On the interaction of conceptual and representational change

Benjamin Angerer

Institute of Cognitive Science, University of Osnabrück
benjamin.angerer@uos.de

Keywords: conceptual change, representational change, heterogeneous representation, theoretical psychology

Conceptual change is often understood as encompassing two aspects: Changes in (a) *what* a concept refers to, e.g. when its meaning is being broadened to include instances not formerly viewed as such, or (b) changes in *how* it is being represented, e.g. when the definition of one of its underlying components is rephrased, or when it is being translated into a novel formalism. This latter kind of change is also referred to as representational change in adjacent areas of cognitive science. In this theoretical contribution, I will argue that because it proceeds from fixed sets of representational primitives, a lot of work on concepts and conceptual change underestimates that changes in how we represent something can precipitate changes in what we are representing – and vice versa [4,5].

Different representations of the same state of affairs – such as different formal notations, sketches, visualisations, analogical models (as well as different forms of mental representations) – can differ widely in their epistemic characteristics, that is, for example, in the ease of expressibility of the knowledge, its discoverability, comprehensibility, and what subsequent strategies of dealing with and acting on this knowledge they afford for human cognisers. A very simple, but instructive example: Even though the mathematical definition of the concepts ODD and EVEN can be made without reference to any specific form of number representation, the extraneous structure some forms of representation impose on numbers make them much easier to recognise, and arguably to discover, than others: Whereas in unary representations such as tallies we need to appreciate the cardinality of the whole represented integer to determine its parity, in positional notations with bases ≥ 2 determining the parity of least significant digit will suffice, irrespective of the integer's overall size. This salience of parity in positional number systems in turn might then prompt subsequent discoveries which – while possible with other forms of number notation – might have been made at a much later point in time or even been overlooked.

In the history of science and technology, conceptual progress often co-occurred with the interdependent development of novel representational formalisms [8]. For instance, the development of Newtonian mechanics was closely tied to the invention of differential calculus, and the emergence of modern mathematical logic lead to its effective physical realisation with the invention of the computer. In education, teachers and lecturers face the difficulty that given their expertise they are conceptualising things in different terms than learners – and the very same representations which are conducive to their own thinking can confuse and overwhelm learners [2,9]. An important part of education research therefore lies in understanding how learners represent things to themselves and developing forms of representation which are easily accessible to them and incorporate their intuitions about the subject in a productive way [3].

In this contribution, I will discuss examples of both, changes in a representational framework driving conceptual change, and cases where the discovery of unexpected properties on an instance of a concept led to changes in how the concept was represented in general. I will argue that the understanding and ultimately modelling such an interaction between representational and conceptual change requires a cognitive architecture that allows for heterogeneous representation of concepts [7,10], and moreover, that change is often driven by a juxtaposition of the extraneous structure imposed on a concept by the specifics of different forms of representing it [1,6].

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