Developing Conceptual Understanding in the Science Classroom

A Workshop for Fremtidens Naturfag

Denmark

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Background

- Botanist (Durham BSc and PhD)
- Taught in the selective independent sector for 20 years (10 as Head of Department)
- 8 years teacher training / and professional development of teachers at University of Warwick
- 5 years as a Director of the National Academy for Gifted and Talented Youth (with responsibility for professional development of teachers)
- Now work as an independent consultant – both in the UK and internationally.

Let us start with 2 questions:

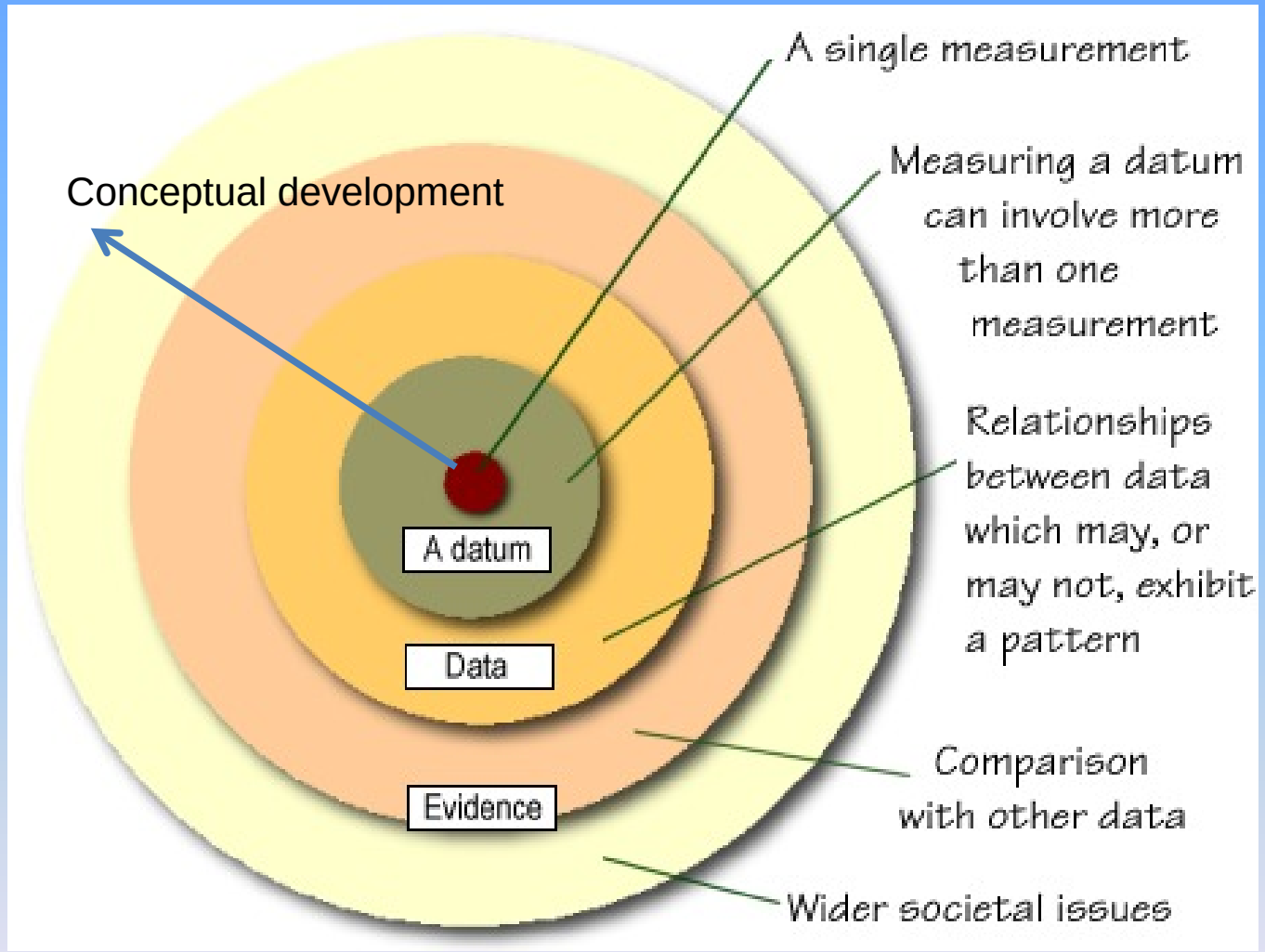
What do we mean by ‘concepts’ in science?

How often do we explore these concepts in depth and breadth?

Concept: ‘A thought, opinion or idea, especially one formed by generalization from a range of examples’

Conceptual: ‘relating to mental activities that form concepts’; ‘to envision or form a concept from observation and experience’

Concepts of Evidence, Gott and Roberts (2010)



To what extent do our assessment tools (tests and public exams) require exploration of concepts or conceptualization involving higher order thinking?

Or do they more routinely require factual recall?

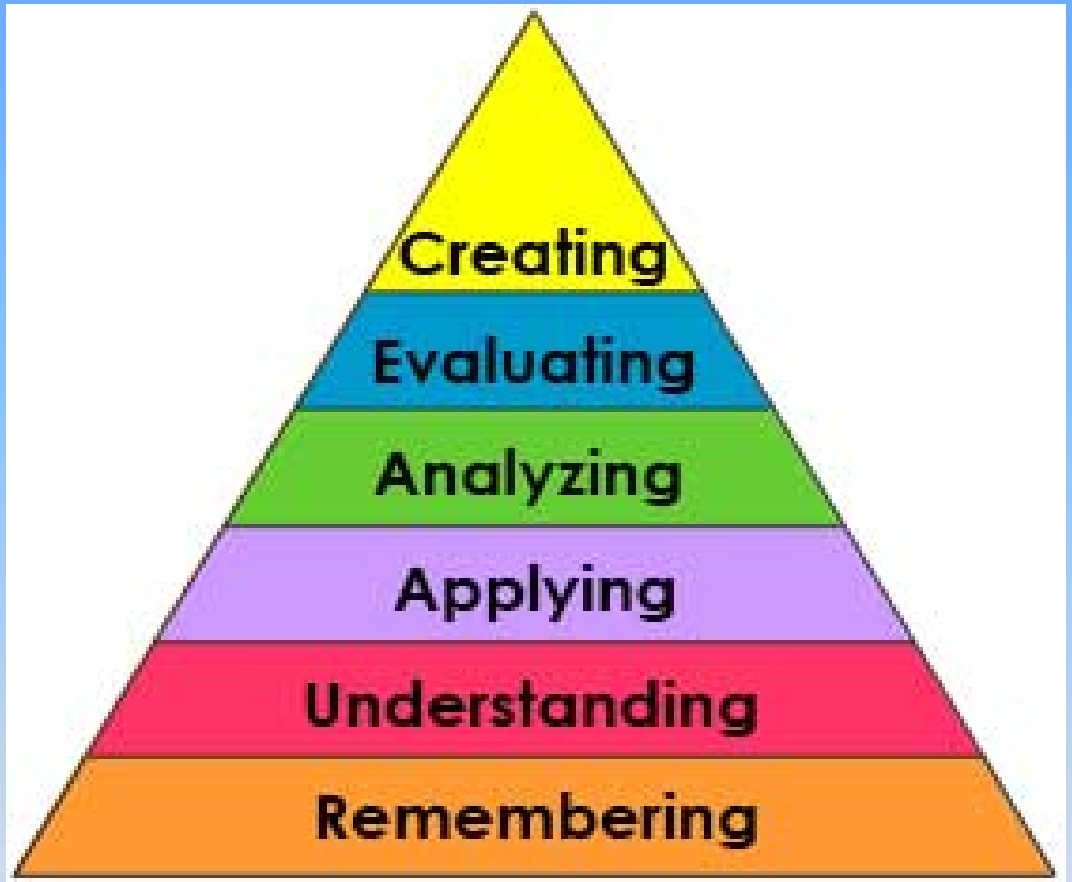
Higher Order Thinking Skills (HOTs)
vs
Lower Order Thinking Skills (LOTs)

In unfamiliar situations these are HOTS

In familiar situations these are LOTS

It is wrong to assume that 'Bloom' is a hierarchy – i.e. that it is necessary to top up the 'LOTS' before proceeding to the 'HOTS'. Knowledge and comprehension can be created and stimulated by starting with observation and thinking exercises.

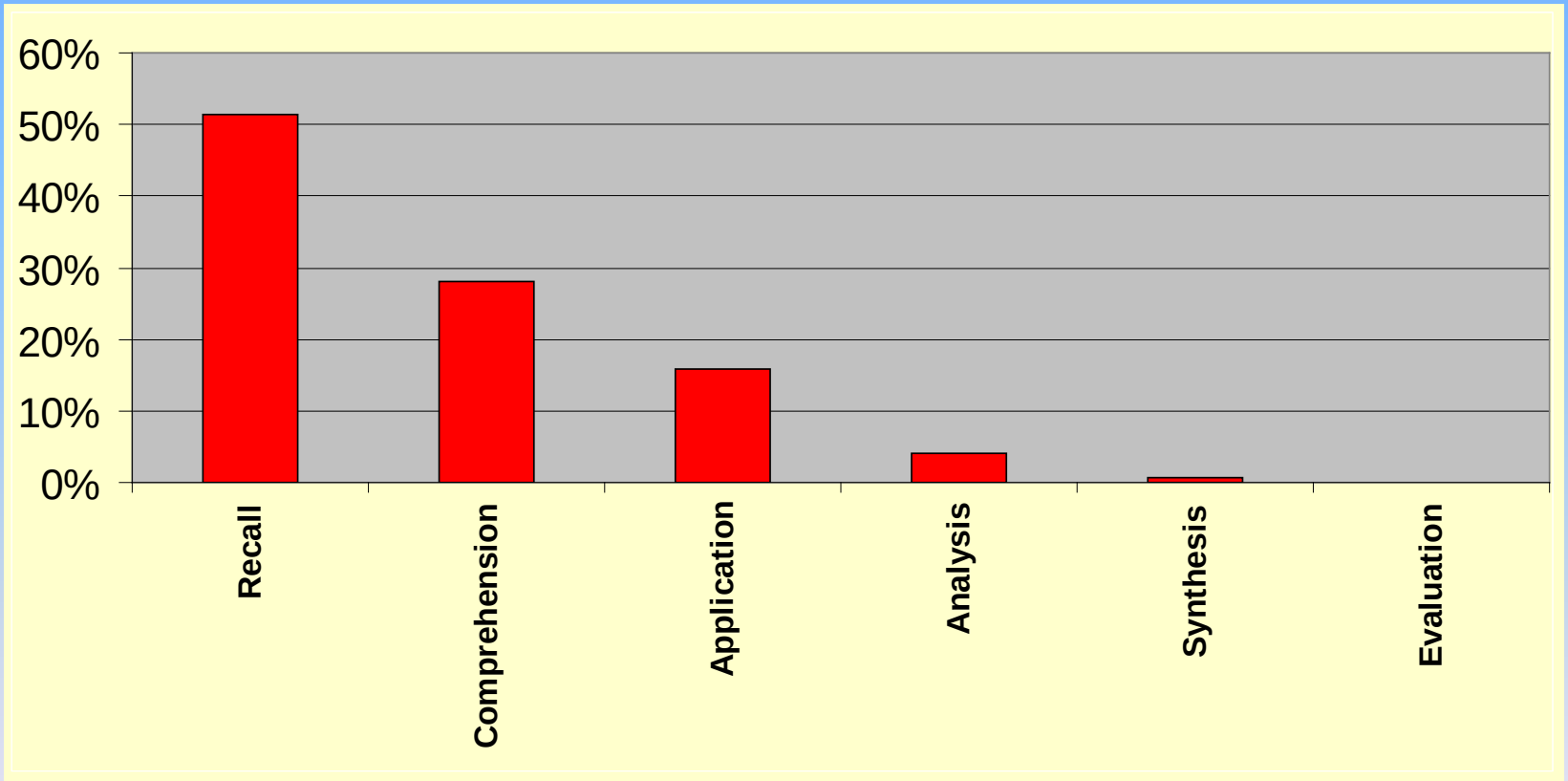
‘New Bloom’



(Anderson and Krathwohl, 2001)

Cognitive Demand: National Tests at Age 14 (England)

An analysis of questions in relation to Bloom



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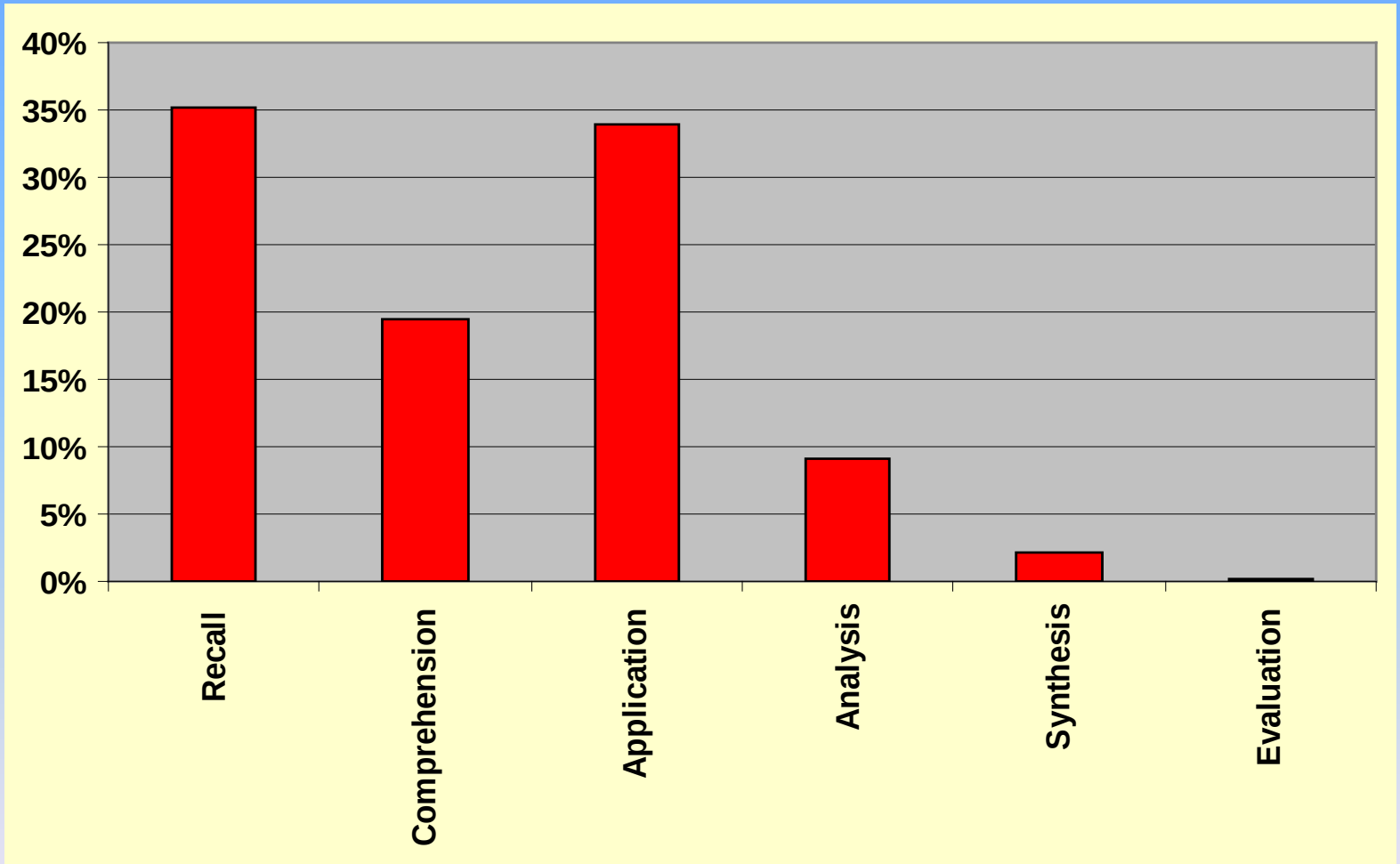
Cognitive Demand: National Tests at Age 16 (England)



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If our examinations do not require advanced levels of conceptualisation why should we, as teachers, be concerned?

Because science teaching is not just about training students to pass exams. Students need to be encouraged to ‘Think like a Scientist’

That does not mean that performance in public exams is not important – good grades are the passport to good universities.

BUT – the more selective universities (e.g. the world's top 100) are more interested in how applicants *think*, rather than what they *know*.

The expertise journey

- What do adult experts do?
- Think of an ‘expert’ in your subject area
- What characterises their ‘expertness’?

- E.g. Nobel prize winners – Sanger (1958, 1980), Mullis, (1993), Jens Christian Skou (1997)

Indicators of Adult Expertise:

Diverse subject knowledge Technical ability Creativity

Problem solving ability Passion for the subject Perception

Critical thinking Original thinking ('out of the box')

Making conceptual links within and beyond subject

Need to Communicate ideas Intuitive linking of ideas

Commitment Intellectual 'playfulness' Confidence

Pushing the boundaries Challenging preconceptions

Precision Evaluating – understanding what works best

Source: Teachers (2,000+) on G&T workshops 2004-2011

- What about students?
- Think of the brightest / most ‘gifted’ student you have ever taught or known.
- Why do you think they were the brightest / most ‘gifted’ ?
- Would you add / subtract anything from this list?
- Do our assessment instruments recognise and reward these characteristics?

A short story!

1. Questioning Skills: Why do we ask questions? Questions have many purposes including:

- To engage/control pupils;
- To check prior learning/recall;
- To lead into new learning;
- To focus thinking;
- To extend thinking;
- To lead pupils though a reasoned sequence;
- To promote problem solving or reflection.

What percentage of teachers' questions is concerned with recalling facts?

What percentage of teachers' questions is concerned with managing the class?

What percentage of questions do you think demand higher cognitive demands of pupils? (Blooms' categories 3 – 6)

Who do you think asks the greatest proportion of higher order questions – primary or secondary teachers?

How many questions does the 'average' teacher ask in their working lifetime (40 years)?

Some questions based on Bloom

See handout

Use this framework to adjust the way you ask questions in the everyday class.

2. Developing Concept Development

Time for some questioning and thinking!

Some short thinking activities.

Exercise 1: Observation, deduction and analysis

Tricky Tracks

Exercise 2: Creative thinking (divergent and convergent)

6 Degrees of Separation

- It is suggested that any two people can link themselves to each other by six steps which provide a logical chain of relationship - Stanley Milgram's (1967) work on social networks at Harvard.

- Can we do the same for science ideas and objects?

- How difficult was that?
- Can we make it more difficult or provide more support? Primary aged children may need some prompts, but they soon catch on!
- Make up some of your own for your own subject and share with a neighbour.
- The exercise works best if you impose a strict time limit.
- Remember: there is no ‘right’ answer!
- But what constitutes a ‘good’ answer? Engaging students in deciding this can develop their analytical and evaluation skills.

But it comes with a health warning! Don't use as a lesson starter!

Emphasis is on creative and lateral thinking, but the more obvious the connection, the more difficult the exercise is.

Works for all subjects / phases with appropriate modification.

Exercise 3: If this is the answer what was the question?

- Water
- Carbon dioxide
- Protein
- Cell
- Metal
- Alkali

- Can we group the answers?
- What patterns might be discerned?
- Think of one from your own subject that you could use next week.

Exercise 4: Tell the story:

Of a graph
(data logging slides)

Of a molecule of calcium carbonate in the sea during and after Jurassic times

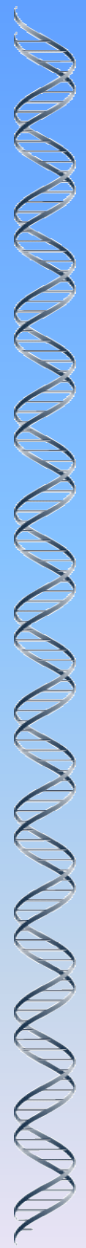
Of a glycine (amino acid) molecule in fish protein as it passes through a human gut

Of a carbon atom in a molecule of carbon dioxide about to enter a stoma in the leaf of a plant

Of a year in the life of a swallow

Exercise 5: Draw the graph of:

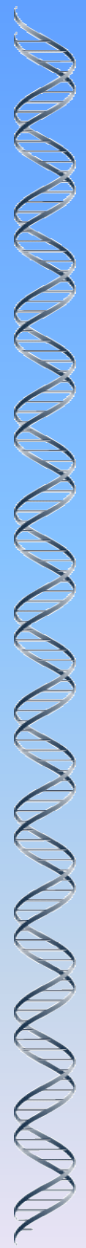
- The pulse rate of an athlete before, during and after a race.
- The pressure in a balloon as it deflates.
- The speed / velocity of your journey to school.



Exercise 6: Thought experiments

What if:

- The density of water was greater / lesser?
- The dinosaurs did not become extinct?
- Gravity on Earth was reduced / increased?
- What if you were the same size as an ant?

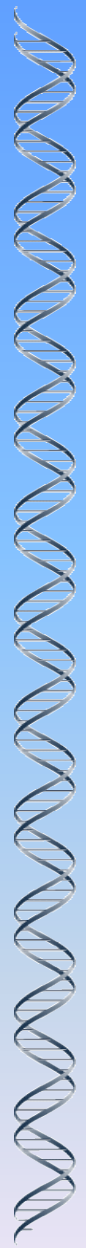


Exercise 7: Building conceptual understanding using toys and curios:

You will be given a toy or an object which Illustrates one or more science principles.

Play with the toy and observe what it does.

Explain the scientific principles on which it operates.



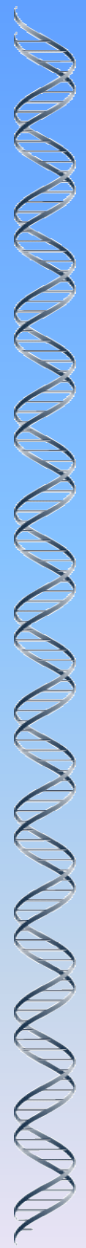
Does it work?

What is the evidence for classroom / school improvement?

London Challenge

NAGTY PGCE+ evaluations

National Science Learning Centre evaluations



Concluding remarks:

How to implement new pedagogical approaches.

Don’t throw the baby out with the bath water!

The 10% Rule!