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Introduction to the Special Issue on "Visual and Spatial Modes in Science Learning"

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Rationale for the SI

This Special Issue (SI) of the International Journal of Science Education is a result of a growing realisation that visual and spatial modes are integral to our learning of science. In a previous special issue of IJSE on "science literacy", Klein (2006) argued that science knowledge should be seen, not as propositions composed of well-defined concepts but, as being perceptually-based, fuzzy and contextual. Cognitive activity is now seen less in terms of symbol manipulation and more as occurring through perceptual simulation and analogy, shaped by language but also distributed over persons, instruments and practices. This complex, emerging view of the mind finds resonance in work on mental models and visual representations in the history and philosophy of science. This research, some of which is cited in the papers in this issue, challenges science education with new conceptual frameworks for exploring models and visualisations with children.

In the last ten years science education researchers have taken up the challenge, as seen in the volumes edited by Gilbert (2005 and others in the series). Much relevant work however remains scattered over interdisciplinary journals and may not come to the attention of science educators. It was indeed at one interdisciplinary meeting, the Gordon Research Conference on Visualization in Science and Education VisSciEd 2007 at Bryant University, that several of the authors of this issue came together with John Gilbert of IJSE, and the idea for the SI was born.

Overview of the SI

The eight papers in this issue originate in different areas of science and bring to consideration a range of contemporary theoretical perspectives. Most of them report empirical research on visualisation and model-based reasoning in science education while a final paper comes from the perspective of engineering education.

The paper by Ramadas, "Visual and spatial modes in science learning", considers the role of visualisation in the conception, formulation and communication of ideas in science. Ramadas emphasises the transformational power of visual and spatial representations, arguing for a wide applicability of this notion in science learning.

Brooks, in "Drawing, visualisation and young children's exploration of big ideas", looks at

children's engagement, through drawing, in an activity that involves observation, design and construction and meaning-making. The six year-old children in her study are at the early stage identified by psychologists when they naturally produce spontaneous and expressive drawings. Their spontaneity, skillfully woven into a context of thoughtful exploration, makes the children's drawings a powerful tool for clarifying and extending their understanding.

Drawings capture meanings that emerge through one's sensory interaction with the world, as Reiner shows in "Sensory cues, visualisation and physics learning." Sensory cues for Reiner arise from visual as well as haptic modes of perception. She focuses on students' use of metaphorical representations to express properties of a concept that are not captured by straightforward pictorial depictions. Both Brooks and Reiner demonstrate the value of diagrams in converting nascent and incompletely-formed ideas into explicit and communicable forms.

The next two papers take up problems of visualising large distance scales, of two vastly different magnitudes, one geological and the other astronomical. In "How students and field geologists reason in integrating spatial observations from outcrops to visualize a 3-D geological structure", Kastens et al. begin with visual and spatial observations carried out in the field. Through a combination of visual-spatial and logical reasoning, their participants proceed from data, through claims, to building up of an argument for choice of a model geological structure. Along the way Kastens et al. demonstrate the use of some novel visual devices for presentation of their own data.

In "Visualisation and reasoning in explaining the phases of the moon", Subramaniam and Padalkar show the intricacies of understanding an everyday phenomenon based on a familiar model, that of the sun-earth-moon system. The majority of their adult subjects initially held the "eclipse model" of the moon's phases. It is indeed striking to see the prevalence and persistence of this model which, on brief reflection and mental visualisation, is discovered to be incompatible with the observed shapes of the moon. Both of these papers show the power of expert diagrams in thinking through complex situations.

A key issue in visual learning is the transition from perception to cognition. Lindgren and Schwartz in "Spatial learning and computer simulations in science" examine pedagogical simulations in science from the perspective of visual perceptual learning. They describe four "effects" to do with perception that serve to relate visual perception with memory, differentiation, structuring and action. They then assess some known computer simulations to see how they might support these innate learning mechanisms.

Assessment of students is the focus of "Visuals and visualisation of human body systems", in which Mathai and Ramadas compare students' expression through text and diagrams, as also mental visualisation defined in terms of transformations. They contrast students' high reliance on the verbal mode with their low tendency to use diagrams, and that in turn with their relative facility in carrying out mental visualisation tasks. They raise the issue of socio-cultural context of visuals, one that is as yet barely acknowledged in visualisation research.

Sorby, in "Developing 3-D spatial skills for engineering students" addresses the issue of the large observed individual differences in spatial skills. Her intervention studies, carried out over a decade and a half, have shown that training, particularly involving sketching practice, can lead to large

gains in performance, not only in engineering but also in science and mathematics in later years, and even significantly stem the drop-out of women from engineering courses. Sorby's results may go beyond the motivational factors that dominate gender research, for she finds similar gains in random and self-selected samples.

The close linkages between perceptual, motor and cognitive activity are underscored by several of the papers. Also demonstrated is the spontaneity and centrality of diagrams in the process of thinking. Kastens et al. (2008 and this issue) see diagrams as part of a class of visual and spatial "epistemic actions" that connect a laboratory or field situation with the representations and concepts of science. All of these ideas point towards a rich and unexplored area of research in science education.

Another conclusion from these papers is that expertise in using visual and spatial modes needs to be developed, for these to become effective tools for thinking. We need to find and test ways of developing such expertise in the science classroom. Science education today is founded on a predominantly verbal characterisation of learning and thinking. Recognising the seminal role of visual learning will open up new ways of looking at all aspects of science education including practical work, classroom discourse, concept understanding and assessment. It may allow us more effective ways of communicating with students, particularly those who have trouble with the dominant verbal and textual mode of the classroom. We hope that the SI will draw attention to these largely uncharted domains of science education.

References

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