Learning science through representational generation/negotiation

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Abstract

This paper will describe the key features and theoretical underpinnings of a representation-intensive pedagogy developed in a six-year research program, and its relationship to the epistemic practices of science. The pedagogy draws on socio cultural, pragmatist perspectives on learning and cognition that view knowledge as grounded in multi modal representations that are discursively generated, negotiated and coordinated in science classrooms. From this perspective, the learning challenges identified by research in the conceptual change tradition are seen as inherently representational in nature, and the central feature of the pedagogy involves students generating representations in response to structured challenges. The paper will interrogate the key aspects of the pedagogy and the way it supports learning, using evidence from a range of units designed by the researchers working in partnership with a small group of teachers. The role of representations in supporting learning will be explored in terms of the way they afford and productively constrain knowledge generation, mirroring the epistemic practices of science. Lesson transcripts, and examples of student artefacts will be presented to demonstrate significant reasoning and learning outcomes.

Synopsis

Background, Framework and Purposes

There is now a growing consensus that learning science at school entails students learning the literacies of a specific discourse community, one that uses a range of subject-specific and general representational tools to construct and justify evidence-based claims about the natural world (Kress et al. 2001; Lemke, 2004; Moje, 2007). Researchers in classroom studies where students were guided to construct their own representations of scientific ideas (Carolan, Prain & Waldrip, 2008; Ford & Forman, 2006; Greeno & Hall, 1997) have noted the importance of teacher and student negotiation of representational meaning and of students having opportunities to explore, elaborate, re-represent and coordinate representations to interpret science phenomena. There is growing evidence (Authors, 2010; Author, 2010) that this can lead to increased student engagement and improved learning outcomes.

This paper will report on aspects of an Australian project that worked with teachers to develop and validate a pedagogy based on student generation and negotiation of representations. It will address the research questions: 1) What are the key features of a pedagogy based on student generation of multi-modal science representations, reflecting the knowledge building practices of science? 2) How does such a pedagogy support student reasoning in science, and 3) What evidence is there that this approach leads to improved conceptual learning?

Methods

The research team worked with four experienced primary and secondary teachers to collaboratively develop a series of teaching sequences on science topics that the conceptual change literature has shown to present learning difficulties. The sequences focused explicitly on student generation and negotiation of representations related to key concepts. In working with the teachers over two years, we developed a set of pedagogical principles based on our experience and on the theoretical ideas described above.

The teachers' practices, student-teacher interactions, and student activity and discussion were monitored using classroom video capture. Key lessons were coded using an emergent scheme generated using Studiocode software, to make apparent the patterns of pedagogical moves and to explore the key features that could be considered fundamental to a representation-intensive pedagogy. Teaching and learning sequences were selectively transcribed and subjected to ethnographic analysis to identify the extent to which and in what ways the pedagogical principles were exemplified, and for evidence of the ways in which the focus on representations supported reasoning and learning about key science ideas. Students were interviewed about their learning, and teachers about their perceptions of the effectiveness of aspects of the sequence. Student workbooks were collected to provide a continuous record of representational work.

Pre- and post- test data were analysed to look for evidence of improved understanding, flexibility in the generation of representations, and the capacity to transfer ideas to a wider range of phenomena.

Results

The pedagogy has the following key principles:

1. The sequencing of representational challenges involving students generating representations to actively explore and make claims about phenomena, involving a) identifying appropriate representations underpinning key concepts; b) establishing a representational need and c) working towards alignment of student generated and canonical representations.
2. Explicit discussion of representations, including a) their selective purpose, b) group agreement on generative representations, c) form and function and d) the adequacy of representations.
3. Meaningful learning through representational/ perceptual mapping between objects/events and representations
4. Ongoing and summative assessment focusing on the adequacy, and coordination of representations.

Moreover, analysis of the patterns of conceptual clarification and orientation, representational challenge, clarification and negotiation of representations, and explanation/resolution showed similar pathways for lessons but differences depending on year level, place of the lesson in the sequence, and topic.

Analysis of the teacher – student exchanges and of student artefacts produced in these sequences demonstrated a strong alignment of the pedagogy with inquiry principles, but with strong framing of representational exploration leading to appreciation of canonical forms. We argue that this constraint on inquiry offers a productive way forward for classroom practice that relates the exploratory, epistemic practices of science, to the need to represent the canonical knowledge forms that remain the key target for science curricula.

Lesson transcripts, interviews, and post-test results will be used to show evidence of significant reasoning and learning. The analysis of reasoning is linked to the use of representations as epistemic tools in science knowledge – building, and draws on Peirce's (1953) triadic model of meaning making, and notions of affordances (Norman 1999) to identify the way representations selectively focus and constrain attention on aspects of the problem space. Teacher framing of the use of multiple, selective representations and student understanding of the partial and selective nature of representations will be illustrated.

Conclusions and implications

There is increasing acceptance of the view that learning involves a process of induction into specific discipline-based discursive practices, and is mediated by representations as the epistemic tools of science. This research represents a serious attempt to translate these theoretical insights into a practical classroom pedagogy that can effectively frame learning in science. Such a program has both practical significance for teacher practice and teacher education, and theoretical significance in bringing science classrooms and science practice into closer alignment. A re-interpretation of conceptual problems in learning science in terms of representational issues, and a program to translate this into a pedagogy, shows promise of making inroads into the problems in learning science well established in the conceptual change literature.

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