Linking Semiotics and Science Education: A Theoretical Framework for “Slowmations”
(Student-generated animations)

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Abstract
A “Slowmation” (abbreviated from “Slow Animation”) is a narrated animation that preservice teachers design and make as a new way to learn about a science concept. It is a simplified form of stop-motion animation that is played at 2 frames/second providing a slow moving image enabling preservice teachers to explain a science concept. Preservice teachers learn how to make one for the first time in a 2-3 hour workshop and then they make their own animation on an allocated topic as an assignment in a science methods course. The theoretical framework for learning from making a slowmation is based upon Peirce’s Semiotic Triad (Peirce, 1931), highlighting the interplay between the referent, representation and meaning making when individuals interpret or make a sign. When creating a slowmation, preservice teachers design and make a sequence of five representations, each being a semiotic system, that progressively link in a semiotic chain to produce the animation: (i) Representation 1 — Preparation; (ii) Representation 2 — Storyboard; (iii) Representation 3 — Models; (iv) Representation 4 — Photographs; and (v) Representation 5 — Animation. A case study is provided to show a preservice teacher’s perceptions of learning science through creating narrated animation. Slowmation is a new way for preservice teachers to learn science content by making a sequence of five representations as a semiotic chain culminating in the animation as a multimodal representation, however, further research is needed to better understand how each representation influences this learning.

Introduction

We are in the midst of a world-wide explosion in personal digital technologies which is creating never before opportunities for students in universities and schools to create their own digital media. Twenty years ago, getting students to make a mini-movie about a science concept was unheard of because of the expense of acquiring a movie camera and a video player. Also, digital still cameras for personal use were non-existent and only came onto the commercial market in 1998. But times have changed. All students now have access to digital still cameras (most own a digital still camera and/or a mobile phone with a camera), iPods® for playing and recording sound tracks, and computers preloaded with free movie making software. It is therefore not surprising that the most popular web sites in the world, Facebook, Wikipedia, MySpace and YouTube, are all driven by digital content created by users because of this widespread accessibility to media making technology. This user-generated content, of course, is what students find engaging. It is time for educators to promote this form of digital content for educational purposes rather than just for social networking.

The exponential growth in personal digital technologies coincides with a growing body of research which suggests that getting students to create a multimodal representation of a science
concept is a good way to enhance learning (Ainsworth, 1999; Prain, 2006; Tyler & Prain, In Press; Waldrip, Prain, & Carolan, 2006). A representation is a sign that stands for something else and can be expressed using different modes — by text, photographs, sketches, voice, numbers, graphs or models. It is through creating a sign and thinking about its meaning that learners develop a better understanding of the world. It has also been argued that students need to become immersed in the literacies and ways of thinking that are used in scientific communities. According to Lemke (1998):

> When scientists think, talk, write, work and teach, they do not just use words; they gesture and move in imaginary visual spaces defined by graphical representations and simulations. They combine, interconnect, and integrate verbal text with mathematical expressions, quantitative graphs, information tables, abstract diagrams, maps, drawings, photographs and a host of unique specialised visual genres seen nowhere else. (p. 88)

There is a growing acknowledgement, therefore, that students need to use various forms of scientific literacies, not only as a way of recording information, but also as a way to facilitate learning. Moreover, learners need to use a range of modalities — text, images, models, and voice—in designing representations (Lemke, 2000; Prain, 2006; Prain & Waldrip, 2006). Importantly, research has shown that constructing a representation helps learners to make meaning of a science concept and this is often preferential to students copying an expert-generated representation from a text book, which is a common practice in classrooms (Hubber, Tytler, & Haslam, 2010; Waldrip, Prain, & Carolyn, 2010).

**Student-generated Animations**

With the wide access to personal media-making technologies, it is now possible for students to make a mini-movie representing their understanding of a science concept. But even with access to the necessary technology, making a movie demonstrating change in a science concept could be difficult for students to create, because inanimate science objects do not move by themselves unless they are motorised. On the other hand, making a movie using a stop-motion animation technique is feasible because it is the creator who manually moves the objects whilst taking digital still photos. Furthermore, having students take digital still photos one by one instead of a continuous 30 frames/second in a video allows them to manipulate, think about, and reconfigure the models as each still photo is taken.

Clay animation (abbreviated to claymation) is the most common form of stop-motion animation but its use in science classrooms has been limited and has been used more often for storytelling. This is because it is very tedious and time consuming to make clay models and show their movement at 20-25 frames/second, which is the normal speed for animation. Although uncommon, there have been several school-based action research studies in Australia using claymation to promote students’ literacy skills. One project, *Clay Animation in the Primary Classroom*, was conducted at Hawthorndene Primary School and investigated the use of clay animation as a teaching and learning tool to enhance outcomes for disengaged and underachieving students (Murtagh, 2004). Titles of the fictional QuickTime movies produced include a “Zoo Trip,” “Snakes”, “Hamburger” and “Elephant Sandwich.” The study concluded that, “clay animation as a teaching and learning tool is an exciting, time-consuming, challenging, motivational process and above all, a lot of fun. It can impact in a positive way on learning, group skills and teamwork, self-esteem, confidence and leadership skills.” Another claymation project, *Student Centred Curriculum – Multiliteracies and Disengaged Learners*, was conducted at Tintinara Area School to assist year 4-6 boys to improve their literacy skills (Murray, Neville, & Webb, 2005). The boys created a sequence of representations by writing stories with a selected theme, designing them with a storyboard, constructing clay figures and backdrop scenes, using digital photography and then completing written evaluations. In the study, the targeted group of
boys became aware of the importance of planning and structuring their narratives, which suggested the need for more explicit teaching of narrative structure so that children could enhance their stories.

In both claymation projects described, however, there were difficulties in storing the clay models over extended periods of time because they dry out and there was a continuous need for adult assistance. Furthermore, the production process was very time consuming needing up to two school terms to complete since students worked on them once a week in special literacy lessons. Moreover, both projects were using claymation to promote students’ literacies and were not representing science concepts. It appears, therefore, that there has been very little use of stop-motion animation as a teaching approach in science classes to promote student learning. Perhaps claymation in its conventional form is too difficult or too time-consuming for teachers of science to organize, or the content has not been readily applicable to animation techniques.

**Slowmation: A simplified form of animation**

A “Slowmation” (abbreviated from “Slow Animation”) is a stop-motion animation made by preservice teachers that is played slowly at 2 frames/second providing a slow moving image to explain a science concept. It is a simplified way of making an animation and is a new way for preservice teachers to learn science by creating an animation to explain the content (Hoban, 2005, 2007, 2009). The animation is a multimodal representation of their learning and integrates features of clay animation, object animation and digital storytelling. Like clay animation (Witherspoon, Foster, Boddy, & Reynolds, 2004), slowmation uses a stop-motion technique involving the manipulation of models made out of plasticine or soft play dough as digital still photos are taken of each manual movement. Like object animation, a range of materials can be used such as plastic models, wooden, paper or cardboard cut-out models commonly found in primary classrooms to animate (Laybourne, 1998). Similar to digital storytelling (Lambert, 2002), a key part of creating a slowmation is that a narration and real-life photos can be added by the students to explain the science concept as the models are animated. In sum, a slowmation displays the following features:

- **purpose** — the goal of a slowmation is for students, preservice teachers or school children, to make an animated mini-movie to explain a science concept and through the creation process, learn about the concept.
- **timing** — slowmations are usually played slowly at 2 frames/second, not the usual animation speed of 20-24 frames/second, needing ten times fewer photos than in clay or computer animation, hence the name “Slow Animation” or “Slowmation”;
- **orientation** — models are made in 3D and/or 2D and usually manipulated in the horizontal plane (on the floor or on a table) and photographed by a digital still camera mounted on a tripod looking down or across at the models, which makes them easier to make, move and photograph;
- **materials** — because models do not have to stand up, many different materials can be used such as soft play dough, plasticine, 2D pictures, drawings, written text, existing 3D models, felt, cardboard cut outs and natural materials such as leaves, rocks or fruit; and
- **technology** — students use their own digital still cameras (with photo quality set on low resolution) and free movie making software available on their computers eg IMovie or SAM Animation on a Mac or Windows Movie Maker on a PC. Its design can also include a range of technological enhancements such as narration, music, other photos, diagrams, models, labels, questions, static images, repetitions and characters.

Making a slowmation involves preservice teachers creating a sequence of five representations: (i) *notes* from reading information in books or from the internet; (ii) making a *storyboard*; (iii) making
models to represent the concept being animated; (iv) taking digital still photos of manual movements of the models; and (v) constructing the final animation along with a narration. Slowmation therefore greatly simplifies the process of making animations by preservice teachers manipulating 2D or 3D models often lying down on a flat surface and requiring a tenth as many photos as a normal animation because they are played ten times slower at 2 frames per second. Examples, resources and free instructions can be seen at the web site www.slowmation.com.

However, there appears to be a lack of literature to theorise the process of learning through animation creation as a way for students to represent science content knowledge. A review of literature using the terms “learner generated animation” and “student generated animation” across five journal databases — Proquest Educational Journals, Educational Resources Information Library (ERIC), ACM Digital Library, ISI Web of Knowledge and JSTOR — only found two research publications and only one of these was in science education. In one study, an animation program called Chemation was specially designed to enable middle school students to create animations of chemical equations and to document their explanations (Chang, Quintana, & Krajcik, 2010). Working with seventh grade students (N = 73), pre and post test results revealed that there was a significant effect on the learning of student participants. However, in this study, software needed to be designed to facilitate students’ designing animations to solve chemical equations. Therefore, as a product with application only to chemical equations, it limits students’ creativity and innovation. In another study, 12 computer science undergraduates used a specially designed program, Carousel, to design their own animations of three different algorithms involving text, pictures, video, animations and speech which also could be shared with other students on a web site (Hubscher-Younger & Hari Narayanan, 2008). After they were uploaded to a web site, the students reviewed and evaluated each other’s animation. Pre and post tests suggested that authoring and evaluating animations was a positive learning experience for most of these students.

What is common to both of these research studies on student-generated animations is that special software for each concept needed to be designed by experts to enable the students to create an animation. Although the number of research studies on student-generated animations is minimal, their educational value was clearly noted, “encouraging students to create their own animations (which are not found in textbooks or commonly employed by teachers) of complex procedural concepts may enhance learning in an otherwise traditionally delivered course” (Hubscher-Younger & Hari Narayanan, 2008, p. 258). However, although both of these articles make claims that getting students to create animations is a good way to learn, neither propose a theoretical framework for learning through creating an animation which is the focus of the rest of this article.

Theoretical Background

When students make an animation to explain a science concept, they are designing a sequence of signs to represent that concept. Drawing on semiotic reasoning, when preservice teachers create a representation of a science concept, they develop meaning from the process because they compare their ideas with those of the referent or object to which they are representing (Peirce, 1931). This triadic relationship involves a dynamic interaction between the sign or representation (what is created by the learner), the referent (what is being represented) and the meaning made (personal interpretation):
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*. 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) (Pierce, 1931, p. 99)

This three way dynamic relationship between a representation, the object or referent, and its meaning was first illustrated in Pierce's (1931) semiotic system shown in Figure 1.

![Figure 1: Peirce's (1931) Triadic Model of a Semiotic System](image)

As shown in the model, the relationship between a representation and the referent (that results in meaning making) is not a linear process, but rather is interrelated and iterative. As emphasized by Anderberg, Svensson, Alvegard, and Johansson (2008), the relationship between the meaning making, representation and referent does not happen in a one way direction around the triangle but is “ambiguous and dynamic. . . .The term ‘interplay’ is here used to refer to the various relations that may exist between conceptions of complex units of subject matter, meanings as part of understanding this subject matter and language expressions used to express these meanings” (p. 15). As supported by Waldrip 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).

Science education researchers also point out that meaning making is enhanced when students create not one, but multiple representations of a concept as a “re-representation” (Prain & Waldrip, 2006), “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” (p. 1844). It appears that the value of students creating more than one representation of a concept provides additional thoughts for learning. Bezemer and Kress (2008) called this process of changing one mode into another, a “transduction”. Importantly, Yore and Hand (2010) believe that getting students to change a representation from one to another is a valuable source for learning because “We believe that the transformation among multimodal representations has the greatest potential in promoting learning and depth of processing” (p. 96).
Getting students to design multiple representations of a concept is also consistent with communication practices used in the scientific community, “scientists co-ordinate features within and across multiple representations to reason about their research and negotiate shared understanding based on entities and processes” (Kozma, 2003). In support, researchers who specialize in analyzing language (Bezemer & Kress, 2008; Kress et al., 2001; Lemke, 1998) argue that learning or meaning making is ‘multiplied’ when students present their ideas using a variety of representations. The challenge, therefore, for science teacher educators is to provide situations to enable preservice teachers to both create a range of representations and to realize the connections between them. Although there have been examples of students making multiple representations of science concepts using a combination of sketches, graphs and tables (Waldrip, Prain, & Carolyn, 2010), there have been very few examples of students creating animated mini-movies, which by nature of the process, involves preservice teachers creating multiple representations to explain science concepts.

The following study provides data collected from preservice primary teachers in 2007 and 2008 showing that it was likely that they developed knowledge of science concepts as a result of creating a slowmation. However, the data were collected pre and post to the students actually creating the slowmation and so only inferences can be drawn about the actual creation process and its relationship to Pierce’s Triadic Model. Implications for additional research that focuses more closely on studying the actual construction process is provided at the end of this paper.

Methodology

The preservice teachers were enrolled in a 13 week science method course in a four year Bachelor of Education degree at a university in Australia. This study involved two cohorts in a science method course with 24 students in each course. Students in each course were invited to volunteer to be in the research project and 16 elementary preservice teachers (14 females and two males) volunteered in 2007 and 13 preservice elementary teachers (9 females and 4 males) volunteered in 2008. The procedure for introducing slowmation was the same for each cohort. The preservice teachers were taught how to create a slowmation in a two hour workshop and then created their own slowmation as an assignment on a designated topic that they had been allocated at the beginning of the course. The software program used by the students was SAM animation with a demonstration version available for free at www.samanimation.com. Both PC and Mac versions are available. Data gathering methods to monitor each student’s science learning included three semi-structured interviews, sketching and reviewing concept maps of their understandings (White & Gunstone, 1992) and noting how they represented their knowledge in the animation as an artifact of their learning. Data were collected at three times during the study using a time series design i.e. at the beginning of the course when they were allocated their topic, during the course when the students were making their slowmation and after they completed it.

Data were analysed according to the topic the preservice teachers were allocated at the beginning of the course and any subsequent change in understanding. Data were analysed from the interviews, concept maps as well as their slowmations collected as knowledge artifacts. Change in science knowledge was monitored according to the number of new concepts or insights about existing concepts for each topic explained in the interviews and/or added to their concept maps. A major increase in science knowledge was identified by the addition of 4 or more new concepts or by delving into one concept in depth. A minor increase in science knowledge was identified by the addition of 2 or 3 new concepts and little or no increase was the addition of one new concept or no change. No increase in science knowledge was identified by having no changes in understanding or the addition of new concepts for each topic.
Results

The study focused on monitoring any change in the preservice teachers’ science content knowledge as a result of them creating a slowmation. Summative data from the two cohorts will be presented followed by a case study from one of the preservice teachers to demonstrate their experience of creating a slowmation in more detail.

Change in Preservice Teachers’ Science Content Knowledge
Using both cohorts, Table 1 shows 19/29 experienced a major increase in scientific knowledge and 9/29 experienced a minor increase and one person experienced no increase in knowledge as a result of creating a slowmation.

Table 1. Change in Science Content Knowledge

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<thead>
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<th>Major Increase in Science Knowledge</th>
<th>Minor Increase in Science Knowledge</th>
<th>Little or No Increase in Science Knowledge</th>
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<td>Cohort 1 (2007)</td>
<td>19</td>
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<td>and 2 (2008)</td>
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Interview data revealed that many of the participants found creating a slowmation to be a different way to learn science as they had to research their topic first in order to represent their understandings in the animation:

*Making the slowmation extended my scientific knowledge. It made me realise that science isn't just about chemists with white coats and… Yeah, it can actually go in so many different directions and cover so many different topics, which I think is important for students trying to understand the concepts at an early age.*
Student A, Cohort 1, Final Interview

*I definitely got a lot out of it. . . I ended having to do a fair bit of research. . . . I found out a lot about density and displacement of water and sort of more key things.*
Student B, Cohort 1, Final Interview

*Actually I did learn, I didn’t even know what a cog was. . . . I learned about how when you changed from first gear it changes the size of the gear and you know that makes pedalling easier.*
Student C, Cohort 2, Final Interview

*Even if you’re not actually putting the new knowledge into the slowmation, you still have to know it to start with… to understand the topic first and then you can work out what parts of the topic are best suited to being presented in the slowmation.*
Student T, Cohort 2, Final interview

*It means you have to learn it to be able to present it. It means you’ve done the work, you have got all the background knowledge and everything and you’ve gained the knowledge to do it.*
Student R, Cohort 2, Final interview
The following case study shows in more detail how one student in the second cohort explained the change in his science knowledge as a result of constructing a slowmation about static electricity.

**Case Study of Brad.**

Brad was a student in his early 20s who had taken science through to the end of high school and had completed one elective subject in his first year at university. He had been allocated the topic, “Static Electricity,” which was a topic that suited grades 5 and 6 (ages 10 – 12). In the first interview it was revealed that he had a positive attitude toward science, although he had limited knowledge of the topic. He realized that rubbing your feet on carpet created static electricity and that he believed it happened more in winter but he wasn’t sure why. During the first interview, he was asked to construct a concept map to represent his knowledge of the topic. When constructing his map he identified 3 examples — car door zapping, hair standing on end and rubbing feet that he believed related to the topic as shown in Figure 3. He did not, however, in the interview know the reason why static electricity occurred and hence there is no “reason” shown in the concept map.

![Figure 2. Brad’s First Concept Map of Static Electricity](image)

In the interview Brad recalled memories from school days of rubbing his feet on the carpet to cause static electricity but was vague about the reason:

> I have memories of school, when we used to sit down in winter and you would rub your feet on the carpet a lot and then you’d lift your feet up and touch someone, and you’d zap them, I don’t know why. I just remember doing it. I think it was obviously something to do with holding a charge or something, holding the electricity, I don’t know.

When questioned on what would be the focus of his Slowmation, he was a little unsure. He knew he could represent some examples but was unclear about the reason and he would have to research it:

> I’m not sure, because when I think about that – like, I can’t necessarily generate any of those things, can I? I’m not envisaging doing it in a real sense, just more trying to represent it happening, maybe I could represent it somehow. I’d probably need some figures or something for taking the photos. It’s easy enough to take a photo of rubbing feet – photo, photo, photo — with the feet moving and a little zap or something for a sound effect. But I need to research that yet, I haven’t found out why that happens. So I think the explanation will need to be part of the narration.

Interview 2 was carried out immediately following the completion and submission of the students’ Slowmation videos, which occurred four weeks after the topic had been allocated. The purpose of the interview was to ascertain whether Brad had developed his scientific content knowledge through designing and creating a Slowmation video. Brad’s primary focus in the video was explaining how
static electricity occurred showing how electrons could be transferred from atom to atom to create a charge.

Brad started his animation with the example of getting a shock from a car and asking the question, “Has this ever happened to you?”. He then went on to show how electrons could be transferred from one atom to another to build up a charge and that touching charged objects earthed the charge which is the spark. It showed that a positive charge came from an object loosing electrons and a negative charge came from an object gaining additional electrons. It was from the rubbing of objects that creates the force to transfer the electrons from one object (the positive charge) to the other (the negative charge).

When asked about knowledge gained from creating the video Brad said:

I didn’t know that you picked up the static electricity off other things, I didn’t know where it came from, I didn’t know why it was coming off the end of my finger. So that basic fact of what charge I was actually carrying on those windy days or rubbing your feet on the carpet… because I remember that from school, my mates would always rub their feet on the carpet and then they would touch your ear and zap you. That was part of that zapping business, the whole why that happened, I never understood that, but now I do.

He also emphasised the fact that what was happening when the shock occurred was the electrons finding balance between a higher charged atom and a lower charged atom “and that is called earthing. It’s the same with lightning, lightning always occurs when there’s lots of wind and there’s friction and the friction builds up the charge and then the discharge is the lightning.” The last interview included modifying the concept map shown in Figure 3 with any new knowledge gained. Figure 3 shows the revised concept map with the “clouds” indicating new concepts. It shows the addition of one more example and a reason for static electricity occurring which was “transfer of electrons” to build up charge. Because Brad had a deeper understanding of what caused static electricity and this was clearly demonstrated in the animation it was deemed that he had an increase in science knowledge.
Discussion and Implications

Getting students (preservice teachers or school children) to create an animation of a science concept has traditionally been too difficult to achieve in university or school classrooms either due to lack of technology or the complexity of making an animation. Accordingly, animation has rarely been used as a teaching approach in schools or universities for teaching science. Moreover, when animation such as claymation has been used, it has been usually been for the teaching of narratives or art.

Slowmation greatly simplifies the process of creating animations enabling preservice teachers to learn how to create one in 2-3 hours. Furthermore, because the technology is easily accessible and familiar — a digital still camera/mobile phone and their own free movie making software — students can design and construct the animation in a classroom or at home. The key point of this article is that students such as preservice teachers are able to develop knowledge about a science concept through making an animation because they are constructing a sequence of representations to explain the concept. This is because creating a mini-movie such as a slowmation involves them thinking about the content or referent in many different ways (See Figure 1) through a progression of representations.

Although the data presented in this study does not provide insights into the actual process of creating an animation, it is likely that the development in student knowledge was related to the making of the five representations that make up the animation (Hoban and Nielsen, 2010). Theoretically, each representation is a semiotic system that connects in a semiotic chain culminating in the animation as a multimodal representation. It is likely that meaning from creating each representation is progressively transferred to the subsequent representation and synthesized in the final narrated animation as shown in Figure 4.

To be conclusive that the process of creating an animation does enhance knowledge would require a more focused study involving collecting data about student learning whilst they are actually creating an animation. This warrants further studies that more closely examine the type of learning occurring when preservice teachers create a slowmation especially focusing on the relationship between the type of literacy artifact created and how each representation facilitated learning as proposed by Pierce’s Triadic model of meaning making.
The design of this additional research could involve allocating a topic to a small group of preservice teachers and then video recording the entire creation process as they research content, design storyboards, make models, take digital still photographs of the models being moved manually and then finally constructing the animation with relevant software. From the experiences of the two studies conducted in 2007 and 2008, this whole process could take place over several hours which makes this type of study feasible. This would not be the case using other forms of animation such as traditional claymation or computer-generated animation as these ways of making an animation would take at least several days if not weeks. With slowmation, however, because the animation process is much simpler, a study that focuses on the learning processes during the creation of a slowmation would be feasible over several hours. A key aspect of this type of study would have preservice teachers "think aloud" as they designed and constructed a slowmation to give insights into their ways of thinking influenced the type of dynamic learning suggested by Pierce’s Triadic Model using animations as representational systems. Hence further research is needed to study the relationship between slowmation and Pierce’s Triadic Model of meaning making to clarify whether this is a reasonable theoretical framework for explaining how learning occurs through the creation of animations as semiotic systems.

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3. See web site www.slowmation.com for free instructions and examples for making a slowmation.

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