HBCSE - Summer Elective Course

Title: Visuospatial thinking in science education

Instructor: Jayashree Ramadas

Credits: 2

Duration: May 1 to June 30, 2016

Contact sessions: Mondays 3-5 pm and Thursdays 11-1 pm

Contact hours: 25+

Course description:

This course gives an overview of a diverse area of study through a few key research readings that bear on the role of visual and spatial thinking in the learning of science. The course begins with some historical reports and exemplars of doing science (Shepard, 1988; Nersessian, 2008). Next we discuss evidence from cognitive science (Smith and Kosslyn, 2015; Tversky, 2010) which suggests that reasoning and problem solving are based on perceptual and motor processes. The theoretical perspective of 'embodied cognition' (Wilson, 2002) links the mechanisms of perception and action to problem solving in the world and further, to reasoning in abstract situations.

Meta analyses of large-scale longitudinal studies indicate that spatial ability assessed during adolescence is a strong predictor of future performance in STEM domains and professions (Wai, Lubinsky and Benbow, 2009). These results are discussed and interpreted by Uttal and Cohen (2012). The course looks at the nature of tests of spatial ability (Hegary and Waller, 2005) to conjecture how performance on these tests might relate to the learning of science.

The idea of model-based reasoning is then introduced which integrates analogical thinking, imagistic representations, mental simulations and thought experiments (Nersessian, 2008; Clement, 1989; 1993). Some pitfalls of mental imagery are discussed with examples of problem solving in elementary physics drawn from Viennot (2001).

Diagrams and gestures are external representations or tools that facilitate the visual, spatial and kinesthetic aspects of mental simulations. These tools combine depictive (experiential) with schematic (abstract) elements. The use of these spatial tools in science learning is exemplified by two studies (Padalkar and Ramadas, 2011; Srivastava and Ramadas, 2013).

Readings:

Clement, J. (1989). Learning via model construction and criticism. In Glover, G., Ronning, R. & Reynolds, R. (Eds), Handbook of Creativity: Assessment, Theory and

Research (pp. 341-381). New York, NY : Plenum.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. Journal of Research in Science Teaching, 30(10), pp. 1241-1257.

Hegarty, M. and Waller, D. (2005). Individual differences in spatial abilities, Chapter 4 in The Cambridge Handbook of Visuospatial Thinking, Cambridge : Cambridge University Press, pp. 121???169.

Johnson-Laird, P. N. (1996). Images, models and propositional representations. In Models of Visuospatial Cognition by Manuel de Vega, Margaret Jean Intons-Peterson, Philip N. Johnson-Laird, Michel Denis, and Marc Marscharck (pp. 90-127). New York, NY : Oxford University Press.

Manuel, D. V. and Marschark, M. (1996). Visuospatial cognition: An historical and theoretical introduction. In Models of Visuospatial Cognition by Manuel de Vega, Margaret Jean Intons-Peterson, Philip N. Johnson-Laird, Michel Denis, and Marc Marscharck (pp. 3-19). New York, NY : Oxford University Press.

Muldoon, C. A. (2006). Shall I Compare Thee To A Pressure Wave? Visualisation, Analogy, Insight and Communication in Physics. Doctoral Dissertation, University of Bath, UK.

Nersessian, N. J. (2008). Creating Scientific Concepts. Cambridge, MA: MIT Press. (i. Model-based Reasoning Practices: Historical Exemplar (pp. 19-60); ii. Model-based Reasoning Practices: Protocol Study Exemplar (pp. 61-90)).

Padalkar, S. and Ramadas, J. (2011). Designed and spontaneous gestures in elementary astronomy education. International Journal of Science Education. 33 (12), pp. 1703-39.

Ramadas, J. (2009). Visual and spatial modes in science learning. International Journal of Science Education, Vol 31 (3), Special Issue on "Visual and Spatial Modes in Science Learning", pp. 301-318.

Shepard, R. (1988). The imagination of the scientist. In K. Egan & D. Nadaner (Eds.), Imagination and Education, New York: Teachers College Press. pp. 153-185.

Smith E. E., and Kosslyn, S. M. (2015). Motor cognition and mental simulation, Chapter 12 in Cognitive Psychology: Mind and Brain. Noida: Pearson India Education Services Pvt. Ltd. pp. 513-43.

Srivastava, A. and Ramadas, J. (2013). Analogy and Gesture for Mental Visualization of DNA Structure. In Treagust, D.F. & Tsui, C.-Y. (Eds.), Multiple Representations in Biological Education. Dordrecht, The Netherlands: Springer, pp. 311-329.

Tversky, B. (2005). Visuospatial reasoning. In K. Holyoak and R. Morrison (Eds.). The

Cambridge handbook of thinking and reasoning (pp. 209-241). Cambridge: Cambridge University Press.

Uttal, D. H. and Cohen, C. A. (2012). Spatial thinking and STEM education: When, why and how, Psychology of Learning and Motivation, 57, pp. 147-181.

Viennot, L. (2001). Reasoning in Physics: The Part of Common Sense. Dordrecht, The Netherlands: Kluwer Academic Publishers. (Chapters 4 and 5, pp. 61-92; 93-120)

Wai, J., Lubinski, D. and Benbow, C. P. (2009). Spatial Ability for STEM Domains: Aligning Over 50 Years of Cumulative Psychological Knowledge Solidifies Its Importance. Journal of Educational Psychology, 101 (4), pp. 817-835.

Wilson, M. (2002). Six views of embodied cognition, Psychonomic Bulletin and Review, Vol 9 (4), pp. 629-36.