Developing a model of understanding in physics education: how do students develop coherent conceptual structures?

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What is understanding in physics education?

Understanding is developing mental representations or simulations of physical situations (Clement, 2008)

Understanding is noticing underlying structure (Gibson, 2000)

Understanding is the development of coherence (Colliver, 1999)

Understanding is the ability to transfer knowledge to novel contexts (Bransford & Franks, 1976)

Understanding is a feeling of knowing (Thagard, 2006)

Understanding and knowing about causes in the data

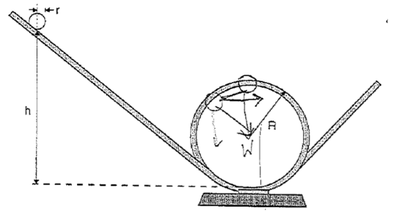
Understanding causality is seen as important for developing scientific understanding (Perkins & Grotzer, 2000). Difficulties in understanding arise for students when they erroneously attribute causality. For example, Ben conceptualises energy as the prime cause of other physical concepts:

102	P	So I'll just do this to say really this is entering on everything is energy
103	I	Yep
104	P	I think that is probably the most fundamental
105	I	More than force?
106	P	Yes in the sense if you didn't have you could have energy but no forces but if you no forces then I mean if you had no energy then if we call something force that force wouldn't be able to make anything accelerate it wouldn't have any impact on the universe

Understanding and appropriate classification in the data

Students encounter difficulties when knowledge has been given incorrect properties when compared to acceptedunderstandings (Chi, 2013). For example, Amy attempts to find a resultant of velocity and a force, objects that belong to different ontological categories:

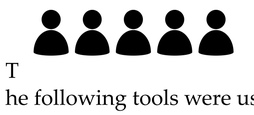
200	P	Down that way [adding diagonal line] So when the ball is here say [at top of loop] the weight is acting down on it but then also wait which way direction is this travelling in this particular diagram?
200	I	Let's say it's going that way round so up there and then
201	P	OK so it's and then it's velocity would be that direction [horizontal line to right] so then the resultant is inwards like that [diagonal down towards centre]



Elements of understanding arising in the data

The study design: capturing understanding?

Five students were interviewed for 30 minutes, once a week, for twenty-two weeks

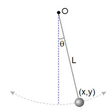


The following tools were used:

Unstructured concept maps (Nicoll, 2001)

Concept inventories (E.g., Hestenes, Wells & Swackhamer, 1992)

Interviews about events (White & Gunstone, 1989)



The interviews were analysed via open coding (Strauss & Corbin, 1998)

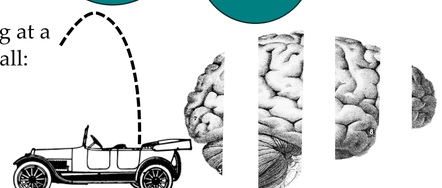
The microgenetic method: slicing cognition thinly

The microgenetic method involves applying a sampling rate that is high compared to the rate of change of the phenomenon being studied (Seigler & Crowley, 1991). This method raises a number of questions regarding how reports of congition may be divided:

What is an appropriate sampling rate at which to observe understanding?
How 'thinly' may reports of cognition be divided?
How may 'noise' and 'signal' be distinguished in reports of cognition?

Understanding, rote learning or insight?

A ball is thrown vertically from a convertible moving at a constant velocity. Ignoring air resistance. Does the ball:
a) land inside the car
b) land in front of the car
c) land behind the car



Can understanding be routine?

Searle's (1980) Chinese Room Paradox asks you to image a person in a locked room is fed questions in Chinese, the room contains a rule book that describes what actions to carry out on the symbols to create a response in Chinese characters. Can understanding be merely following rules?

Understanding, rote learning or insight?

A metal disc with a hole in the centre is heated uniformly. Does the hole: a) expand b) contract c) remain the same size?

Aha! moments- sudden understanding

Some models report concept change may be a sudden and discontinuous change in understanding: insights (Chi, 2013; Clement, 2008). There are several well known examples of scientists developing understanding in a 'flash' of insight for example, Kekule's benzene dream. Though they are reported to be rare (Fisher & Moody, 2002), moments of insight may be significant learning events.

The mistaken conflict between rote and meaningful learning

There may be a spectrum of learning:

Rote learning results in isolated concepts ... Meaningful learning leads to conceptual integration (Ausubel, 2000)

Some physics educators feel rote learning has become the norm, and high achievement in assessments may not reflect understanding (Redish, 2000). One student claimed the current system 'doesn't reward good learning so much as it rewards regurgitation, and good memory' (Danielak, Gupta & Elby, 2010, p3). Rote learning is portrayed as damaging:

Meaningful learning

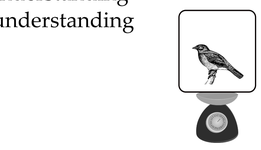
- 'To us, rote learning and the conformity it engenders may be likened in some respects to a form of intellectual slavery' (Mintzes, Wandersee & Novak 1998, pxix)
- Rote learning has become the norm, and high achievement in assessments may not reflect understanding (Redish, 2000).
- One engineering student claimed 'the current education system... doesn't reward good learning so much as it rewards regurgitation, and good memory' (Danielak, Gupta & Elby, 2010, p3).

Versus

Rote learning

- Other researchers argue rote learning is necessary for meaningful learning (Willingham, 2009).
- Students' knowledge acquisition, it is claimed, has been hindered by 'progressive' teaching methods (Hirsch, 2001).
- In the U.K., the former Secretary of State for education has affirmed 'the critical importance of knowledge acquisition' (Gove, 2013).

This debate is not between mutually exclusive positions: Understanding without knowledge is impossible but knowledge without understanding is impotent.



Understanding, rote learning or insight?

A bird is placed in a sealed container which is in turn placed on a set of scales. The bird is initially at rest on the floor of the box and then takes flight. What happens to the reading on the scales?
a) it increases b) it remains the same c) it decreases