Models and Analogies in Conceptual Restructuring

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The purpose of this symposium is to bring together recent work on the role of analogies and models in conceptual restructuring from cognitive scientists representing different disciplines and examining similar phenomena from diverse perspectives. Theodore Arabatzis and Despina Ioannidou approach the topic from a philosophy and history of science perspective. Their contribution focuses on the analysis of the ways in which the planetary model mediated the conceptual transformation of J. J. Thomson's 'plum-pudding' model of the atom and transformed the concept of the electron. Cognitive analyses of conceptual changes in the history of science are rare but particularly important from a cognitive science point of view because they provide an opportunity to understand very complex kinds of conceptual processes over long periods of time that are difficult if not impossible to study in the laboratory. Nancy Nersessian is using cognitive-historical ethnographic methods to study how engineering scientists create in vitro models of the phenomena they want to study and manipulate them in order to understand them. As she explains, engineering science is fundamentally analogical practice since simulation models are analogue representations of the entities and processes under study. Stella Vosniadou and Irini Skopeliti approach the topic from a cognitive developmental point of view. They are interested in finding out whether elementary school children can understand analogies and models and can use them to restructure existing knowledge in the process of learning science. John Clement approaches the topic mostly from a science education point of view. He has studied the role of models and analogies in promoting the understanding of science concepts for a very long period of time and has developed an integrating framework that identifies several roles for analogies and explicates the kinds of conceptual changes they promote. The moderator of this symposium is Dedre Gentner who is internationally known for her pioneering work on analogy.

Theodore Arabatzis and Despina Ioannidou

The mediating role of models in conceptual transitions: how the electron became a quantum entity

The extensive philosophical literature on models has focused on their role as mediators between theories and their empirical domains. With a few notable exceptions (e.g. Morgan & Morrison, 1999; Nersessian, 2008), their role in effecting conceptual change has not been explored. In this paper we discuss this particular function of models via a case study: the transition from a classical to a quantum theory of atomic structure (or, equivalently, from a classical to a quantum concept of the electron). In that transition the model of the atom as a planetary system (or, equivalently, of the electron as a planet) was rather crucial. In 1911 Ernest Rutherford abandoned the "plum-pudding" model of the atom, which had been developed by his mentor J. J. Thomson, in favor of a planetary model. The latter was suggested by experiments on the scattering of alpha-particles, which indicated that the mass of the atom is concentrated near its center. Despite its empirical grounding, however, the planetary model gave rise to severe conceptual and empirical difficulties. If the atom were structured as a miniature planetary system, it would have to be mechanically unstable. Furthermore, it would have to continuously emit radiation, until its eventual collapse. In response to those difficulties, Niels Bohr modified the planetary model, incorporating assumptions from the fledgling quantum theory and transforming in the process the concept of the electron. Thus, the planetary model functioned as a mediator between two successive versions of the concept of the electron. (Arabatzis, 2006). The focus of our analysis will be the heuristic and constraining function of that model in that conceptual transformation.

Nancy J. Nersessian

Engineering Analogies

Engineering scientists are a breed of engineer – often interdisciplinary – whose research aims to make fundamental contributions to basic science as well to create novel engineering artifacts and technologies. Practical or ethical considerations require that most often they investigate real-world phenomena through simulation models – physical or computational. That is, rather than devising ways of engaging the in vivo phenomena under investigation, they "engineer" selective, surrogate in vitro models of the phenomena and draw inferences about the phenomena by means of manipulating these. Such engineering science is a fundamentally analogical practice in that experimentation is by means of simulation models that are analogue representations of entities and processes under investigation. I draw on examples of such analogies as they have led to conceptual innovation and change in two engineering research laboratories – tissue engineering and neural engineering – on which we have been conducting cognitive-historical ethnographic research for several years. I investigate both dimensions of their practices of engineering analogies that in some instances lead to conceptual change: the nature of their analogies and how these are used by the engineers and the processes of designing and constructing their analogue models.

Stella Vosniadou and Irini Skopeliti

The role of analogies and models in children's comprehension of counter-intuitive science text

Learning science requires children to radically restructure their naïve explanations of physical phenomena (Vosniadou, 2008). Are children successful in engaging in such restructuring processes and what role can models and analogies play? For sometime now we have been investigating elementary school children's comprehension of counter-intuitive science text with and without the use of verbal analogies and/or dynamic visual models. Our results show that children fail to understand even the most fundamental ideas in counter-intuitive science texts. In addition, they generate erroneous inferences which reveal intrusions from prior knowledge and are similar in many respects to misconceptions, or synthetic conceptions, revealed in cross-sectional and longitudinal developmental studies.

We hypothesized that analogies would have the potential to help in the restructuring process because they draw upon children's existing knowledge from a different but familiar domain to facilitate the understanding of a new and unfamiliar explanation. We also hypothesized that the presence of a dynamic visual model would facilitate the comprehension of the scientific explanation not because it draws on familiar past knowledge but because it can make more explicit the structure and function of the explanatory mechanism. Results confirmed both hypotheses showing significant gains for the analogies and dynamic models groups compared to the controls. They also showed that the interventions were not equally successful for all children but had the greatest effect on the children who were in the transition to understanding the scientific explanation and had rejected some of the presuppositions of their naïve theories that constrained their understanding of the scientific explanations. In general, the children who were able to understand the analogies were also able to use them to restructure their physical explanations.

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John J. Clement

Roles for Analogies in Model-Based Conceptual Change

How can individuals learn new concepts that are very different from their present conceptual systems, especially in the face of persistent misconceptions? I review different learning strategies aiming to promote conceptual change in explanatory models in science, such as those using discrepant events (anomalies) and those using analogies. This can be seen as setting up a contrast between dissonance producing and constructive strategies. Others have argued that an approach combining these is often needed that also uses multiple cycles of model evaluation and revision.

As one direction for extension of this work, we recently identified four different roles for analogies used by experts solving explanation problems, suggesting that analogies may have more varied purposes than commonly recognized. Some of these appear to utilize imagery (Clement, 2008a, 2008b). This work on examining the finer grained level of strategies promoting "smaller" learning processes, such as analogies, can be complemented by reviewing major types of conceptual change identified in the literature--"larger" processes at a more coarse grained level (Thagard, 1992). An integrating framework is suggested by arguing that the several identified roles for analogies can be mapped as learning strategies to the types of large scale conceptual change they promote. This suggests that mapping the relations between specific learning strategies and larger conceptual change processes is an important future research agenda.

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