather than measure what we value?

• Has this impacted on science teaching and can we address the focus on understanding and make the learning experience more meaningful and successful?
Main Problems

• Students learning to pass exams but not understanding

• Students who don’t understand unable to learn.

• Not able to link concepts (i.e. Energy)

• Our own difficulty in defining; learning, knowledge, facts, details, concepts and ultimately understanding.
Projected Attainment KS3 - GSCE
(Autumn Package Predictor Levels)

Time (Year)

KS3 Levels Of Attainment

GCSE Grade (Yr 11)

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Fieldwork

• Comparative data was used to assess level of attainment in the department, against other core departments within the school.

• Autumn package was use to assess level of attainment within the department, against National tends.

• Autumn package and CAT scores (both based on KS3 results) were used to baseline predicted target grades for end of KS4.

• Informed discussion and meetings were held with both staff and students.

• Setting, ability and commonality of weak areas was reviewed with staff, students and areas of assessment.

• Commonality of problems was discussed with other core departments.

• Students were interviewed on ‘strengths’ and ‘weaknesses’ within science.
Main Findings - Students

- Content was intensely covered, practical ability rigorously used. Content and application was re-iterated and a well differentiated curriculum in place within the department. Assessment was on going and both formative and summative assessment use in conjunction with Autumn Package QCA data and predictions.

- **Understanding was weak** at all Key Stage levels while students were good at training to pass exams.

- Core principles and miss-conceptions reflected National concerns.
  - Students who *could learn by rote* and those who could not found acceptance of *scientific principles and linking of abstract ideas difficult*.
  - Students who *gained knowledge* found application to new areas difficult or unrelated.

- Cross curricular linking between concepts such as Energy was *poor*.
Findings - Staff

Our own understanding in the following areas raised concerns and more questions.

• Are all learning styles catered for, is this relevant?
• Do we have a clear idea of core scientific principles and concepts?
• Are we clear in our definitions of:
  – Understanding?
  – Learning?
  – Knowledge?
  – Concepts?
• Are we convinced what students learn is appropriate and are we content driven?
• Is it an advantage to have specialist teachers in specialist roles?
• Do we have a holistic approach to Science, and teaching Scientific thinking to develop?
Findings – Good Practice

• Areas that worked well in raising achievement and confidence were examined as well as teaching methods that seemed to engage a deeper understanding.

• Providing a climate of honesty and openness, curiosity and self-belief

• Tackling misconceptions head on and going back to core principles (Key Concepts)

• Starting at the beginning and building up sequential Knowledge and understanding from the onset (concrete preparation)

• Linking of abstract ideas.

• Allowing students questions to drive the curriculum and learning – encouraging cognitive conflict.

• Providing a logical platform of Key questions and opportunity for students to discuss and formulate possible outcomes – examining cognitive conflict.

• With the end in mind, working backwards to basics to provide a start point. Often original historical questions.
Core Concepts

- environment & ecosystems
- food webs
- food chains
- energy transfer
- conservation of energy
- energy & mass
- matter
- atoms
- positive/negative
- Big Bang
- entropy
- steady state [ balance ]
- reactions
- cycle of energy / mass
- compound / elements
- tropism / feeding
- exo / endothermic reactions
- photosynthesis / respiration
- conservation of mass / energy
- chemical reactions
- periodic table, properties, relationships
- atoms & electron configuration
- formation of subatomic particles & charge

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Research - Knowledge and Understanding

Constructivist techniques
Perkins discussed the Active, Social & Creative learner in terms of;

**Knowledge and Understanding**

- Active learner – discuss, debate, hypothesise. Knowledge and understanding is actively acquired
- Social learner – knowledge and understanding socially constructed in dialogue
- Creative learner – knowledge and understanding created or recreated through scientific theory, historical stories.

‘A need for a philosophical argument, so learning logically conveys meaning. A need for a psychological model of active engagement may lead to better retention, understanding and active use of knowledge.’

*(Perkins 1992)*
Inert knowledge
Ideas, concepts, details which remain abstract and unlinked. Not connected to the outside world.

Ritual knowledge
Routine in response or remembering.
E.g. Columbus discovered America in 1492

Conceptually difficult Knowledge
Learners find it hard to accept that ‘bodies in motion will continue at the same rate and direction until another force acts on them’

Foreign Knowledge
Alien to culture, belief or timescale
(Education Theory, Teaching, learning. David Perkins 99)
Multi sensory Learning Style

Visual

Auditory

Kinaesthetic

This characteristics are how people may prefer to access information, rather than learn it. A cognitive preference is a thinking preference (cause) that gives observable behaviours called personality (effect). This is a discrete variable and not a categorical one.

However, characteristics at ends of the spectrum are noticeable and combinations have been categorised. These traits or styles are a result of thinking preference.
The Four Dimensions of Cognitive Style

The Four Role Quadrants


Dichotomy Corollary
‘A persons construction system is composed of a finite number of dichotomous constructs’ (p59)

‘His constructs are organised into systems, groups of constructs which embody super ordinate systems’ (p12)

‘Constructs are used to predict happenings..the validation of evidence is quickly available’ (p13)

Kelly postulates that: “man is his own scientist continually predicting on all events and validating or dismantling Constructs and some construct systems.”

(Ref; George A. Kelly 1963 A Theory of Personality Norton USA)
Key Questions

Do we learn understanding or does understanding allow learning?
Key Questions

Can we clearly define...

– Thinking
– Learning
– Understanding
– Knowledge
– Details/facts
– Concepts
– Misconceptions
– Processes and Preferences/styles?
As George Kelly describes, we are scientists in our own worlds experimenting continually.

Drawing on evidence to make predictions and reasoning in science we have;

- an aim - what we want to do, comprehend, understand
- the predictions or tests
- a method - our mental tools
- the experiment - the doing
- the result - of action or thinking
- the conclusion - making sense/understanding
- evaluate - was the outcome expected
- affirmation/re-evaluation
George Kelly describes

“man is his own scientist continually predicting on all events and validating or dismantling Constructs and some construct systems”

The whole of science is nothing more than a refinement of everyday thinking.

- Albert Einstein
In education we deal with and test ability to make correct;

- Statements or facts
- Being able to describe or outline a series of facts or processes
- Understanding how they link, fit together or the relationship between them (conceptualisation)
- Application to our relationships, understanding and process systems
- Evaluation of our thinking, understanding and the outcomes of these process systems
- Affirmation or re-evaluation
Conclusion

1. Individuals have thinking and learning which drives behaviour. They also develop preferences.

- i) Thinking preference order
- ii) Learning preference of
- iii) Behavioural preferences operation

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In very simple terms learning seems to be a sequence of:

- Statements
  - Descriptions
    - Explanation
- Facts / Knowledge
  - Outline knowledge
    - Understanding
- Details
  - Concepts

The wrong way around?
Perhaps what we do more often than we realise is not:

detail → concept → application

but

concept → detail → application
Conceptual and detail preference students

• Detail oriented students may readily accept facts without a deeper understanding and can learn to a great degree following research, processes, systems, at a greater level.

• Conceptual orientated students may not accept the facts until they deal with the concept.

• In other words some students will prepare to work from the outside in (conceptual) others from the inside out. (Detail)
Using construct theory

main fact --------- an agreed placement/theory/process --------- main fact

construct
(understanding)
Description, outlining and evaluating are the learning processes that fix the understanding in place, but the construct is the key to understanding in depth.

• We tend to learn and forget facts but not so much understanding, especially when the facts fall into place and are reiterated and reaffirmed in different ways forming other links and constructs.

• This suggests that the construct must be in place first and must not be assumed it is in place or formed.

• Learning capital cities for a small child is hard without knowing the countries and perhaps a conceptualisation of the world as a planet first should be considered. Without it misconceptions can arise. In the same way as the scale of heavenly bodies and their place in the universe, if this is lacking students confuse planets, moons, stars and the sun. Discussing chemical reactions without the concept of the atom and matter can be confusing. Key concepts or constructs, it can be argued, must come first. Layer after layer of logical argument should be carefully constructed on key questions.
If key understanding is missing many students seem to pick up misconceptions and struggle to learn what they don’t understand.

• If they don't understand can they truly accept?

• To make matters worse we can often assume that the start of the understanding is beyond them.

• Often misconceptions are dichotomous and students have the opposite value with the detail on the construct.

This implies the construct should be given.
National Curriculum Statements

Level 2 materials can be classified by colour, texture
Level 3 materials can be classified as solid, liquid, gas.
Level 4 materials are made from particles
Level 4/5 Particle arrangements for solid, liquid, gas.
Level 5 Materials made from one type of atom are elements.
Level 5/6 Elements combine to make new substance called compounds
Level 6 Magnesium + Oxygen → Magnesium Oxide
Level 6/7 Mg + O → MgO
Level 7 Mg + O₂ → MgO
Level 7/8 2 Mg + O₂ → 2MgO

4-7 Years using suggested NC Levels (1 - 4 weeks using CCS)

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Core Concepts
(Curriculum Pathways)

Problems?

- environment & ecosystems
- food webs
- food chains
- energy transfer
- conservation of energy
- energy & mass
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- positive/negative
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- entropy__________reactions
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- periodic table, properties, relationships
- atoms & electron configuration
- formation of subatomic particles & charge

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## Building constructs in Science

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Outcome 2006

Year 8 Piloted scheme last year with 2 middle ability cohorts (46 students). At the end of year 8:

– Almost every student acquired at least level 6.

– More students acquired level 7 than the subsequent year 9.

– Most students went up 2 levels in one year (Normal National and school average is 2/3 level).

– Many students outperformed the sets above.

– All were able to access and began GCSE the following year one year early.

– Results and work confirmed by outside consultants/inspectors.
Outcome 2007

It was quickly crafted into subsequent top cohort in year 9 and year 10 middle group. (2006/7 Cohorts)

- Both year groups had significantly higher GCSE results (above 20% increase).
- Year 7 and 8 students began the new course with all staff.
- Within several weeks students are performing high level conceptual science which can only be measured using year 11 GCSE material.
- Work and results validated by 3 outside consultants.
- External audit conducted.
- Presentation of work to parents.
Recommendations

• Core concepts which were previously in year 11 should be brought forward and worked on from the start as a start point for understanding.

• Lessons and curriculum should start with key questions and build up a logical sequence of concepts/constructs.

• Once core concepts are breached detail can be assimilated by the process of learning during a lesson and sequence of lessons. Only then should formal application be introduced.

• Abstract ideas can be consolidated by presenting constructs to students as a learning aid and overview.
Recommendations (Continued)

• There appears to be a principle concept in science which has a common theme throughout all other concepts.

• Several core concepts are at the heart of scientific understanding.

• Core Concepts allow access to understanding and application to various Key scientific ideas or Concepts.
Initial Core Concept Model

- Principle Core Concept
- Core concepts
- Key Concepts
- Detail and application
Initial Core Concept Model

- Principle Core Concept
- Core concepts
- Key Concepts
- Detail and application

Learning

Consolidation
Examination results for Key Stage 4 Previous grade spread for double Award compared to 2008 Core Science results. (Average grade per student and percentage of students obtaining A*-C pass)

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<th>Year</th>
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In order to develop a new approach to the teaching of science, CCS has integrated and developed 6 key areas.

Constructive use of Cognitive Conflict
1. Philosophy

A philosophical approach to ask ourselves:

‘In what direction were we steering pupils’?
And whose questions were being answered?

Deductive Reasoning to set up conflict and use it

Big Picture first and full story – ‘The what, how, why’
2. Core Concepts & Concept Regression

An approach to the problems with learning and understanding have been simplified by defining each.

Accelerated understanding, rather than accelerated learning.

Core concepts are identified behind what we are teaching to expose student weaknesses or lack of understanding in prerequisite constructs.

Searching for the heart of the problem to find a starting point.
3. Behaviour, Learning & Thinking Preference

We have looked at the theoretical difference between behavioural and learning preferences to evaluate our own understanding of thinking styles and mechanisms. (BFFM)

We have concluded that: behavior is driven by Learning which is driven by thought. Any subsequent ‘learning preferences’ is an outcome of a thinking preference.

There are two axioms for thinking. Open preference (Concept) and closed (Detail). These are preferences of concept and detail.
4. Mapping Thinking

Using the PCT psychological model of Kelly (Personal Construct Theory), to rationalise how thinking may develop and define a system (*Concept Regression & CCL-Matrix*), tools (*I-Bar*), models (*CCS*) and a theory (*CCL*), for conceptual understanding to detail learning, content, knowledge and application.

Holistic approach
5. A Logical Curriculum

This has been integrated into a structured curriculum at key Stage 3 that logically links and builds high level abstract ideas in what the students may consider a more rational way.

Key questions that steer the teaching and learning have been taken from students and their common scientific misconceptions. These can be visually presented.

Reducing fragmentation and misunderstanding
6. Reversing the Knowledge-based Curriculum

We are now able to teach high level concepts and ideas at an early age rather than in later years.

Impact on assessment has been measured comparatively using internal and external data.

Conceptualisation and Understanding of concepts