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Multimodal science teaching and learning

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The theme of this special issue is *Multimodal Science Teaching and Learning*. It brings together six papers that were originally presented at a seminar that took place at the International Science Education Conference 2018 in Singapore and follows a similar theme. The full-day seminar brought together eminent researchers and practitioners in the fields of multiple representations and multimodality in science education to share and discuss the practical applications of multimodalities in science classrooms and explore intersections and challenges across the various pedagogical directions when working with multiple modalities. Consistent among the various papers is the use of a theoretical lens in social semiotics. A social semiotics perspective to science teaching and learning considers the language of science as a cultural tool for meaning-making, where the mode used to inscribe the scientific ideas produces the intended meanings for the meaning-maker (Kress et al., 2001). Such a perspective deviates from the more traditional cognitivist lens used to understand the role of multiple representations in science education. While the latter has been successful in explaining why multiple representations are beneficial for science learning, this traditional view offers little in terms of how and under which conditions multiple representations can be introduced and used in science classrooms (Wu & Puntambekar, 2012). It is thus the focus of the papers collected in this special issue to explore this pedagogical space. The papers in this special issue are organised into the following sub-themes: *The multimodal nature of science teaching and learning, Interpretive vs constructive pedagogies* and *Teachers' multimodal practices*.

The multimodal nature of science teaching and learning

Teaching and learning is essentially multimodal (Jewitt, 2006). While language, whether written or spoken, is traditionally considered the de facto mode in school-based teaching and learning, it is hard to imagine teachers using just written or verbal modes to communicate with their students. As well, content, regardless of the subject matter (e.g., science, mathematics, geography, history, etc.), is seldom inscribed in words alone. Further, technology now enables various modes for representing content through instant messaging, blogging, podcasting, digital storytelling, etc., and literacy is no longer confined to reading and writing. In this era of new media made possible by the development of digital technologies (Lankshear & Knobel, 2011), literacy extends to and includes the capability to interpret and construct using multiple modes of representations.

Similarly, science teaching and learning is particularly multimodal (Kress et al., 2001). Scientific ideas are of course inscribed in various modes of representations – mathematical, drawings, pictures, tables, graphs, gestures as well as written/verbal language (Gilbert, 2010). For a particular science concept (e.g., matter), one can perhaps think about various representations (e.g., a drawing of a solid, the particle model of solid, atomic model of solid) that can be used to signify the concept, but each mode privileges a particular idea or element of the concept (e.g., drawing of a solid affords meaning-making at the macroscopic level while the particle model affords thinking of matter at the microscopic or nano-level). Some of these representations do not resemble the referents and/or draw from other ways of thinking about semiotic systems, which compounds the challenge of interpreting the meanings inscribed in these representations. As such, there is a perennial debate about when to introduce these representations in school and how to conceptualise them for best effect. In this respect, Cheng et al. demonstrate in their paper how a multimodal approach to teaching the particle model can help. Using an adaptation of Lemke (1990) thematic pattern with multimodality to analyse the sequence of modes of representations students worked with, Cheng et al. show how students' engagement with a sequence of multimodal representations can help to realise the scientific meanings of the particle model.

Developing the competence to interpret the meanings inscribed in different modes (e.g., a circuit diagram, a pressure-temperature graph, kinematics

equations) and use the formal representations of science to solve problems and communicate ideas have long been regarded as key learning outcomes in science curricula. However, studies on students' learning of the formal language of science show that this is neither straightforward nor easy for many students (Lemke, 1990; Martin & Veel, 1998). In this issue, Volkwyn et al. address this challenge by developing a working definition for representational competence based on social semiotic theory, and demonstrate how it can be operationalised to design multimodal activities and help university physics learners develop representational competence in the topic of one-dimensional kinematics.

Science teaching is also multimodal. Science teachers use pictures, symbols and physical models to present scientific ideas, as well as other instructional materials including textbooks with photos, text and other modes of representations to support students in making meaning. However, students may not make sense of the representations used by the teacher in the ways intended (see, for example, Carney & Levin, 2002; Cook, 2011). Nor do teachers always realise that students are struggling with the representations in use. The paper by Yeo et al. addresses this issue by demonstrating how one elementary science teacher orchestrated a series of visual ensembles of modes to realise the definition of "heat" and identifying the teacher's considerations in his selection and use of the visual ensembles of modes.

Beyond the modes created using educational media such as the classroom whiteboard, the advancement of technology has made available a range of technology-enabled modes such as animation, simulations, videos, virtual reality and argumented reality for supporting science learning. Making modal choices in the technology-enhanced learning environment comes under investigation in the paper by Nielsen et al. as they aim to understand pre-service teachers' considerations in their selection of modes to use in designing and creating digital explanations.

Interpretive vs constructive pedagogies of science teaching and learning

We can possibly think of two different applications of multiple modes of representation for supporting science learning – interpretive, where the learner interprets representations made by others, and constructive, where the learner

produces the representation. A common use of multiple representations is to aid science learning by offering alternative means of representing a concept (Tang et al., 2014) so that each mode complements or constrains the interpretation of another (Ainsworth, 2006). This interpretive perspective has shifted towards constructive pedagogies with the advent of the knowledge age. With respect to representing, the shift is towards students constructing representations rather than interpreting representations made by others through, for example, model-generation approaches (Gilbert & Justi, 2016) or drawing-to-learn in science (Ainsworth et al., 2011). However, various studies (e.g., Waldrip & Prain, 2013) also show that teachers find it difficult to facilitate learning in a representation-focused classroom. In this respect, the papers by Tytler et al. and Adams et al. illustrate pedagogical practices that can be adopted to orchestrate science learning during multimodal science activities.

Teachers' pedagogical practices in a multimodal science classroom

Using multiple representations for science teaching and learning has posed challenges for science teachers. While teachers use multiple representations to illustrate scientific meanings, they are often not aware of the affordances or limitations of different modes of representations nor are they aware of the challenges students face in making sense of the representations used in teaching (Eilam & Gilbert, 2014). In a constructive learning environment, teachers also find it hard to make use of the representations students produce for the purposes of advancing learning. Pre- and in-service teacher education programmes probably do not include sufficient emphasis on orchestrating learning in a multimodal science classroom. As such, one of the goals of this special issue is to showcase teachers' pedagogical practices in different multimodal science learning contexts and classrooms and highlight the considerations teachers need to make in selecting modes and representations to support student meaning-making. Each of the papers showcases some aspects of multimodal pedagogical practices. In this respect, Tytler et al. show the need for teachers orchestrating learning in a representation-constructing activity to exercise responsiveness and creativity in responding to the varied student representational work. This requires teachers to have a strong sense of direction of where their lesson should be leading. Adams et al. identify some talk moves that are productive in supporting science learning

when working with visual representations. Yeo et al. show that for teachers to select the modes that are apt for realising meanings, they need to be aware of what a mode can or cannot do in realising conceptual meanings and further, how to use these to provide the necessary pedagogical supports for learning. Nielsen et al. identify the common considerations pre-service science teachers make in their selection of modes in creating digital explanations. Collectively, these four papers provide a glimpse into teachers' multimodal practices and considerations in selecting modes and representations; the findings of these studies will be significant in informing professional development of science teachers in the use of multimodality in science teaching and learning. Similarly, the findings of Cheng et al. point to the importance of providing professional development in knowing how to develop apt multimodal scaffolds to support students in learning challenging concepts such as the particle model, while Volkwyn et al. show us how a semiotic audit can usefully identify the representational demands on students, and hence be helpful in designing a sequence of representational activities to support students to develop representational competences.

We are confident each of the papers in this special issue contributes to the practice of using multimodality in science education in a significant way. The work we present here is nonetheless the tip of the iceberg. We hope the studies here will propel further inquiry into the use of multimodal representations in science education and education in general.

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