# Cognitive accounts of modelling and conceptual change

Graduate Course, HBCSE, TIFR
2020-21, August - December, Semester 1

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Credit: 2

Duration: 15 Weeks

Time: Every Tuesday, 3 - 5 pm.

## Outline:

Modelling and conceptual change are two important themes in science education research. There exists extensive literature discussing them in the context of learning and instruction. However, theoretical accounts of these phenomena,, through the lens of cognitive science and focusing on underlying mechanisms, are sporadic and scattered.

Also, most existing accounts tacitly assume information processing models of mind, which is now considered to have serious limitations. It is thus important to make these assumptions explicit and discuss their implications. Discussions based on recent advancements in cognitive science also need to be brought to the fore to understand the emerging models of conceptual change and modelling.

This course aims to address both of the above mentioned concerns, by discussing some of the core aspects related to modelling and conceptual change, based on recent insights from cognitive science. In particular, some of the key threads that will be discussed as part of the course are:

1) How is knowledge possible through modelling?

How is knowledge possible is an age old philosophical question and we are far from having a satisfactory, conclusive answer to it. However, science has proven to be a representative of what can be called as reliable knowledge and there is now consensus that all what science does is modelling. This enables us to rephrase the above philosophical question in a more tractable way. This course will discuss processes involved in modelling based on recent insights from cognitive science. Based on our knowledge of how the mind functions and interacts with the world around, we will explore how modelling results in knowledge generation.

2) A cognitive account of idealisation - a key process in modelling and conceptual change

Idealizations are deliberate distortions that generate representational forms of objects, phenomenon and processes, as part of mathematical modelling of the physical world. Often the results of the process are forms akin to `spherical cows' which gives the impression of a grotesque misrepresentation. Contrary to the apparent flight from reality, idealization has proved to be of invaluable significance in the creation of scientific explanations. As an illustrative example, consider earth, which in reality is a huge, complex object with a molten core, multiple layers of differing density, continents, oceans and mountains. Representing it as a point particle is no less stark a distortion than the `spherical cow'. Yet all the three laws of Kepler and many other insights about motions of planets follow by making use of this idealization. In fact it would not be far fetched to say that idealisation was the methodological innovation that resulted in the birth of modern science.

How idealisation plays a key role in scientific knowledge generation is puzzling and counter intuitive. This course will discuss this from the perspective of cognitive science and explore their role in modelling and conceptual change.

3) Modelling, encapsulation and nominalization

Making sense of processes presents a unique challenge, due to their dynamic, online nature. The operational nature of concepts in processes makes it very difficult to view them as a compact self contained whole. The inability to view it as a permanent object on its own may hinder the process of concept development itself. In what may be considered as an idealisation as well as concept development and variously known as encapsulation/reification the operational nature of concepts can be transitioned into a structural form. Nominalisation may be considered as a form of reification, wherein the operational form in the verb is transitioned into a structural noun form gradually in the process of concept development. This course will explore and discuss the relationship between modelling, encapsulation and nominalization

4) Representational Vs artifactual approach to modelling

Representational and artifactual approaches are two ways of making sense of modelling. In the former, the focus is on the relationship between a representation (the final product of the modelling process) and the corresponding target system. Whereas the latter emphasise the construction acts involved throughout the extended and dynamic process of modeling. This course will discuss various assumptions and the model of the mind underlying both of the above mentioned approaches. We will also look at existing accounts of modelling like the one given by Hestenes which claims to be aligned with the artifactual approach but subtly involve elements of the other.

## Learning Goals:

- Develop an understanding of modelling and conceptual change from the perspective of cognitive science
- Understand the role of theories of mind in different accounts of modelling and conceptual change
- Develop a cognitive account of the process of idealization
- Understand the relation between nominalisation, encapsulation and modelling

## Readings:


1. Nersessian, N. J. (2002). The cognitive basis of model-based reasoning in science. The cognitive basis of science, 133-153.

2. Tall, D., Thomas, M., Davis, G., Gray, E., & Simpson, A. (1999). What is the object of the encapsulation of a process?. *The Journal of Mathematical Behavior*, *18*(2), 223-241.

3. Wilensky, U., & Papert, S. (2010). Restructurations: Reformulations of knowledge disciplines through new representational forms. *Constructionism*.

4. Knuuttila, T., & Boon, M. (2011). How do models give us knowledge? The case of Carnot's ideal heat engine. *European journal for philosophy of science*, *1*(3), 309.

5. McMullin, E. (1985). Galilean idealization. *Studies in History and Philosophy of Science Part A*, *16*(3), 247-273.

6. Morrison, M., & Morgan, M. (1999). Models as mediators. *Perspectives on natural and social science. Cambridge University Press, Cambridge*.

7. Weisberg, M. (2007). Three kinds of idealization. *The journal of Philosophy*, *104*(12), 639-659.

8. Redish, E. F. (2017). Analysing the competency of mathematical modelling in physics. In *Key competences in physics teaching and learning* (pp. 25-40). Springer, Cham.

9. Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and instruction*, *16*(3), 183-198.

10. Ainsworth, S. (2008). The educational value of multiple-representations when learning complex scientific concepts. In *Visualization: Theory and practice in science education* (pp. 191-208). Springer, Dordrecht.

11. Kirsh, D. (2010). Thinking with external representations. *AI & society*, *25*(4), 441-454.

12. Lehrer, R., & Schauble, L. (2015). The development of scientific thinking. *Handbook of child psychology and developmental science*, 1-44.

13. Knuuttila, T. (2011). Modelling and representing: An artefactual approach to model-based representation. *Studies in History and Philosophy of Science Part A*, *42*(2), 262-271.

14. Barsalou, L. W., Wilson, C. D., & Hasenkamp, W. (2010). On the vices of nominalization and the virtues of contextualizing. *The mind in context*, 334-360.

15. Chandrasekharan, S., & Nersessian, N. J. (2015). Building cognition: The construction of computational representations for scientific discovery. *Cognitive science*, *39*(8), 1727-1763.

16. Chandrasekharan, S., & Nersessian, N. J. (2017). Rethinking correspondence: how the process of constructing models leads to discoveries and transfer in the bioengineering sciences. *Synthese*, 1-30.

17. Pande, P. (2020). Learning and expertise with scientific external representations: an embodied and extended cognition model. *Phenomenology and the Cognitive Sciences*, 1-20.

18. Chandrasekharan, S. (2016). Beyond telling: Where new computational media is taking model-based reasoning. In *Model-based reasoning in science and technology* (pp. 471-487). Springer, Cham.

19. Bergen, B. (2015). Embodiment, simulation and meaning. *The Routledge handbook of semantics*, 142-157.

20. Pulvermüller, F., & Fadiga, L. (2010). Active perception: sensorimotor circuits as a cortical basis for language. *Nature reviews neuroscience*, *11*(5), 351-360.

21. Matlock, T. (2004). Fictive motion as cognitive simulation. *Memory & cognition*, *32*(8), 1389-1400.

## Class Structure and Assessment:

The course will discuss one paper per session. The crediting students will take turns in presenting the paper and leading the discussion. The auditing students can volunteer to present, but presentation is not mandatory. The presentation and discussion have to be structured in such a way that there is maximum participation from everyone and discussion is enabled.

Assessment is based on the following accounts:

1) Presentation of papers
2) Participation in discussion
3) Two term papers - a mid term and a final term paper. The topic of the mid-term paper will be assigned by the instructors and the expected length is around 1500 words. It will have half the weightage in score compared to the final term paper, whose expected length is 3000 -5000 words. For the final term paper students can choose a theme related to modelling or conceptual change, in consultation with instructors..

Both instructors will independently grade the students and the scores will then be averaged.