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Using “Slowmation” to Enable Preservice Primary Teachers to Create Multimodal Representations of Science Concepts

Garry Hoban · Wendy Nielsen

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Abstract Research has identified the value of students constructing their own representations of science concepts using modes such as writing, diagrams, 2-D and 3-D models, images or speech to communicate meaning. “Slowmation” (abbreviated from “Slow Animation”) is a simplified way for students, such as preservice teachers, to make a narrated animation using a combination of modes. In this study, 13 preservice primary teachers learned how to create a slowmation during a two-hour class in a science methods course and then created one about an allocated science topic as an assignment. The research question that guided this study was, “What are the preservice teachers’ perceptions of making a slowmation and how was the science concept represented in the animation?” Data included pre and post individual interviews, concept maps constructed during the interviews and the animations as artifacts. Three case studies provide a window into the perceptions of preservice teachers making a slowmation and show how they represented their concept. Slowmation is a new form of student-generated representation which enables them to use their own technology to construct a narrated animation as a multimodal representation to explain a science concept.

Keywords Multimodal · Representations · Science methods · Slowmation · Student-generated animation

Introduction

Research has identified the value of students learning science concepts from single or multiple representations created by experts (Ainsworth 1999, 2006; Goldman 2003; Kozma 2003; Seufert 2003; van der Meij and de Jong 2006). What is now becoming apparent in the research literature is the value of students constructing their own representations of science concepts (Hand et al. 2009; Prain and Waldrip 2006; Tytler and Prain 2010; Waldrip et al. 2006). Students can create representations using a range of modes for communicating

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meaning such as writing, diagrams, images, 2-D and 3-D models, speech and music. A mode is a, “meaning-making system in order to articulate the meanings demanded by the social requirements of particular communities” (Kress et al. 2001, p. 43). Specific forms of student-generated representations that have been identified for science learning include writing (Hand and Choi 2010; Prain 2006; Ritchie et al. 2010), diagrams (Hubber et al. 2010; Prain and Waldrup 2006; Subramaniam and Padalkar 2009), flow charts (Davidowitz et al. 2005), physical models (Prins et al. 2008), and the use of multi-media such as power point presentations (Waldrup et al. 2006).

A recent insight from research is that meaning making by creating representations may be enhanced when students create more than one representation of a concept: “multiple representations refers to the practice of re-representing the same concept through different forms, including verbal, graphic and numerical modes, as well as repeated student exposures to the same concept” (Prain and Waldrup 2006, p. 1844). This process of re-representation has been called *transmediation* which, “relates to the student’s translation of content from one sign system to another” (Suhor 1984, p. 250). Students, therefore, may represent science concepts using a single mode such as writing, images, models or voice, as well as using a combination of modes that is often facilitated by technology (Lemke 2000; Prain 2006; Prain and Waldrup 2006). According to Yore and Hand (2010), “the transformation among multimodal representations has the greatest potential in promoting learning and depth of processing” (p. 96). This view is consistent with Lemke’s (1998) suggestion that encouraging learners to create a sequence of representations can sometimes “multiply meaning” (p. 92). To better understand how students make meaning through creating representations requires an understanding of semiotics — the study of signs, from which we draw the theoretical framing in this study.

Theoretical Background

Drawing on semiotic reasoning, when learners interpret an expert-generated representation, they may develop meaning because they compare their interpretation of the representation to the referent or object being represented (Peirce 1931/1955). This triadic relationship involves dynamic interplay between a representamen (the sign or representation), a referent (the concept/content being represented) and the interpretant (meaning made):

A sign, or *representamen*, is something which stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign, or perhaps a more developed sign. That sign which it creates I call the *interpretant* of the first sign. The sign stands for something, its *object*. It stands for that object, not in all respects, but in reference to a sort of idea... that is to have a *like* content...The triadic relationship is *genuine*, that is its three members are bound together by it in a way that does not consist in any complexus of dyadic relations. (Italics in original) (Peirce 1931, p. 99–100)

This dynamic relationship explained in Peirce’s (1931/1955) triadic model of a semiotic system was first shown diagrammatically by Ogden and Richards (1923) (See Fig. 1):

Building on Peirce’s (1931/1955) model, Lemke (1998) also explained how a semiotic system involves the interplay of three influences:

I believe that all meaning-making, whatever semiotic resources systems are deployed, singly or jointly, has become organized around three generalized semiotic functions

(Lemke 1989, 1990, 1992, 1995). When we construct meaning we always simultaneously construct a ‘presentation’ of some state-of-affairs, orient to this presentation and orient it to others and in doing so create an organized structure of related elements....How much more is this true when we take into account the co-deployment of visual, gestural, graphical, mathematical and other resource systems! (p. 91–92)

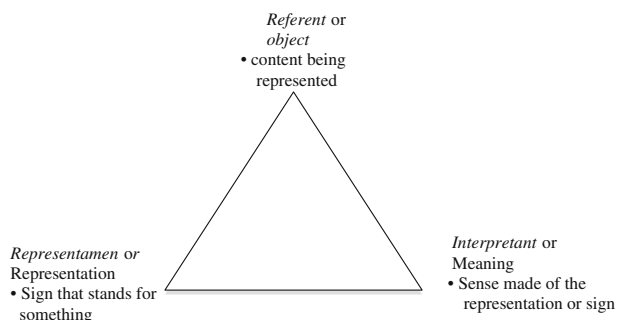
Although originating early in the 20th century, Peirce’s (1931/1955) semiotic theory for understanding the process of meaning-making when learners interpret expert-generated representations still has currency in science education research (Gilbert 2007; Prain 2006; Prain and Waldrup 2006; Tytler et al. 2007). According to Waldrup et al. (2010), “with any topic in science, students’ understandings will change as they seek to clarify relationships between their intended meanings, key conceptual meanings within the subject matter, their referents to the world, and ways to express these meanings” (p. 67).

It would appear that there is also educational value in students (school or university students) creating their own representations or “signs” of science concepts. When students design and make a representation of a science concept, they make decisions about the relationship between the content (referent) and how it is to be represented (representamen), including the most appropriate mode/s to use. Moreover, it is important that students think about which mode — written, auditory or visual — is the most suitable for a particular concept and for a particular representation. According to Waldrup et al. (2010), students need to learn how to represent their understandings using: “a broad range of representational opportunities and modes” (p. 69). When students construct a representation using more than one mode, it becomes a multimodal representation in which, “semiotic mode[s] combine as resources for meaning making. . . .as the resources of different modes are combined, meanings are corresponding, complementary and dissonant as they harmonize in an integrated whole” (Jewitt 2009, p. 301). In designing and making a multimodal representation, students make decisions about which modes to use that relate in complementary ways to enhance meaning-making which has been called “intersemiotic complementarity” (Royce 2007). Over the last 20 years, opportunities for students to be “multimodal designers” have increased exponentially with personal access to media-making technologies.

Using Technology for Creating Representations

What is creating new possibilities for students generating different forms of representations incorporating multiple modes is their increased access to new digital technologies. Over the

Fig. 1 Based on Peirce’s (1931/1955) triadic model of a semiotic system



last 20 years, students have gained ready access to technological devices such as digital still cameras, video cameras and more recently, iPods, supported by the affordances of Web 2.0 technology. This access not only enables students to learn *from* technology by accessing information, but also gives them the capacity to learn *with* technology by constructing their own knowledge representations (Jonassen et al. 1996; Kim and Reeves 2007; Willett 2007). According to Prain (2006), increased use of new media in the teaching of science in and out of the classroom provides exciting opportunities to facilitate learning: “manipulation of computer-generated texts, where students integrate imagery, sound, mathematical symbols, diagrams, and writing, alters the role of written language as the major or dominant medium of learning” (p. 180).

But even with access to new digital technologies, some forms of multimodal representations, such as animations, are challenging for students to make in a science classroom. For example, students can make a video that shows them personally explaining a science concept, but animating science objects generally requires mechanical movement, which is beyond the scope of most science classes or students. In contrast, making an animation using a stop-motion animation technique is feasible, because the creator manually moves objects whilst taking digital still photographs at predetermined intervals, thus overcoming limitations for mechanical movement in animating objects. Furthermore, taking digital still photos one-by-one instead of continuously at 25 to 30 frames per second, as in a standard video, allows students to manipulate, think about, discuss and reconfigure the individual sequences represented in each photograph as the animation plays (Hoban and Nielsen 2010). Yore and Hand (2010) contend that getting students to make stop-motion animations is a good way for teachers to introduce content as, “students take a series of still photographs and produce a time-series or time lapse collection or a flipbook to illustrate relative motion” (p. 99). However, traditional stop-motion animation (e.g. clay animation), which involves manually moving plasticine or clay models that stand up vertically and taking enough photos to play at 25 frames per second to simulate movement, is challenging for classroom teachers to organize.

Slowmation: A Simplified Way for Students to Make Animations

A “Slowmation” (abbreviated from “Slow Animation”) is a simplified way for learners, such as preservice teachers or school students, to make a narrated animation to explain a science concept (Hoban 2005, 2007, 2009). Slowmation has similarities to clay animation and digital storytelling but is much simpler to implement in a classroom. In short, a slowmation displays the following features:

- *purpose* — the goal of a slowmation is for students such as preservice teachers to engage with science content by making a narrated animation as an instructional resource to explain a concept and through the process, create a multimodal representation of the concept;
- *timing* — slowmations are usually played slowly at 2 frames per second, much slower than the usual animation speed of 25 to 30 frames per second, and therefore needing ten times fewer photos than clay or computer animation, hence the name “Slow Animation” or “Slowmation”;
- *orientation* — models are typically made in 2D rather than 3D (although not exclusively) and usually manipulated in the horizontal plane (lying flat on the floor or on a table) and photographed using a digital still camera mounted on a tripod looking down at the models, which makes it easier to manipulate and photograph the models;

- *materials* — because models do not have to be held in a vertical orientation (as is typically the case with claymation), many different materials can be used such as soft play dough, plasticine, 2-D pictures, drawings, written text, paper, felt, cardboard cut-outs, existing 3-D models and natural materials such as leaves, rocks or fruit; and
- *technology* — students use their own digital still camera or mobile phone camera (with photo quality set on low resolution) and free movie-making software on their computers (e.g., iMovie or SAM Animation on a Mac or Windows Movie Maker on a PC). In designing the slowmation, students can enhance the explanation of a science concept by adding a narration, text or music. Still photos that are key to the explanation can be “copy and pasted” to form “static images” that stay longer on the screen as long as needed to suit a narration.

Although many animations have been used previously in science education courses (Berney and Betrancourt 2009; Marbach-Ad et al. 2008; Sanger and Greenbowe 2000; Sperling et al. 2003; Williamson and Abraham 1995; Yang et al. 2003), in nearly all cases, they were expert-generated as educational resources to be viewed by students for learning science.

The use of slowmation, however, in our science education courses is different. Because slowmation is a simplified way of making an animation, it is the preservice teachers (e.g. our students) who design and make the animation as an instructional resource to explain a science concept. According to Jonassen et al. (1996), when learners become designers, it makes them think like teachers and promotes multiple ways of making meaning:

The process of articulating their knowledge about the domain ... forced them to reflect on that knowledge in new and meaningful ways. We have all stated at one time or another that the quickest way to learn about subject matter is to have to teach (design) it ... when learners actively construct knowledge from multimedia, they acquire cognitive, metacognitive and motivational advantage over learners who attempt to absorb knowledge. (pp. 95–97)

Slowmation has been in development in science method classes at an Australian university over the last 5 years. The purpose of the study in this paper, therefore, is to explain the preservice teachers' experiences of making a slowmation by addressing the following research question: What are the preservice teachers' perceptions of making a slowmation and how was the science concept represented in the animation?

Method

Participants and Context

A cohort of 24 preservice primary teachers were enrolled in a 13-week science method course in 2009 which was a final year elective in a four-year Bachelor of Education degree at the University of Wollongong in Australia. The preservice teachers had previously completed a compulsory science education subject in the first year of their program and many had also completed an additional science education elective in their second year. The purpose of this fourth year elective course was to extend the science knowledge of the preservice teachers. We did this by allocating science topics to individual students in Week 2 of the course, topics that they may not have covered before. Through assignments based

on these topics, our intention was that the students would spend considerable time with their own topic and then share their knowledge with their peers towards the end of the course. Topics allocated to the preservice primary teachers at the beginning of the course included flying insects, eclipses, strange plants, minerals and crystals, metals, kitchen chemistry, electricity, heat, light, chemical reactions, extreme weather patterns and simple machines.

There were three assignments in the course, all of which focused on the allocated science topic. The first assignment involved the preservice teachers researching the topic and collecting 20 resources on that topic. In Week 4 of the course, the preservice teachers participated in a two-hour workshop on making a slowmation in preparation for the second assignment where they would make a slowmation of their own on a concept within their allocated topic. It should be noted that most of the students who had begun their teacher education program at the University of Wollongong participated in a similar workshop during their first-year science methods subject and had previously made a slowmation. Hence, the second assignment for our students involved making a 1 to 2 min slowmation about a concept from their allocated science topic with the intention of the slowmation being an explanatory resource for primary children. The assignment was due in Week 7 of the term and the students showed and discussed their slowmations during this class meeting. The third assignment involved the preservice teachers creating an 8-lesson unit of work on their allocated topic based on the 5Es planning framework (Bybee 1997), which would include the slowmation from assignment 2 as an explanatory resource in one of the lessons. Thirteen of 24 students volunteered to take part in the research study, nine females and four males.

Data Gathering Methods

To address the research question, a range of qualitative methods were used to gather data. We collected data from three complementary sources: (i) two interviews were conducted by a research assistant. A pre-slowmation interview was conducted immediately after students were allocated their topic in Week 2 to ascertain their prior knowledge. The post-slowmation interview took place when students submitted their animation in Week 7; (ii) concept maps were sketched by the preservice teachers during the first interview and were subsequently modified in the second interview. The concept maps were intended to complement the interviews (Derbentseva et al. 2007; Novak and Gowin 1984; Van Zele et al. 2004; White and Gunstone 1992); and, (iii) the narrated animations were collected as artifacts for the study. It should be noted that no data were gathered as the students were actually constructing their slowmations, and thus we are not able to make claims about the relationship between creating a slowmation and the preservice teachers' learning of science knowledge. Rather, the focus of this study was to ascertain the preservice teachers' perceptions of their experiences in making a slowmation and to show how the students represented their allocated topics in the animations they created.

Data Analysis

We analysed the data for (i) students' perceptions about their experiences of how they made their slowmations and (ii) how they represented the allocated topic using different modalities. Thus, during interviews we sought elaboration from the students about how they gathered information about their topic and how they went about the process of constructing their animations attending particularly to the modes they used in the design. From our rich data set, we purposively selected three students (Bogden and Biklen 1998;

Miles and Huberman 1994) with different levels of confidence in terms of science knowledge and technological expertise to demonstrate their experiences of making a slowmation and to show how the concept was represented. The results are presented in three case studies (Merriam 1998; Stake 1995; Yin 2003) — one preservice teacher who was confident in both science and the use of technology; one who was not confident in either; and one who was confident in science but not in the use of technology.

Results

All 24 preservice teachers in the class were able to create a narrated slowmation explaining a concept from the science topic that had been allocated. Interview data revealed that many of the participants found creating a slowmation to be a different way to represent science knowledge as compared to their previous experiences in learning science, as they had to research their topic first in order to understand it and then represent the concept in the animation as an instructional resource for the purpose of explaining it to primary children. The first case is about Brad, a student who was confident in both his science knowledge and his use of technology.

Case Study 1: Brad's Representation of Static Electricity

Brad was a preservice primary teacher in his early twenties who had studied science to the end of high school and had completed one core science subject in his Bachelor of Education degree at university. He was now in the fourth and final year of the degree. Brad was completing this fourth-year elective as a night course while employed in a local primary school as a teacher of technology to different primary classes and was quite confident that the technological side of creating a slowmation would not cause any problems for him. In Week 2 of the course he had been allocated the topic, "Static Electricity," which is a topic that is often confusing for preservice primary teachers. Following class that evening, Brad was interviewed to ascertain his prior knowledge about static electricity and his attitudes towards science and technology. During the first interview he indicated that he had a positive attitude toward science although he had limited knowledge of static electricity.

Brad's Perceptions of Making a Slowmation

In the interview, which occurred in Week 7 after the slowmation assignment was submitted, we asked Brad about his experiences of making the slowmation. He explained that he did not initially understand what caused static electricity and remembers puzzling about this in his school days, so he needed to research why it occurred before he could make the slowmation. Brad did this by reading web sites on the internet that he had found for his first assignment (gather 20 resources on the allocated topic). He stated that he read about the concept until he felt he understood it:

So I used a lot of those web sites to actually read up and understand what it is I was going to be talking about and started developing ideas for how I could show those concepts now that I understood them better. I started to visualise them into a movie to find a way of telling that story in 2 min.

After researching the explanation for why static electricity occurred, Brad constructed a storyboard focusing on why a person's hand sometimes get "zapped" by static electricity when

opening a car door. His storyboard had around 40 sketches and he scripted a narration at the same time so that the modes of 2-D images, writing and narration were complementary:

It seemed to go hand in hand, I think once I had the idea of what I wanted it to look like then I had to think about what I wanted to say, because the picture could only tell half of the story... so I came up with some sort of visual element that would support what I was saying as a narrator.

Having constructed a storyboard with the modes of 2-D images and writing, Brad then realised that he had seven or eight different sequences or scenes of photos and so he developed models for each scene. He primarily used 2-D cardboard cut-outs for atoms and molecules with a range of plus signs to represent protons, minus signs to represent electrons, and zero signs to represent neutrons. Having made the models, which he laid flat on the floor with a camera mounted on a tripod looking down in a bird's eye view, he then photographed them as he manually moved them. He said he took nearly 400 photos over several nights and his partner helped him move the cut-out models as he took the photos. Once the photos had been taken, Brad downloaded them onto a computer and used the software program Windows Movie Maker to create the animation.

Brad's Representation of Static Electricity

Brad's animation lasted 2 min and 18 s and explained the concept of static electricity. He designed it using a combination of five modes — diagrams, writing in the form of labels, images of real cars, 2-D and 3-D models and voice. He drew on his own experiences of getting a shock whilst opening a car door and began the animation by asking the question, "Has this ever happened to you?" In his slowmotion, he used a variety of modes to show how electrons moved from one atom to another to build up charge. This included images of a real car door, and models of atoms created from cardboard cut-outs, some with a deficit of electrons resulting in a positive charge and some with an excess of electrons resulting in a negative charge. He used these modes to show how electrons could be transferred from one atom to another to build up a charge and that touching a charged object would ground the charge, which can be seen as a spark. As Brad explained in the accompanying narration, it was the friction of rubbing objects together that generated the force to transfer the electrons from one object (forming the positive charge) to another (forming the negative charge). Figure 2 shows a sequence of three hand movements from his animation representing the transfer of electrons during a static electric shock represented by a cardboard cut-out lightning bolt pasted over a photo of a real door.

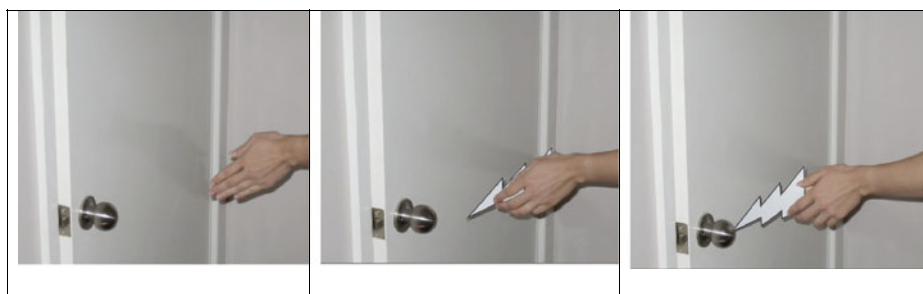


Fig. 2 Sequence of images from Brad's slowmotion

Brad used the mode of a voiceover narration throughout his slowmation to explain the movements in the 2-D models of the atoms, which were demonstrated visually. An excerpt from the narration shows his use of voice as a mode:

Electrons can transfer from one atom to another by rubbing together. When two atoms rub together, some of the electrons might jump from one atom to another altering the balance of charge on each atom and balance is the key word here. An atom with less electrons than protons is positively charged whereas an atom with more electrons than protons is negatively charged. When an object builds up excess charge it can discharge giving a zap.

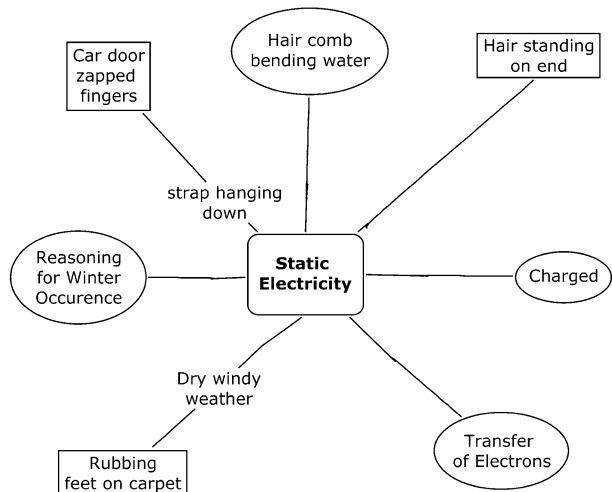
Brad aligned the mode of narration (recording his own voice) to complement the mode of slow-moving visual images that showed atoms rubbing together, resulting in a transfer of electrons from one atom to another and the static electric ‘zap.’

We wondered how our students felt about the slowmation as an assignment, as compared to some other form of assignment that might be used in the science methods class. Brad commented on the creative opportunities of making a slowmation:

You have to prove your learning, especially in a creative manner, you have to be pretty visual, the whole idea of having to visualise and make that happen means you really had to know what it is you are trying to say. You have to cut it down to bare facts, proving it in that short period of time. I certainly feel like I walked away from it knowing something about static electricity, stuff I did not know earlier. I answered my own question — ‘why does it happen?’

Whilst he used several modes in constructing his slowmation, we are limited in making claims about Brad’s learning from his experiences from the actual making process, since we did not gather data during the time he was constructing his slowmation. However, we used the pre and post interviews and concept maps to consider if there were any changes in Brad’s knowledge. Figure 3 shows Brad’s pre and post slowmation concept map constructed during the interviews. The concept map shows that he started with three ideas or experiences (rectangles) about static electricity being “car door zapping”, “hair standing on end” and “feet rubbing on carpet” and that four new ideas (ovals) were added after

Fig. 3 Brad’s initial (*rectangles*) and revised (*ovals*) concept map



the construction: “reasoning for winter occurrence,” “charged,” “transfer of electrons,” and “hair comb bending water.”

As a preservice teacher who was confident in both his attitude toward science and his knowledge of technology, Brad's case study shows that he had a positive experience of making his slowmation reporting that he would try it out with his own students in the classes that he taught. In particular, his slowmation was a good example of a multimodal representation whereby he used 2-D models and photos of real-life cars complemented by a narration to explain why cars sometimes give us small shocks, which had puzzled him since he was a school student. The next case shows how a different type of preservice teacher, a person who lacked confidence in both science and technology, also created a slowmation to explain a science concept using a combination of modes.

Case Study 2: Liz's Representation of Flying Insects

Liz was a mature-age student who had completed her formal science education in Year 10 and did not study any science subjects in her last 2 years of high school. She had completed the first-year science methods course 3 years previously. In the second week of the fourth-year elective course that is the focus of the current research, she was allocated the topic “Flying Insects,” a topic about which she knew very little. From her first interview Liz mentioned that she was concerned about the topic and more generally, lacked confidence in science because she had little background knowledge. She also described her technological expertise as “very limited”. Although she had used a digital still camera before, she had not downloaded images to her computer or uploaded anything to the internet. For these reasons, and for the purposes of our study, we consider Liz to be lacking confidence in both science knowledge and technology expertise.

Liz's Perceptions of Making a Slowmation

Liz's primary concern about creating a slowmation was the time required to complete the task. As we explored her background knowledge during the first interview, Liz stated that she knew that flying insects had something to do with air, but was unsure about the relationship between the two. She thought that some insects could fly as an adaptation to their habitat, but did not offer any details. She realised that the K-6 curriculum involved knowledge of insects and their adaptations, but she was uncertain about the role of flying in insects' ability to exist in a habitat. She also mentioned that flying may have something to do with insects collecting pollen and that this may be a cyclic pattern, but again, she was unsure. During the second interview, we asked about her preparation for making the animation. She had read several books but gained most of her information from reading the various web sites identified from the first assignment and she found, “a really good one from Berkeley University where they have actually made mechanical insects.”

Even though Liz's experience with technology was limited, she had little trouble using the available technology to make the slowmation and found it particularly easy to make “static images,” whereby a photo is copied and pasted to stay on the screen longer than a half-second to complement the narration:

I found it really easy with copying the pictures, if I looked through it a few times and thought, 'oh that one looks like a bit too much of movement,' you can then just copy and paste one photo to last a bit longer to suit the narration. That was really easy.

One of the difficulties she experienced, however, was getting up and down off the floor to move the models when taking the photos: “like a few times with the wings, I’d be like ‘Oh, was I on the way up or was I on the way down?’” However, this was overcome when her partner helped to move the models as she took the photos.

Liz’s Representation of Flying Insects

Liz’ slowmation ran for 1 min and 38 s and featured a combination of three modes — voice, 2-D diagrams and 3-D models—to represent her knowledge about flying insects. She sketched drawings of wings and used cardboard cut-outs for models. She chose not to use text as labels unlike other preservice teachers because, “my explanation was more in the actual narration.” Further, she had assistance from her partner in making and manipulating some of 3-D models of insect wings. This enabled her to represent the additional dimension of wing movement in the slowmation: “I got my partner to make me a little model, so I’ve got the wings going up and down and are part of an exoskeleton.”

Liz’s animation explained that wings were part of the exoskeleton of the insect, that insects had two pairs of wings and that sometimes the wings overlapped. She included a model of the wings of an insect in the slowmation, as she explained in the post-creation interview, “I’ve got the wings going up and down and just talking about them being part of the exoskeleton. They have hind wings and fore wings that are actually joined or overlapped, so they work together.” Later in the animation, the narration compared the wings on an insect to a fixed wing on a plane to explain flight. Figure 4 presents a sequence of still photos showing a transverse view of a fixed plane wing from her animation, and the accompanying narration explained the sequence:

Wings on insects and planes share a similar shape called an aerofoil. They are curved on top and flat on the bottom. Air travelling over the wing has to travel further because of the curvature so this air moves faster than air below the wing. Fast moving air exerts less pressure than slow moving air. The difference creates suction called lift. Lift is what pulls a wing skyward.

While the explanation for fixed wing aircraft flight is accurate, the analogy to the insect wing modeled in the slowmation is incorrect.

During the interview, Liz offered further explanation that showed that she had developed some incorrect ideas as she confused insect wing flight with airplane wings and flight:

So I have a diagram and little wings like that and I’ve got the air going over, so it goes over the top faster, faster than over the bottom so that’s the air flow and its like

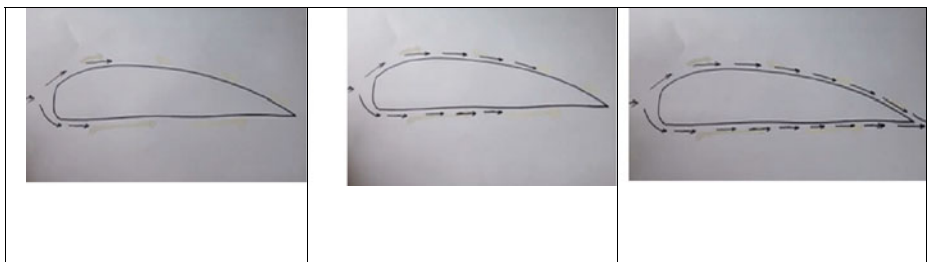


Fig. 4 A sequence of images from Liz’s slowmation

an aeroplane and it's called an aerofoil. So insect wings are like an aeroplane, the aerofoil makes the air go over the top faster than the bottom and ... the faster moving air exerts less pressure. The air going over the top exerts less pressure than air on the bottom and that creates suction and lift, and lift is what propels the insect upwards.

Although Liz's concept of lift is accurate in relation to fixed wings, in the case of insects, however, it is the rapid beating of the moving wings that creates the high/low pressure regions and thus, lift. Insects fly because of a combination of vortices and eddies created by the angled movement of the wing, which is different to the lift created by the forward motion of a fixed-wing aircraft. It is interesting to us that Liz attempted to use this analogy, but unfortunately, she seemed to lack sufficient understanding or experience with the concepts to recognize the alternative conception in her representation. She did, however, explain her new knowledge of insect wing structure during the second interview:

Insects are the only invertebrates that can fly. I've got a couple of things about what the wings are made of for example in the slowmation. The wings are made of chitin and they have a network of veins that provide support and flexibility to assist flight and the chitin is the membrane [that] is kind of distorted or angled which helps with the manoeuvrability and how the air goes over the wing....All this information was new to me.

From the interviews and viewing her pre and post concept maps as shown in Fig. 5, it can be seen that she developed some new ideas about flying insects (shown in ovals), however, this also included her alternate conception about how insect wings produce flight.

Liz's slowmation is an example of a possible limitation in regard to student-generated representations. Although her representation of flying insects was scientifically correct in most respects, it did contain an alternative conception in terms of how insect wings produce flight. We see the possibility of alternative conceptions being generated as inevitable when students are interpreting and creating representations of science content. However, because an animation is a digital representation, it can be easily shared to promote class discussion

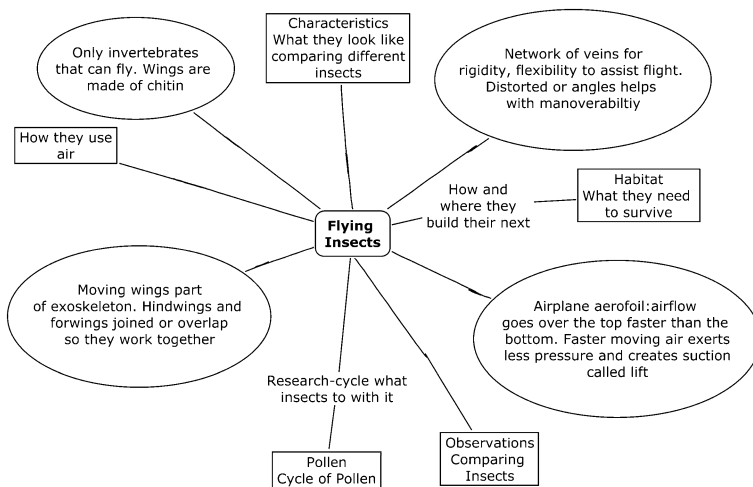


Fig. 5 Liz's initial (rectangular) and revised (ovals) concept map

concerning the strengths and weaknesses of particular features of student-generated animations. We therefore used an opportunity during a whole class discussion in Week 7 of the course, when each of the preservice teachers showed their slowmations, to provide feedback to the designer. Sharing the student-generated representation with the whole class created an opportunity for alternative conceptions to be identified, discussed and clarified. It should be noted, however, that of the 24 slowmations examined by the preservice teachers in the class, Liz's was the only one that represented an alternative conception. Other topics of the class discussion in Week 7 included aspects of the technology used and clarity of explanation in the animations.

Liz enjoyed the process of making a slowmation and mentioned that she planned to construct a slowmation with a kindergarten class that she had been hired to teach as a relief teacher later that week. We consider this to be indicative of her growing confidence with the ease of making a slowmation using her own technology. In particular, her slowmation was a good example of a multimodal representation whereby she used 2-D and 3-D models supported by a narration to explain how some insects fly. The final case study is about Tara, a student who was confident in science but not in her use of technology.

Case Study 3: Tara's Representation of an Eclipse

Tara was a student who had come to university directly from school. She had been part of a gifted and talented program while in primary school stating, "we did a bit more science than anyone else." She had continued her interest in science by studying Biology in Year 12. In the four-year Bachelor of Education course, she had completed a core science subject as well as another science elective. She maintained that she had a positive attitude toward science, especially about Biology, but she lacked confidence in her own technical expertise and had not constructed a digital animation before. She was allocated the topic of "eclipses" for her assignments and had expressed little concern about the topic, feeling confident in her scientific knowledge. She knew that there were two types of eclipses, lunar and solar. During the pre slowmation interview in Week 2, Tara recalled seeing a lunar eclipse while on practicum the previous year and how she had discussed this with her students. She mentioned,

When lunar eclipses happen, the moon turns red and that's because when it happens, the sun is shining its light through the Earth's atmosphere and makes the moon turn red, and the redder it is, that means there's more dust and particles in the air for that to happen.

When explaining solar eclipses, she stated:

It's a white ring where the moon is in front of the sun and the sun is shining through past the moon and you get this circle that goes like – this white circle. But I only remember that from having the newspapers talk about the difference between the two.

While her background knowledge of eclipses was sufficient, Tara was not confident with the technology used to make a slowmation. She had used a digital camera before but had not downloaded images to her computer. Tara expressed her primary concern in creating a Slowmation video: "the actual technology side of formulating it together is what I'm a bit stressed about."

Tara's Perceptions of Making a Slowmation

In her initial interview during Week 2, Tara decided to focus her slowmation on explaining solar eclipses, as she felt 1 to 2 min was insufficient time to explain both types. She also

knew that eclipses had something to do with the relative positions of the earth, moon and sun. During the second interview in Week 7, Tara said that she gathered information from looking at various web sites that had been identified in the first assignment for the subject. One of these was a BBC website that Tara thought was a good source of information alongside another by scientist Fred Espenack. When making her slowmation, she used cut-out paper circles to represent the sun and moon and designed a very detailed storyboard as a plan for the animation. She explained how she kept checking that the visual mode of the images and the audio mode of the narration were correct and complementary:

I was busy trying to make sure that the visual product and what the narration was saying was right and it looked good and sounded good and would be entertaining and engaging. Then I went back and thought, 'OK is what I've done making sense? Is it right?'

When making her narration, she recorded it in "blocks" making sure that the visual mode synchronized with the voice mode as she continually checked for accuracy.

Tara's Representation of a Solar Eclipse

Tara's slowmation ran for 2 min and 33 s and was designed to represent her knowledge about solar eclipses. She used a combination of four modes — voice, diagrams, 2-D models from paper cut-outs and images of a real eclipse. A key feature of her slowmation was the images of the 2-D models that she made juxtaposed with photos of a real eclipse that she had downloaded from "Google Images," which were inserted into the slowmation immediately following the photos of the models. For example, following the explanation and modelling of the "diamond ring effect," she made a static image (lasting 5 s by copying and pasting the image to suit the narration) of the effect using a photo of a real eclipse. Further, Tara visually showed and narrated a range of features of a solar eclipse such as "partial solar eclipse," "totality," "Bailey's Beads," and the "Diamond Ring Effect" as explained in her narration:

A solar eclipse happens when the moon passes between the sun and the earth. When the moon begins to block out the sun's light, it is called "first contact." The sky begins to darken as the crescent of the sun begins to get smaller. This is referred to as a "partial solar eclipse." As totality nears, less and less of the sun can be seen until just a tiny crescent is visible peeping out from behind the moon. This gives what is commonly called the "Diamond Ring Effect." Narrow shafts of sunlight can be seen shining through the valleys of the moon. These are known as "Bailey's Beads." Totality then occurs and for a few short minutes the sun is completely blacked out by the moon: the sun is totally eclipsed. At this time the sun's corona can be seen shining all around the moon, which only occurs in a total solar eclipse.

The narration in Tara's slowmation was illustrated by the following sequence of images, as shown in Fig. 6.

Tara's pre and post concept map is shown in Fig. 7 and she included some new terms about solar eclipses (shown in ovals), especially "partial eclipse," "total solar eclipse," "Bailey's Beads," and the "Diamond Ring Effect."

Tara's slowmation is an example of using simple materials such as cut-out pieces of paper that enabled her to explain the concept of a solar eclipse, which is often confused by preservice primary teachers. In particular, her slowmation was a good example of a multimodal representation whereby she used 2-D models (cut-out pieces of paper) that were



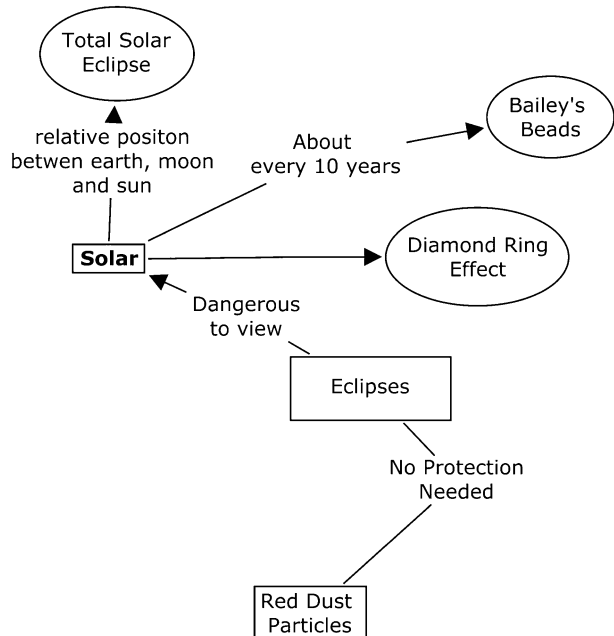
Fig. 6 A sequence of images from Tara's slowmation

juxtaposed with images of a real solar eclipse enabling her to provide a narration to explain several key features of a solar eclipse. The next section is a discussion of the findings presented in the three cases in relation to the preservice teachers' experiences of making a slowmation.

Discussion

The main finding from this study is that the process of making a slowmation provided a means for all the preservice teachers to make a narrated animation as a multimodal representation to explain a science concept. The slowmation process is a simplified way to make a narrated animation enabling the preservice teachers to use their own technology (digital still camera, everyday materials and software on their own lap top computers) and is readily taught in a two-hour class. Slowmation, therefore, is a new form of student-generated representation, which adds to the body of science education literature on representations including such forms as writing (Hand and Choi 2010; Prain 2006; Ritchie

Fig. 7 Tara's initial (*rectangular*) and revised (*oval*) concept map



et al. 2010), diagrams (Hubber et al. 2010; Prain and Waldrip 2006; Subramaniam and Padalkar 2009), flow charts (Davidowitz et al. 2005), models (Prins et al. 2008) and power point presentations (Waldrip et al. 2006).

From a theoretical perspective, when the preservice teachers make a slowmation, they are thinking about the concept they are trying to represent (referent), the design of the representation (representamen), and which modes to use in a complementary manner to provide a coherent explanation of a science concept (Kress et al. 2001; Lemke 1998; Peirce 1931/1955). For example Brad used five modes (diagrams, text, photos of real objects, images of 2-D and 3-D models and voice) to explain static electricity, Liz used three modes (voice, diagrams and 3-D models) to explain flying insects and Tara used four modes (voice, diagrams, 2-D models and photos of a real eclipse) to explain solar eclipses. The challenge for the preservice teachers is to re-represent science content in a way that is an explanatory resource for children by using their own technology to make and match different modes, so that the auditory mode of the narration complements the visual mode of the slow-moving images. In essence, the preservice teachers were designing the narrated animations as multimodal representations to have “intersemiotic complementarity” (Royce 2007, p. 63).

Although it cannot be claimed from the data collected in the current study that the preservice teachers learned science through the actual making of the slowmation, the preservice teachers made many decisions about how to best represent the science concept in their slowmation, which occurred with different designs and with a combination of modes. For example, Brad decided to demonstrate something that had puzzled him since his own school days and began with a real life problem — why do people sometimes get “zapped” when they open a car door? Tara focused on juxtaposing slow-moving images of 2-D models in relation to photos of a real eclipse and Liz focused on using 2-D and 3-D models to demonstrate how insect wings create flight.

Liz’s case also points to the value of sharing the slowmations created. Although her slowmation represented many correct aspects of insect wings, including that they are made from chitin and have a membrane on the wings with a veinous structure, she confused the operation of insect wings with fixed-wings on airplanes. This confusion was clarified during the whole class discussion in Week 7 when the students showed their slowmations to the whole class using a data projector. The animations were played to the class and each video prompted discussion about the concept being represented. We engaged in this discussion to share and extend our students’ science knowledge, which was a goal of the course. Hence, because a slowmation is a digital animated video that can be displayed in class, the sharing is a potentially powerful teaching and learning tool and further, is a strong motivation for preservice teachers to engage substantially with science content in order to represent it as accurately as possible. Slowmation, therefore, is a new way of making preservice teachers’ representations of science knowledge “public” and may be an opportunity to become aware of and to discuss alternative conceptions if they are evident in the animation.

We note, however, two limitations in this study. First, although the students explained how they made their slowmations, this research involved post-hoc discussions around perceptions of their experiences. It would have been preferable if the preservice teachers had kept a journal as a reflective record during the design process, which would provide an additional data source to triangulate our interpretations. Another limitation is the time taken to create the animation. Our preservice teachers learned how to make a slowmation in a two-hour class and most reported spending 5–10 h making their own slowmation at home, and, of course, this time could be used for learning

science in other ways. However, all of the students stated that they found the process of creating a slowmation to be highly engaging, and preferred it to conventional types of assignments, such as an essay or exam. Also, they each produced a digital artifact, which was shared with others by showing it to the class and/or uploading it to a site on the internet. Sharing the slowmations with others raises additional possibilities for learning by seeking feedback on their ideas. Further research is needed to monitor the process of students making slowmations to study if and how the actual process of creating a digital animation of a science concept enhances students' knowledge construction and understanding.

Conclusion

Current literature in science education has emphasized the value of students constructing their own representations of science concepts and where possible, translating these into other representational forms (Anthony et al. 2010; Hand and Choi 2010; Hand et al. 2009; Prain and Waldrip 2006; Tyler and Prain 2010; Waldrip et al. 2006; Yore and Hand 2010). We believe that slowmation provides this potential, whereby preservice teachers seek information, represent it using different modes and then use their own technology to combine them as a multimodal representation.

This research study and others (Hoban and Nielsen 2010; McKnight et al. 2011) suggest that slowmation has the potential for widespread use, because the creation process is relatively simple and uses accessible technology. Preservice teachers or other learners use their own digital still camera or mobile phone camera, everyday materials in constructing their models and have access to free movie-making software on their personal computers. For our preservice teachers, an important motivation for them is to represent a science concept in a slowmation as an explanatory resource for primary children. Moreover, we believe that the time put into the construction of an animation is worthwhile because the content is expressed in the form of a multimodal representation that is easily shared, thus opening up other possibilities for critique by peers or science educators. This promotes opportunities for discussion through the collective sharing and inquiry into the animations produced by students in a classroom. Whilst this study has focused on the use of slowmation for preservice primary teachers, other studies have involved preservice secondary teachers creating slowmations to explain science concepts (Keast et al. 2009).

Clearly, further research on slowmation is needed. Whilst this paper presents an argument that slowmation is a new form of student-generated representation that is multimodal, the studies conducted so far have mainly involved pre and post data collection and have not focused on data collection during the actual creation process. According to Yore and Treagust (2006), there have been few studies to investigate the, "enhanced cognition that occurs during the transformation from one representation to another representation or one mode to another" (p. 208). Designing such studies would need to include audio and video recording of students during the construction process in addition to pre and post data collection to ascertain if they build understanding of science concepts through the creation process. As media-making technologies become even more accessible to students over the next few years, we believe that possibilities for preservice teachers to create multimodal representations of science concepts will be further enhanced and additionally may provide opportunities for children in schools to also create slowmations as a way to represent their developing science knowledge.

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References

- Ainsworth, S. (1999). The functions of multiple representations. *Computers & Education*, *33*, 131–152.
- Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction*, *16*(3), 183–198.
- Anthony, R., Tippett, C., & Yore, L. (2010). Pacific CRYSTAL Project: explicit literacy instruction embedded in middle school science classrooms. *Research in Science Education*, *40*(1), 45–64.
- Berney, S., & Betrancourt, M. (2009). When and why does animation enhance learning: A review. Paper presented at the European Association for Research on Learning and Instruction, Amsterdam, May.
- Bogden, R. C., & Biklen, S. K. (1998). *Qualitative research in education: An introduction to theory and methods*. Boston: Allyn and Bacon.
- Bybee, R. (1997). *Achieving scientific literacy: From purposes to practice*. Portsmouth: Heinemann.
- Davidowitz, B., Rollnick, M., & Fakudze, C. (2005). Development and application of a rubric for analysis of novice students' laboratory flow diagrams. *International Journal of Science Education*, *27*(1), 43–59.
- Derbentseva, N., Safayeni, F., & Canas, A. (2007). Concept maps: experiments on dynamic thinking. *Journal of Research in Science Teaching*, *44*(3), 448–465.
- Gilbert, J. (2007). Visualization: A metacognitive skill in science and science education. In J. K. Gilbert (Ed.), *Visualization in science education* (pp. 9–27). Dordrecht: Springer.
- Goldman, S. (2003). Learning in complex domains: when and why do multiple representations help? *Learning and Instruction*, *13*, 239–244.
- Hand, B., & Choi, A. (2010). Examining the impact of student use of multiple modal representations in constructing arguments in organic chemistry laboratory classes. *Research in Science Education*, *40*(1), 29–44.
- Hand, B., Gunel, M., & Ulu, C. (2009). Sequencing embedded multimodal representations in a writing to learn approach to the teaching of electricity. *Journal of Research in Science Teaching*, *46*(3), 225–247.
- Hoban, G. (2005). From claymation to slowmation: a teaching procedure to develop students' science understandings. *Teaching Science: Australian Science Teachers' Journal*, *51*(2), 26–30.
- Hoban, G. (2007). Using slowmation to engage preservice elementary teachers in understanding science content knowledge. *Contemporary Issues in Technology and Teacher Education*, *7*(2), 1–9.
- Hoban, G. (2009). Facilitating learner-generated animations with slowmation. In L. Lockyer, S. Bennett, S. Agostino, & B. Harper (Eds.), *Handbook of research on learning design and learning objects: Issues, applications, and technologies* (pp. 313–330). Hershey, PA.
- Hoban, G., & Nielsen, W. (2010). The 5 Rs: a new teaching approach to encourage slowmations (student-generated animations) of science concepts. *Teaching Science*, *56*(3), 33–37.
- Hubber, P., Tytler, R., & Haslam, F. (2010). Teaching and learning about force with a representational focus: pedagogy and teacher change. *Research in Science Education*, *40*(1), 5–28.
- Jewitt, C. (Ed.). (2009). *The Routledge handbook of multimodal analysis*. Abington: Routledge.
- Jonassen, D., Myers, J. M., & McKillop, A. M. (1996). From constructivism to constructionism: Learning with hypermedia/multimedia rather than from it. In B. G. Wilson (Ed.), *Constructivist learning environments* (pp. 93–106). Engelwood Cliffs: Educational Technology.
- Keast, S., Cooper, R., Berry, A., Loughran, J., & Hoban, G. (2009). Using slowmation to stimulate thinking about "pedagogical intent" in science teaching and learning. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA, April.
- Kim, B., & Reeves, T. (2007). Reframing research on learning with technology: in search of the meaning of cognitive tools. *Instructional Science*, *35*, 207–256.
- Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning and Instruction*, *13*, 205–226.
- Kress, G., Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). *Multimodal teaching and learning: The rhetorics of the science classroom*. London: Continuum.
- Lemke, J. (1998). Multiplying meaning: Visual and verbal semiotics in scientific text. In J. R. Martin & R. Veel (Eds.), *Reading science: Critical and functional perspectives on discourses of science* (pp. 87–113). New York: Routledge.

- Lemke, J. (2000). Across the scales of time: artifacts, activities, and meanings in ecosocial systems. *Mind, Culture and Activity*, 7(4), 273–290.
- Marbach-Ad, G., Rotbain, Y., & Stavy, R. (2008). Using computer animation and illustration activities to improve high school students' achievement in molecular genetics. *Journal of Research in Science Teaching*, 45(3), 273–292.
- McKnight, A., Hoban, G., & Nielsen, W. (2011). Using *slowmation* for animated storytelling to represent non-Aboriginal preservice teachers' awareness of "relatedness to country". *Australasian Journal of Educational Technology*, 27(1), 41–54.
- Merriam, S. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey Bass.
- Miles, M., & Huberman, A. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks: Sage.
- Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University.
- Ogden, C. K., & Richards, I. A. (1923). *The meaning of meanings*. New York: Harcourt, Brace & Co.
- Peirce, C. (1931/1955). Logic as semiotic: The theory of signs. In B. Justus (Ed.), *Philosophical writings of Peirce* (1893–1910) (pp. 98–119). New York: Dover.
- Prain, V. (2006). Learning from writing in secondary science: some theoretical and practical implications. *International Journal of Science Education*, 28(2–3), 179–201.
- Prain, V., & Waldrip, B. (2006). An exploratory study of teachers' and students' use of multi-modal representations of concepts in primary science. *International Journal of Science Education*, 28, 1843–1866.
- Prins, G., Bulte, A., van Driel, J., & Pilot, A. (2008). Selection of authentic modelling practices as contexts for chemistry education. *International Journal of Science Education*, 30, 1867–1890.
- Ritchie, S., Tomas, L., & Tones, M. (2010). Writing stories to enhance scientific literacy. *International Journal of Science Education*, 32, 1464–5289.
- Royce, T. D. (2007). Intersemiotic complementarity: A framework for multimodal discourse analysis. In T. D. Royce & W. L. Bowcher (Eds.), *New directions in the analysis of multimodal discourse* (pp. 63–109). Mahwah: Erlbaum.
- Sanger, M., & Greenbowe, T. (2000). Addressing student misconceptions concerning electron flow in aqueous solutions with instruction including computer animations and conceptual change strategies. *International Journal of Science Education*, 22, 521–537.
- Seufert, T. (2003). Supporting coherence formation in learning from multiple representations. *Learning and Instruction*, 13(2), 227–237.
- Sperling, R., Seyedmonir, M., Aleksic, M., & Meadows, G. (2003). Animations as learning tools in authentic science materials. *International Journal of Instructional Media*, 30(2), 213–221.
- Stake, R. (1995). *The art of case study research*. Thousand Oaks: Sage.
- Subramaniam, K., & Padalkar, S. (2009). Visualisation and reasoning in explaining the phases of the moon. *International Journal of Science Education*, 31, 395–417.
- Suhor, C. (1984). Towards a semiotic-based curriculum. *Journal of Curriculum Studies*, 16, 247–257.
- Tytler, R., & Prain, V. (2010). A framework for re-thinking learning in science from recent cognitive perspectives. *International Journal of Science Education*, 32(15), 2055–2078.
- Tytler, R., Prain, V., & Peterson, S. (2007). Representational issues in students learning about evaporation. *Research in Science Education*, 37, 313–331.
- van der Meij, J., & de Jong, T. (2006). Supporting students' learning with multiple representations in a dynamic simulation-based learning environment. *Learning and Instruction*, 16, 199–212.
- Van Zele, E., Lenaerts, J., & Wieme, W. (2004). Improving the usefulness of concept maps as a research tool for science education. *International Journal of Science Education*, 26, 1043–1064.
- Waldrip, B., Prain, V., & Carolan, J. (2006). Learning junior secondary science through multi-modal representations. *Electronic Journal of Science Education*, 11(1), 21.
- Waldrip, B., Prain, V., & Carolan, J. (2010). Using multi-modal representations to improve learning in junior secondary science. *Research in Science Education*, 40(1), 65–80.
- White, R., & Gunstone, R. (1992). *Probing understanding*. London: Falmer.
- Willett, R. (2007). Technology, pedagogy and digital production: a case study of children learning new media skills. *Learning, Media and Technology*, 32(2), 167–181.
- Williamson, V., & Abraham, M. (1995). The effects of computer animation on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching*, 32, 521–534.
- Yang, E., Andre, T., Greenbowe, T., & Tibell, L. (2003). Spatial ability and the impact of visualization/animation on learning electrochemistry. *International Journal of Science Education*, 25, 329–349.
- Yin, R. (2003). *Case study research: Design and methods*. Thousand Oaks: Sage.
- Yore, L., & Hand, B. (2010). Epilogue: plotting a research agenda for multiple representations, multiple modality, and multimodal representational competency. *Research in Science Education*, 40, 93–101.
- Yore, L., & Treagust, D. (2006). Current realities and future possibilities: language and science literacy — empowering research and informing instruction. *International Journal of Science Education*, 28, 291–314.