Durham University
School of Education

‘The thinking behind the doing’ of biology

Ros Roberts

Rosalyn.Roberts@dur.ac.uk

In summary

Durham University School of Education

- The generation and critical evaluation of good quality data requires the understanding of ideas rather than practicing set procedures.
- ‘Working scientifically’ does not explicitly specify these ideas.
- To highlight that *thinking* is necessary a concept map sets out the key ideas about the quality of data and their inter-relationships
- Evaluating the quality of data from Biology practical work (both inside and outside the classroom) provides opportunities to employ all the ideas from the map

Background

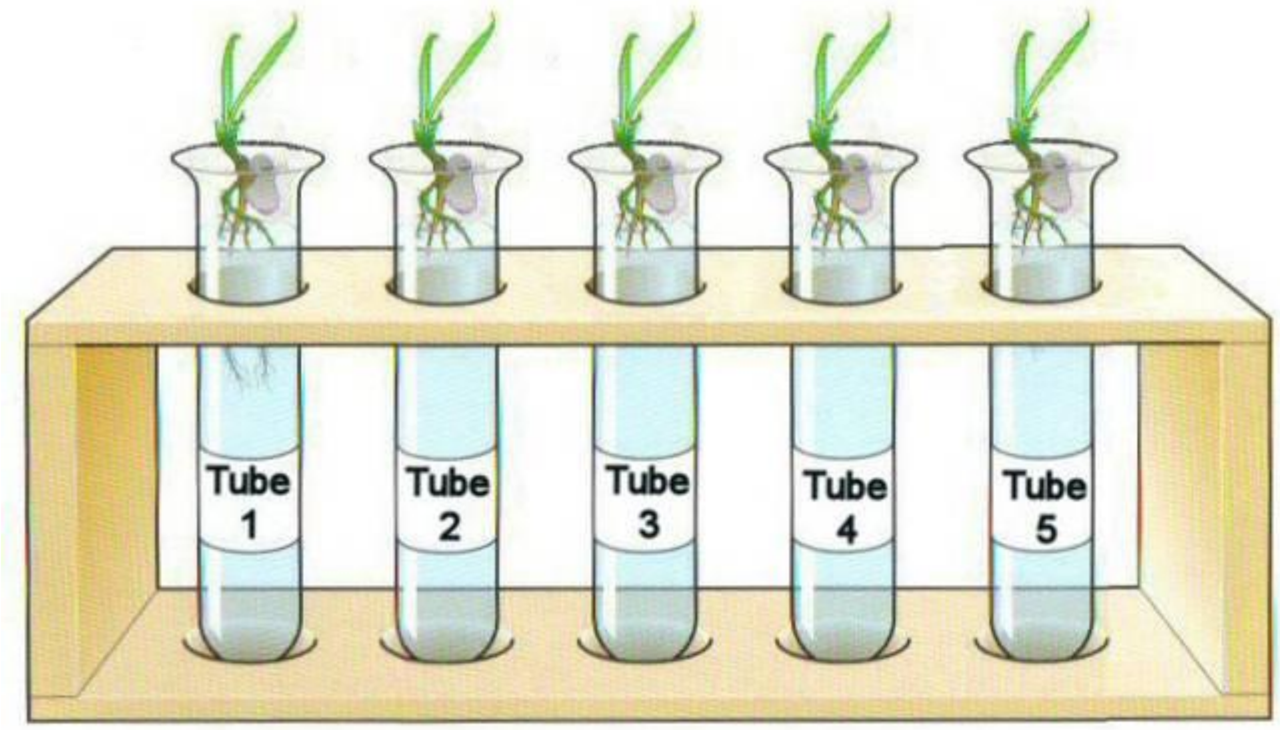
- Scientific Literacy
- School curricula have emphasised 'investigations' / 'inquiry' / 'How Science Works' / 'Scientific practice'
- 'Working Scientifically'
- develop understanding of the nature, processes and methods of science, through different types of scientific enquiry that help them to answer scientific questions about the world around them;
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.

Investigating plant nutrients

Image from SAPS

Durham University

School of Education



Tube 1 – Complete culture solution
Tube 2 – Without Nitrogen
Tube 3 – Without Phosphorus
Tube 4 – Without Potassium
Tube 5 – Distilled water (Control)

Investigating factors affecting *Gammarus* distribution

Image from Field Studies Council

Evaluating claims

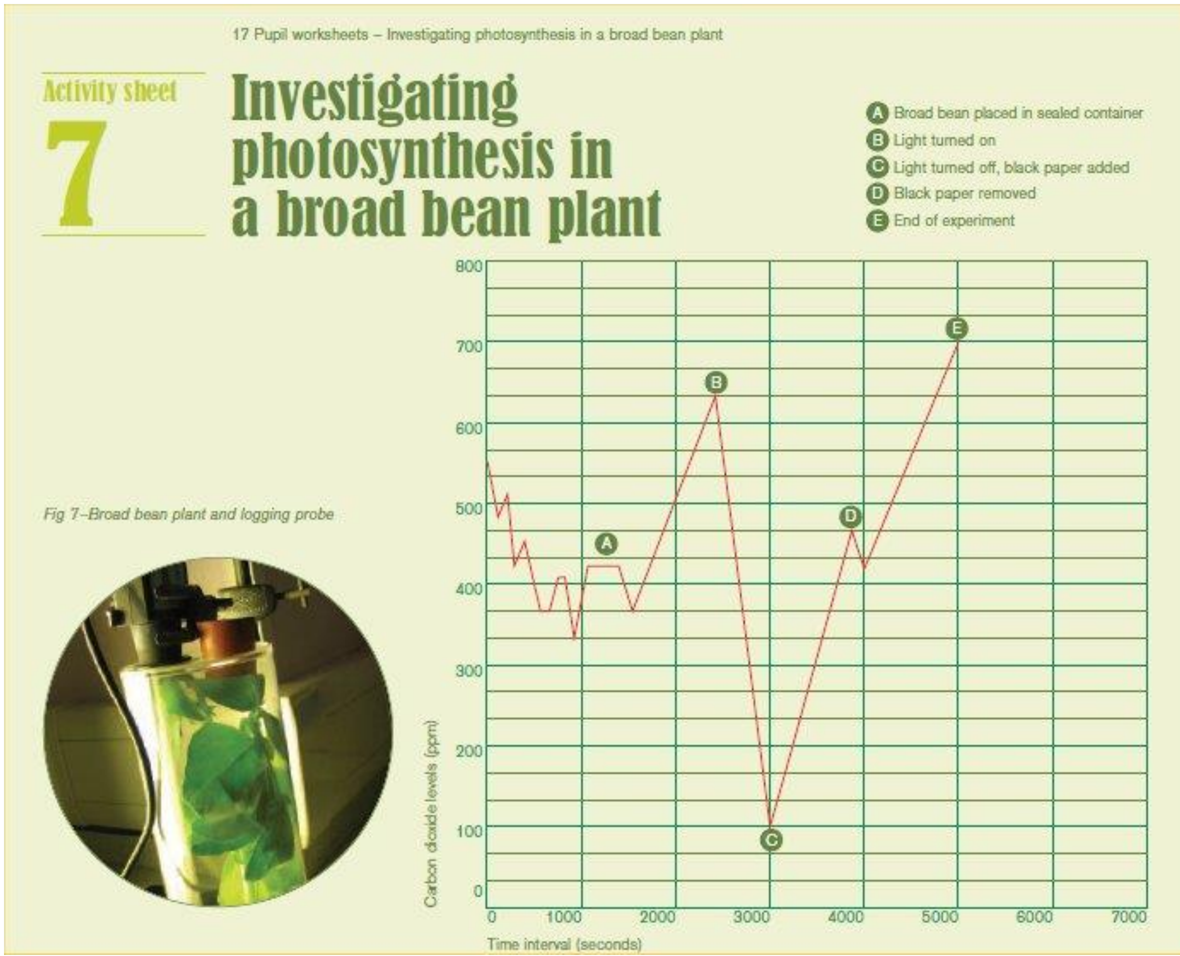
Durham University
School of Education

[WRAP (2013) pg3. ISBN: 978-1-84405-465-7]

"Many consumers do not recognise that packaging protects food in the home. While there is recognition that packaging is important to keep the product safe on its way to and in the store, there is less recognition that it plays a role at home. In fact, the prevailing view is the opposite, i.e. that keeping products in the packaging leads them to spoil more quickly. This in turn leads many consumers to adopt unpacking strategies that potentially decrease the longevity of products (i.e. taking products out of their packaging or piercing the packaging to 'let it breathe')."

Making and evaluating claims

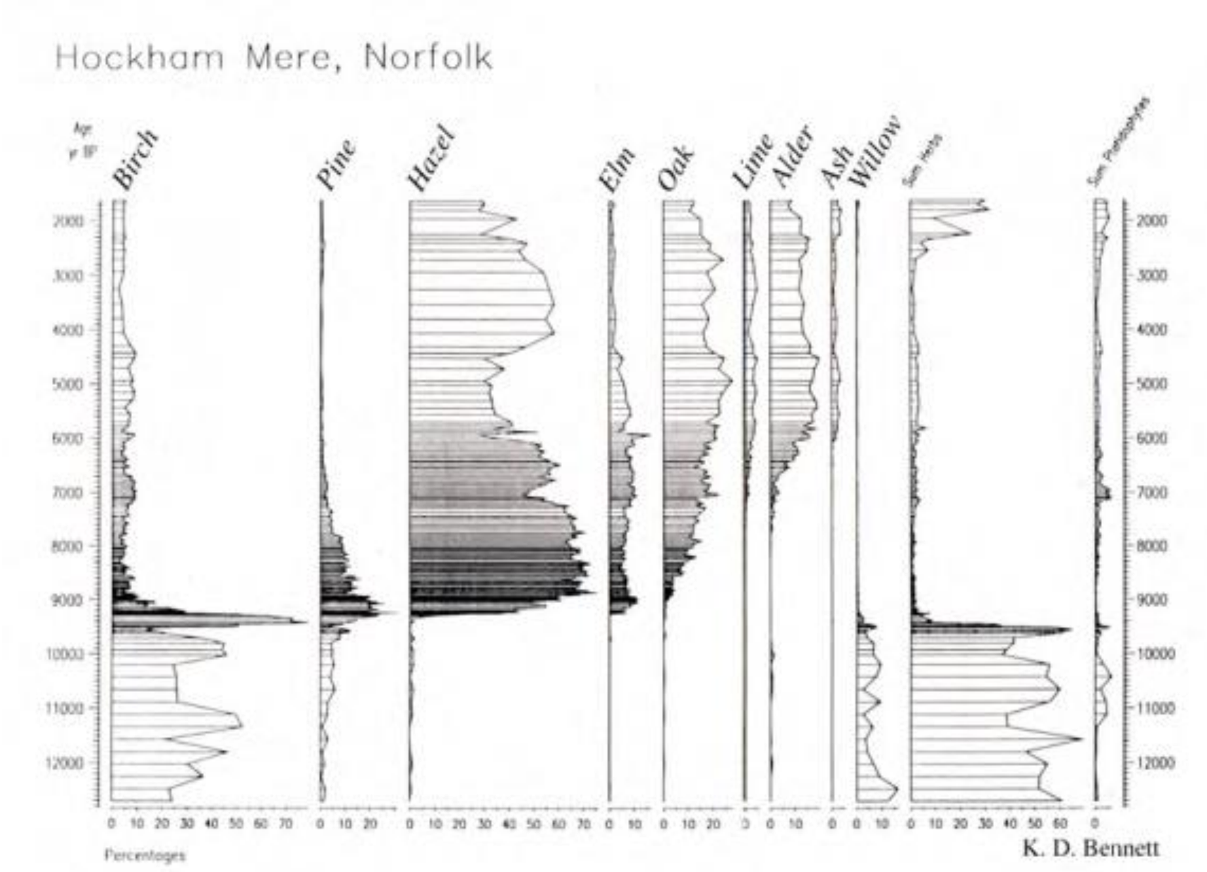
Durham University
School of Education



Evaluating data

Pollen in peat bog cores

Durham University School of Education



Ref. SAPS: Bog core analysis, succession and climate change

Working scientifically

Durham University
School of Education

e.g.

- *"make and record observations and measurements using a range of methods … and evaluate the … methods and suggest possible improvements"*

and

- *"evaluate data … showing awareness of potential sources of random and systematic error."*

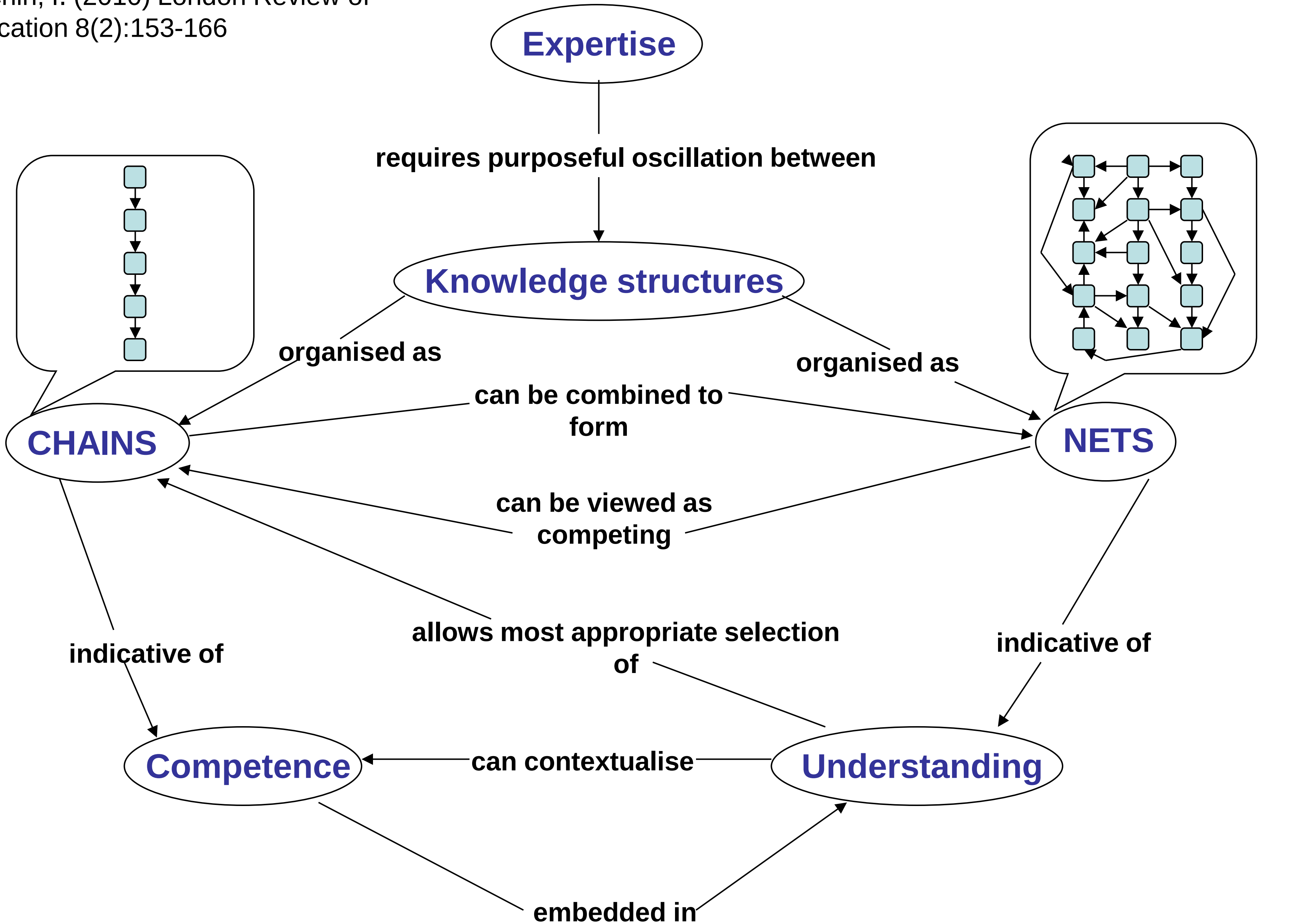
The problem of under-specification

This requires an understanding of the interconnecting ideas that affect the quality of biological data underpins Working Scientifically.

But

- What are the ideas and how can they be taught?

Kinchin, I. (2010) London Review of Education 8(2):153-166



Chains of practice in science (1)

Durham University School of Education

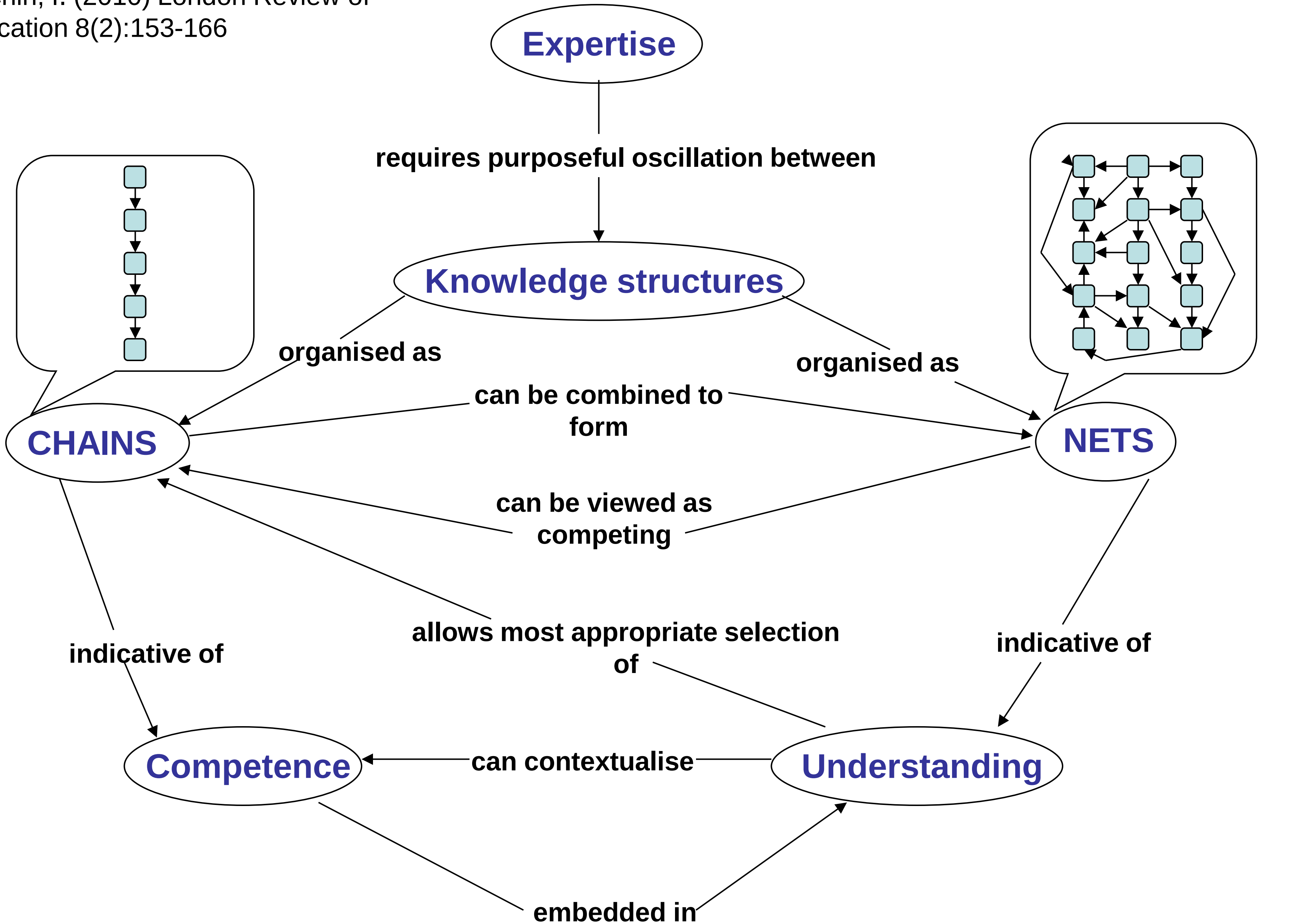
- Observable
- Tacit ‘thinking on your feet’
- Lend themselves to descriptions of practice (ie processes/’skills’ such as ‘planning’, ‘collecting’, ‘analysing’, ‘evaluating’ etc)
- A ‘skill’ – therefore developed by practice/doing?
- Characterised by performance?
- Such descriptions provide little guidance of ‘what’ to teach so that students are able to do this

Chains of practice in science(2)

Durham University School of Education

- ‘Very little thinking’ (at the time)
- Importance of specified procedures and techniques
  - ‘shortcuts’
  - Ensure ‘QA’
- Useful to ensure ‘correct answer’
  - Used in school science to illustrate substantive ideas
- Scientific ‘Write ups’

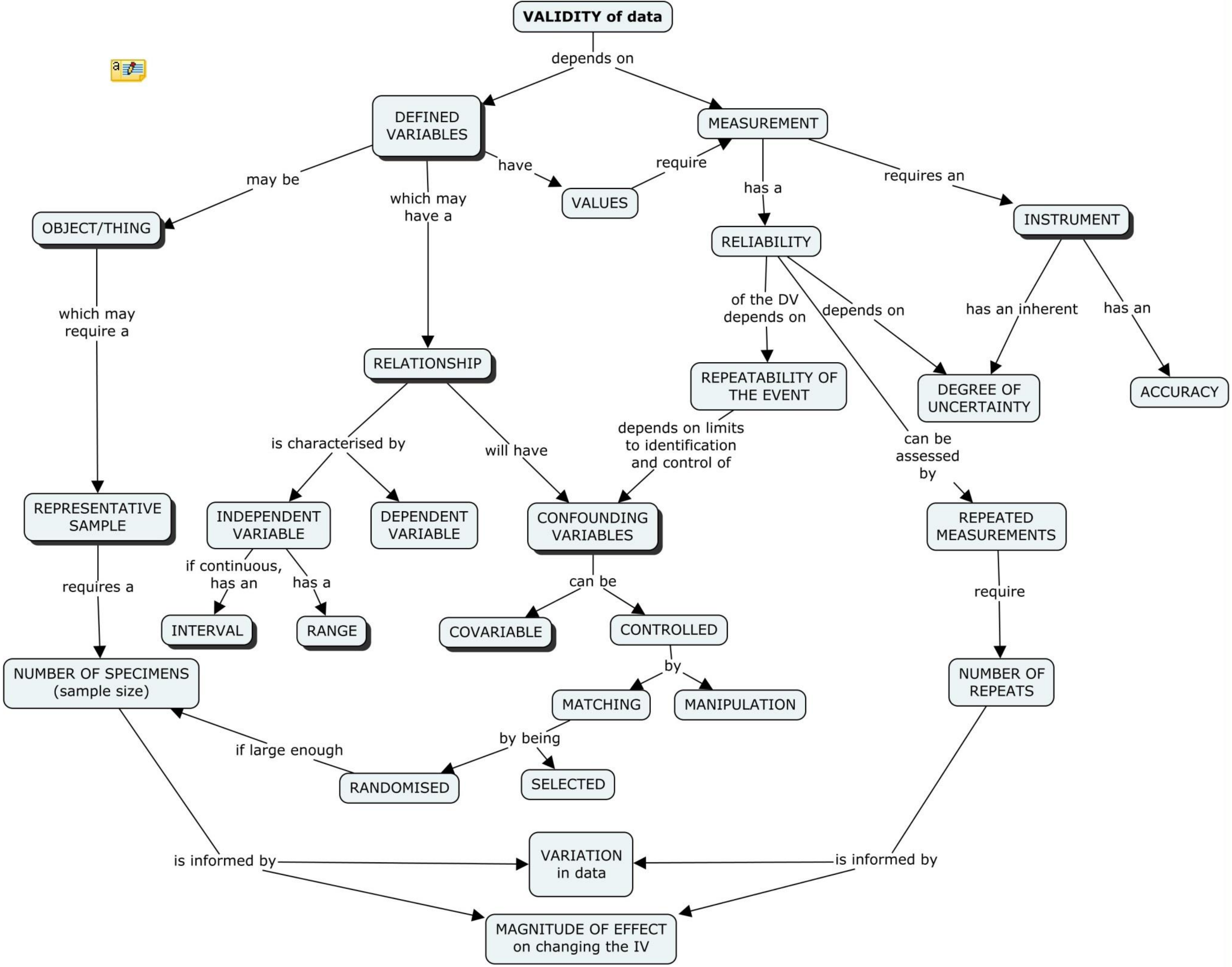
Kinchin, I. (2010) London Review of Education 8(2):153-166



Network thinking

Durham University
School of Education

- If 'the thinking behind the doing' is a knowledge base of concepts to be understood (rather than 'processes' to be mastered) it ought to be possible to represent that understanding with a concept map.
- A basis for curriculum development
  - Making the 'thinking behind the doing' explicit



Roberts & Johnson (2015). DOI: 10.1080/09585176.2015.1044459. Concepts directly informed by substantive knowledge are highlighted with a shadow.

Understanding Evidence has a knowledge base: the Concepts of Evidence

Durham University
School of Education

These are the ideas that are needed to develop an understanding of the quality of evidence

Validated against 'pure' and 'applied' work-place science and in contexts of 'public understanding' of science

- The PISA 2015 Draft Science Framework (OECD, 2013) addresses the importance of evidence in both its 'procedural knowledge' and 'epistemic knowledge' elements
- In the US, the new Framework for K-12 Science Education (NRC, 2012) the dimension of 'Scientific and Engineering practices' corresponds to understanding evidence.

http://www.dur.ac.uk/rosalyn.roberts/Evidence/cofev.htm

Summary of our research

Durham University School of Education

- Lab-based investigations and fieldwork draw on the same ideas about evidence – different emphasis and different sequence
- Ideas about evidence can be explicitly taught and assessed
- Understanding can be applied in creative, open-ended investigations
- Understanding can be applied to ask questions in socio-scientific issues
- Ideas about evidence can be utilised in evaluation and argumentation

Key points

Durham University
School of Education

- The map represents a network of intricately linked ideas - and decisions when investigating are based on nuanced application of the ideas, involving mental juggling according to context
- There is no ‘one scientific method’ – these ideas are arguably important to all scientific research
- Working Scientifically in Biology draws on all these ideas
- The intimate integration of substantive knowledge with scientific practice. Neither stands alone, each is only as good as the other
- Viewing ‘scientific practice’ as a network of ideas to be understood has significant implications for teaching and learning

Curriculum implications

Durham University
School of Education

- Ideas that can be specified, sequenced and taught explicitly
- Students require opportunities to develop this ‘network thinking’ (using practical and ‘non-practical’ work; inside and outside the classroom)
- Practical work is important in developing this understanding
  - students carry out trials and work iteratively in response to the data – making nuanced decisions as they work (which are not features common to illustrative practicals)
  - the focus should be on getting good enough data to tell us something and not agreement with a ‘right answer’

Conceptual demand of an investigation is affected by …

Durham University
School of Education

Factor	Less difficult		More difficult
Specialised Substantive knowledge	Low	→	High
Independent variable	Categoric	→	Continuous.
Reliability of DV	High	→	Low
Magnitude of changes in DV for each value of IV	Large	→	Small
Measurement of DV and other variables	Straightforward	→	Less straightforward
Control of confounding variables	Manipulated	→	Matched
Sampling of 'objects'	Low variation in kind	→	High variation in kind.

[These factors can all be identified from the concept map]

Further information

Durham University School of Education

- Philip Johnson & Ros Roberts (due March 2016), A concept map for understanding ‘Working Scientifically’. *School Science Review*, 97(360), 15-22
- Ros Roberts & Philip Johnson (2015), Understanding the quality of data: a concept map for ‘the thinking behind the doing’ in scientific practice. *The Curriculum Journal*, 26(3), 345-369

- *Research into Understanding Scientific Evidence*. http://community.dur.ac.uk/rosalyn.roberts/Evidence/cofev.htm