ESERA 2017 Conference
Dublin City University, Dublin, Ireland.
21st - 25th August 2017

THE MATTER OF LEARNING: RECONSIDERING THE THEORETICAL BASIS OF CONCEPTUAL CHANGE RESEARCH

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Since the inception of conceptual change research the field has been plagued by an inability to adequately define what concepts are or how they change. By considering the simple example of a ball being thrown in the air, this paper expounds the difficulties in defining conceptual change and links these to the theoretical roots of conceptual change within constructivist theory. By recognising advances in both philosophy and the natural sciences over the last few decades, it is argued that learning should be charcterised as the co-adaptation of brain, body and context. Such a characterisation provides an improved foundation for research.

Keywords: conceptual change, complexity, neuroscience

THE PROBLEM WITH CONCEPTS

Despite debate since at least the 1970s, there remains no consensus around what concepts are or what conceptual change involves. To demonstrate this, consider the case of pupils describing the forces acting on an object being tossed in the air; an example which appears throughout the literature. Pupils often describe projectiles rising and then falling as the ‘impetus’ from an initial push is dissipated and gravity takes over. McCloskey (1983) used evidence of this to make the case for pupils holding a coherent yet naïve theory of projectile motion. However, in the same volume, DiSessa (1983) developed his account of ‘p-prims’: fragmented understandings often stemming from experience. For example, the point at which a ball thrown vertically is stationary may invoke an understanding of ‘balance’ (diSessa, 2006, p. 274). This may in turn lead to pupils erroneously considering that there is no resultant force acting on the ball. The well-established fault line between so called ‘coherence’ and ‘fragmented’ views of concepts influences understandings of conceptual change and pedagogy. A teacher who considers pupils to have a coherent naïve theory may develop rational arguments to dissuade them. Whereas, recognising fragmented understandings suggests the need to integrate these views in order to build a scientifically accepted account.

Whilst these ‘cognitive’ views have a basis in Piaget’s (1929, p. 27) description of a “whole world of thought” that a child accesses, other researchers draw on Vygotsky’s (1962 [1934]) social constructivist account to develop a sociological view of conceptual change. Take for example Graham *et al.*’s (2013) case study of 11, 17-year-olds describing a ball thrown directly upwards. The researchers suggest that “students socially form their ‘impetus-theory-like’ explanations in response to the conversation generated by the teacher” (Graham *et al*., 2013, p. 88). They discuss how learners slot their understandings into the potentially unfamiliar terminology used within a classroom, producing a ‘spontaneous’ misunderstanding. This framing of learning through situated, social action has a long history, and attempts have been made to bridge cognitive and situational components of conceptual change. Mercer (2007) draws attention to the different facets of this debate: firstly, whether understanding is individual and mentally constructed or distributed within groups and socially constructed; secondly, whether conceptual change takes place within minds or between minds; thirdly, whether we are considering the social development of understanding or its transmission socially. If we accept that neither an extreme cognitive view nor a strict sociological view will allow us to explain conceptual change, the problem becomes not just one of whether concepts are fragmented or coherent, but also of where concepts are situated and where change takes place. In short, we are still not able to explain what concepts are, where they are, or how they change.

Whether we take an individual, cognitivist view, or a sociological one, constructivist views of conceptual change are premised upon concepts developing in the light of existing ones. This formulation accounts for thought *and* experience, challenging both extreme empiricist and extreme rationalist epistemologies. However, there remains at constructivism's heart a tension in that 'concepts' retain a dualist characterisation: existing somewhere beyond the material world and yet somehow interacting with that world. Dualism dominates the history of western thought through Plato and Aristotle to Descartes and Kant, yet was considerably undermined in the latter part of the twentieth century. Firstly, the so-called 'linguistic turn' eroded assumptions that there is a fixed relationship between the signs we use to represent the world and the world itself. So the notation we use to describe projectile motion (e.g. Leibniz's, Euler's or Newton's) affects our understanding of how an object falls. More broadly though, this calls into question the characterisation of concepts as true reflections of the world. Secondly, both cognitive neuroscience and philosophy of mind have opposed what Ryle (2009 [1949], p.5) called "the dogma of the Ghost in the Machine". As our understanding grows of how our brains interact with the minutia of context, the distinction between mind and matter becomes ever more untenable. For example, in relation to watching an object being thrown in the air, neuroscience suggests that our responses would differ whether we observe the motion from the first of third person perspective (Jackson, Meltzoff, & Decety, 2006), and our acceptance of any description of forces acting would be influenced by our relationships with others and their subtle gestures (van Baaren, *et al*., 2009). Studies of this kind show a clear link between mind, matter and material context; something which is often overlooked within conceptual change research. In recognising the decline of dualism, the question arises as to whether we can sustain an ontological distinction between individual minds, social interaction and material context. I propose that we cannot.

LEARNING AS COMPLEX ADAPTATION

A good way forward for conceptual change research is to focus upon observable changes in pupil behaviour. However, Brock and Taber (2016, p.5) note that a change in behaviour is not sufficient to indicate a change in the "underlying substrate of mental resources". I propose that there is no need to postulate such a mental substrate, divorced from the material systems involved in learning: the brain, social systems and the broader material context. The science of complexity recognises the impossibility of fully understanding such systems, due to their sensitivity to tiny differences and the non-linear nature of interactions within them (Cilliers, 1998). Nevertheless, we can still recognise that learning involves the co-adaptation of brain and context, and that behaviour emerges from this.

To develop this point, let us reconsider Graham *et al.*'s (2013) study, in which pupils suggest that an object at the top of a toss has balanced forces acting upon it. Whilst neuroscience is not advanced enough to make strong claims, we know that the pupils have responded to stimuli, and this demands careful consideration of the specific context. Graham *et al*.'s suggestion that the misconception arises 'spontaneously' through social interaction with the teacher, can be made more tangible by recognising that a pupil's response emerges from both the ongoing 'internal' processes of an embodied neurological system, and the stimuli within the full richness of the classroom context. This context includes patterns of sound: words and sentences, patterns of light from ball, images and diagrams, and the patterns of behaviour of other people.

A closer look at Graham *et al*.'s paper reveals that the pupils have previously been discussing the horizontal forces on an aeroplane firstly moving at constant speed and then accelerating. It is reasonable to suggest therefore that they have been 'primed' to be considering a stationary object to have balanced forces acting upon it. The patterns of language used include specific terminology, as Graham *et al.* contend, but also the visual representations and causal explanations deployed. Classroom context need not be treated as an amorphous process of 'social construction'. Pupils are interacting with the teacher and each other through words, diagrams, facial expressions, movement, and all the other facets of human interaction. Callinan

(2014) recently established the importance of gestures in pupil learning, demonstrating the potential of conceptual change research in exploring these subtleties. When a pupil gives an incorrect response therefore, there is no need to assume some deficiency in their mental substrate, or in an amorphous social construct. By seeing the response as emergent from brains, bodies and material context we are able to apply the full weight of neuroscience, cognitive science, linguistics, gesture analysis, and any other area of empirical study relevant to the situation.

In leaving behind the untenable, dualist character of concepts, we align research with the existing focus of our educational systems upon pupil responses. Mastery of Newtonian physics is demonstrated through giving appropriate responses to multiple, nuanced problems. In Graham *et al.*'s study, one pupil bravely went against the group and suggested a downward resultant force when the ball was rising. Without being able to specify all of the complexities involved, we can say that this pupil's neurological response was robust enough to give a scientifically acceptable answer. By evaluating learning in these terms we need not resort to assumptions about concepts, nor must we return to a (behaviourist) view that cognition is not important. Brock & Taber (2013) distinguish between 'explicit thinking', which is in constant flux, and more stable 'cognitive structure' which they tentatively link to long-term memory. I am here arguing that it is much more fruitful to evaluate the resilience of a pupil's response to different problems and contexts, whilst recognising 'explicit thinking' as emergent from, and integral to, the interaction of brain, body and those contexts. It is time to leave behind unanswerable questions around the development of concepts and instead focus our research upon the specific contexts in which pupils develop their responses to scientific problems.

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