Chapter 4
Slowmation: A Process of Explicit Visualization

John Loughran

Abstract The notion of visualization conjures up an interesting image of what it means to think about teaching science. A concrete approach to supporting teachers' development of their professional knowledge about teaching science through visualization is evident in the use of slowmation. This chapter considers the conceptual basis of slowmation and illustrates how through a process of visualization, images of teaching about science are able to be made both concrete and useable for teachers. The chapter illustrates how, when science teachers introduce slowmation as a teaching procedure, they begin to see into the science concepts they are teaching in new ways. Slowmation creates a working environment in which the teacher is 'forced' to unchunk their knowledge of scientific concepts and begin to visualize the chunks that matter in developing a deeper understanding of the concepts for teaching. As slowmation is conceptualized through the theoretical framework of semiotics, the notion of visualization becomes a helpful way of supporting teachers' active production of their professional knowledge of practice.

Keywords Slowmation • Teaching procedure • Visualization • Introspective visualization • Interpretive visualization • Stop-motion animation • Science • Concepts

4.1 Introduction

Despite the fact that some argue that there is "a pervasive lack of clarity about precisely what constitutes visualization" (Vavra et al. 2011, p. 22), the notion of visualization still conjures up an interesting image of what it means for teaching science.

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B. Eilam and J.K. Gilbert (eds.), *Science Teachers' Use of Visual Representations*, Models and Modeling in Science Education 8, DOI 10.1007/978-3-319-06526-7_4,

Science itself is steeped in a history of the use of models, representations and other forms of visualization crucial to explaining, and illustrating complex, abstract or sometimes unobservable phenomena.

In his review of visualization in mathematics education, Bishop (1989) noted that there are two ways in which visualization has been described: (1) "the what of visualization" i.e., the product, object or visual image; and, (2) "the how of visualizing" i.e., the process, activity or skill associated with visualizing. Further to this, Vavra et al. (2011, p. 22) stated that from their review of the literature that "three important distinctions in the conceptualization of visualization" were apparent. The first was of *visualization objects* (pictures, models, diagrams, geometrical illustrations, simulations, animations, etc.). The second was *introspective visualization* which refers to "mental objects pictured by the mind". The third was of *interpretive visualization* which involves "making meaning from visualization objects or introspective visualizations in relation to one's existing network of beliefs, experiences and understandings". Each of these features has a part to play in developing an understanding of the way in which slowmation (described in detail later in the chapter) can influence students' learning about science and how important visualization therefore is to the teaching of science in schools.

Slowmation (Hoban 2009; Hoban et al. 2011) is an abbreviation of 'slow-animation' and offers a way for students to create their own 'low-tech' animations of science concepts. Slowmation is a digital version of a 'flick/flip book'. A flip book has a series of pictures that vary gradually from one page to the next so that when the pages are quickly turned (flicked/flipped), the pictures appear to move in ways that simulate motion or illustrate changes in a scene (for a detailed history see www.flipbook.info/history.php).

By creating the impression of a moving scene, a flip book becomes a form of animation. Slowmation works in exactly the same way. It is based on taking a series of individual digital photographs and animating them in a simple format by combining them in a sequence known as "stop-motion animation". In terms of the notion of visualization, slowmation comfortably sits in Vavra's category of a visualization object or Bishop's 'what of visualization'. However, as this chapter will illustrate, seeing beyond the object, or product, is important to genuinely understanding the real value of slowmation as a form of visualization; and is all the more important when considering Gilbert's (2005a) compelling argument about visualization playing a central role in science.

Gilbert (2005a) suggested that visualization should be highly regarded in the teaching and learning of science in schools. He was of the view that visualization is a metacognitive skill and that "if visualization is an important aspect of learning – especially in the sciences, where the world-as-perceived is the main focus of interest – then not possessing, having failed to develop, metavisual competence will have serious consequences" (p. 18). This chapter takes up Gilbert's point about the need to further develop students' metavisual competence in school science and does so through a consideration of the nature of slowmation as an important visualization process – both for students' learning of science and for teachers' teaching of science. This chapter examines how, when science teachers introduce slowmation as a teaching procedure, they create new ways of seeing into science concepts. In so doing, they create new opportunities to enhance their professional knowledge of practice.

4.2 Visualization in Science: Informing Approaches to Science Teaching

Visualization in science is well recognized as important with websites devoted to such work designed to engage and entice people to science concepts and phenomena as well as to encourage the production of new and compelling visualization objects (see for example, http://www.sciencevisualization.com/; http://svs.gsfc.nasa.gov/; http://www.wired.com/wiredscience/2012/02/science-visualizations-2011/). However, drawing learners into science through visualization is one thing, incorporating its use in meaningful ways in science classrooms is another; and there are compelling reasons for pursuing it in concerted ways.

Gilbert's (2005b) edited book *Visualization in science*, devotes a section (five chapters in all) to the significance of visualization in science, science education and cognition, thus framing science teaching and learning through the lens of visualization and creating a platform from which an argument about the importance of visualization strongly comes to the fore. For example, Rapp, in his consideration of mental models, drew attention to the place of visualization in science when he noted that:

> Much science involves the explanation of complex, causal relationships in dynamic situations. One line of thinking suggests that only by illustrating these dynamic explanations in a form that captures salient relationships will students understand the complexity (or in some case, the simplicity) underlying a conceptual theory. Also, as some scientific explanations cannot be observed in the everyday world, visualization can provide experience with these concepts … [but] a visualization is by no means a panacea for teaching difficult science topics … [however] three characteristics of learning … specifically relevant to thinking about the design of educationally valid visualizations for science classrooms [are] … First, visualizations are often quite engaging … Secondly, visualizations can be interactive and … interactivity can foster learning through the construction of mental models … Finally, learning is fostered by conveying information in a succinct, guided manner that aligns with the nature of mental representations. (Rapp 2005, pp. 53–54)

There have been studies designed to attempt to determine the extent to which the use of visualization enhances students' learning of science. Cifuentes and Hsieh (2004) in a study with middle school science students, were of the view that visualization should be a focus for curriculum development as a consequence of their exploration of the use of visualization as a study strategy. Clement et al. (2007), using talk aloud protocols with students and experts, concluded that there were observable indicators of the presence of imagery and how it was used in learning and that dynamic imagery from one context could be transferred to a new model being constructed for a new context, thus leading to a deeper level of conceptual understanding. This view is similarly supported by Kuhl et al. (2011) who also concluded that in comparing learning from static as opposed to dynamic visualizations that, although measurable differences in learning outcomes were not evident, that qualitative differences in learning were clear – as a consequence of data (also) from the application of a think aloud protocol. Their major point was that conclusions about learning through visualizations should not be limited to outcome-oriented measures but also to process-oriented approaches that draw attention to learning for understanding as opposed to simple factual recall.

Extending the notion of learning through dynamic visualizations, McClean et al. (2005) developed animations for cellular and molecular processes in order to move beyond the more typical two-dimensional visualization tools. In studying the impact of these dynamic visualizations they found that students who used the animations in addition to traditional teaching, as well as individual study activities, performed better in terms of retention than those who did not use the animations, but also that their understanding of complex systems and processes was enhanced.

> The value of the animations to significantly affect learning suggests … [they are a] major factor in drawing attention to a topic, which in turn acts as a stimulus to transfer the content into working memory … animation and narration lead to deeper learning than a narration in the form of a lecture … animation appears to be an important technology designed to support education. We have already shown that test scores of content material are improved by the use of animations. (pp. 177–178)

McLean et al.'s (2005) work supports views on learning that have been prevalent for some time, as for example Shapiro's (1985) view that learning is enhanced through visualization because visualizers devote more attention to the material being processed. Likewise, Wu et al. (2000) showed how the use of eChem (visualization tool) led to substantially improved learning about chemical representations. However, for many animation programs, the need for computer programs, educational technologies and other complex (and/or expensive) hardware and software demands, has been an impediment to 'classroom take up' despite support for, and advice about, such technologies and the value of their application in school science and mathematics learning (see for example, Thomas 1995).

Some of the reluctance to 'take up' may be linked to teachers' beliefs. Robblee et al. (2000) suggested that teachers' views about how students learn and their perspectives on their own roles impacted their pedagogical decision making and were therefore important when considering the use and value of interactive computer models. Similarly, Hsieh and Cifuentes (2006) noted that although student learning was enhanced through the use of visualization that not all students were happy to use computer assisted visualization techniques and that perhaps such barriers may be linked to individuals' learning characteristics: "15 % of students in the visualization/computer group felt negatively about the use of visualization. They claimed that visualization demanded too much time and effort, and that they needed a teacher's guidance in how to visualize on computers and how to make use of features of drawing and painting tools to generate visual representations of concepts" (p. 144). Addressing these issues in order to assist in visualization is then important if animation is to be a meaningful and helpful learning tool in the ways so often suggested in the literature. As detailed below, slowmation offers such an opportunity and therefore creates pedagogical possibilities for teachers through which visualization in science might be capitalized upon in order to enhance student learning – the pedagogical imperative driving teachers' practice.

4.3 Slowmation

The theoretical framework underpinning slowmation is semiotics – the study of signs and its relationship to meaning making. Peirce (1931), an early leader in the field of semiotics, identified three terms that help to explain how meaning is made when a sign represents an object: (i) an object or referent is the concept or content being represented; (ii) the sign that is created is called a representation; and, (iii) the meaning generated from the sign is called an interpretant. When a representation of a science concept is created using animation, the maker(s) develop meaning from the process because, in the process, they are comparing their ideas with those of the referent or object they are attempting to represent. Such a triadic relationship is dynamic in nature because it involves interaction between the sign or representation (what is created by the learner), the referent (what is being represented) and the meaning made (personal interpretation).

> This three way dynamic relationship between a representation, the object or referent, and its meaning was first illustrated in Pierce's (1931) semiotic triadic model … this semiotic theory for understanding the process of meaning making through creating representations still has currency in science education research … [and as Waldrip et al. (2010) explained] "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). (Hoban et al. 2011, p. 991)

In science classrooms, slowmation can be used to create a working environment that influences not how a teacher might approach teaching a particular concept/topic, but also how a student's learning might be enhanced. Creating a slowmation can help teachers to unchunk their knowledge of the scientific concept/idea under consideration (e.g., particle theory) and begin to visualize the chunks that matter in developing a deeper understanding of that concept for teaching. In implementing slowmation, teachers are placed in a position whereby they begin to confront and manipulate the knowledge that they have, adjust and accommodate that knowledge, and through the visualization (slowmation) begin to recognize specific aspects of their understanding of the concept. Through that process, slowmation helps to make the concept concrete and useable in ways that the literature (above) suggests is important for a teacher to be more informed in working to enhance student learning.

In a project aimed at 'unpacking' the teacher learning process through slowmation with pre-service science teachers (explained in more detail later in this chapter), deeper understandings of teachers' practice and the factors shaping that practice have been studied. Before considering some of those research outcomes, it is first important to understand how slowmation works as a pedagogical approach to science teaching and learning.

4.3.1 Creating a Slowmation

A common and well recognized form of stop-motion animation is "clay animation" (claymation) as used in movies such as Wallace and Grommit and Harvey Krumpet. However, the creation of claymations on a commercial basis are complex, tedious and incredibly time consuming. Therefore the thought of attempting to create three dimensional science models from everyday classroom materials is so daunting that their use as a visualization tool has typically been confined to commercial interests. As a consequence, if they are used, students end up viewing expert-generated animations designed to present science content structured and presented in ways perceived as being helpful for student learning. However, expert-generated animations have their barriers to student learning because they can present key concepts too quickly and as a result, may not explain them sufficiently well for students – usually because they tend to demonstrate concepts in real time: "animations must be slow and clear enough for observers to perceive movements, changes, and their timing, and to understand the changes in relations between the parts and the sequence of events … [they need] to direct attention to the critical changes and relations" (Tvertsky et al. 2002, p. 260).

Clearly, if learners are able to design and create their own animations rather than be passive consumers of information supplied by others (Chan and Black 2005), then they are in a much better position to visualize scientific concepts in ways that would support their learning. Bransford et al. (2000, p. 215) argued that making and manipulating models of concepts is valuable because they "develop a deeper understanding of phenomena in the physical and social worlds if they build and manipulate models of these phenomena." But, as noted earlier, designing and creating animations is typically limited in school science classrooms because the process is usually too complex and/or time consuming. Slowmation offers a way of breaking down those barriers and capitalizing on learning through visualization and encouraging teachers to implement such practices in their science classrooms.

A slowmation is created through a process (see, Hoban et al. 2011, for a full description of the sequence of five multimodal representations) that encourages the 'creator' to think carefully about the concept to be represented so that it can be illustrated in practice through the resulting animation. The first step in the sequence is the research phase through which pertinent information, ideas and understandings of the concept to be demonstrated need to be ascertained and carefully considered. Concepts/themes that involve some form of cycle or sequential change are particularly suited to slowmation, hence mitosis, meiosis, changes in states of matter or life-cycles are common topics. In this research phase, initial questioning of prior knowledge and the information necessary to depict the concept arise as the information and thoughts about how it might best be represented begin to surface. Therefore, visualization of both the referent and representation is initiated. (This aspect of slowmation can be a catalyst for teachers to see beyond content knowledge alone and begin to seriously consider what it is that they know and understand about a concept/topic and how their representation influences their approach to its teaching.)

The second step in the sequence is the storyboard and this places the creator in a position whereby the salient features of the information from the research need to be concretized as representations that might appropriately illustrate the creator's perception of the 'chunks' that "will explain the concept". At this time, questions may arise about whether text, narration or other forms of representation are needed to ensure the slowmation will portray that which the creator visualizes as the major aspects of the concept being illustrated. An important aspect of storyboarding is that it also helps the creator to think carefully about the sequence of events and whether or not the chunks are sufficiently clear and helpful in portraying in a concrete form that which is understood in the mind's eye of the creator. (For teachers, this again creates an opportunity to think about the concept as a learner not a 'deliverer of content' and so continues to challenge the ways in which chunking and representation of ideas impacts approaches to teaching.)

The third step is the creation of models that will be the physical representations of the concept. One reason why slowmation is so appealing is that, as opposed to commercial claymations, sophisticated modeling is not necessary. Clay, playdough, existing models, drawings and other low tech representations are all that is necessary, and the way they are used to create the 'scenes' is by laying them flat on a background in the horizontal plane rather than as self-sustaining creations in the vertical plane. This also allows for the individual changes in the models necessary in creating the digital photographs (next step explained below) to be managed quickly and easily.

The fourth step is the digital photographs. The creation of animation is based on small movements of the models across a number of photographs so that when they are played together they simulate movement. The incremental movement possible in the horizontal plane is simple and efficient and allows for digital photographs to be taken by 'framing' the events from above using a tripod (to hold the camera in place) thus creating the sense of movement within a scene against a consistently framed background. At this step, the storyboard is used to ensure that the script of the slowmation follows the ideas as set out and conceptualized as a consequence of the research and the manner of representation imagined by the creator. Considering the chunking of ideas and information about the target concept (referent) then becomes real and concrete as the imagined process of movement and change is able to be checked against the reality of the design in action. (For teachers, this may well be the first time that their 'mind's eye' visualization of a concept is made concrete for themselves and begins to highlight elements of their own understanding that influence what they might focus more attention on in their teaching of that concept.)

The fifth and final step is bringing the photographs together in a sequence to create the slowmation. Again, because of the low tech nature of slowmation, it is a simple matter of loading the digital photographs into any form of freely available (and typically supplied) movie-maker software on a computer (e.g., QuickTime Pro, MovieMaker, etc.). Having done that, the individual frames are able to be played at a predetermined speed (two frames/second is common, but can be varied dependent on the number of photographs being used and the intended length of the final slowmation) thus creating the slowmation product.

Slowmations have become popular in science teaching at all levels of schooling (for examples, see http://slowmation.com/). However, understanding the real value of slowmation may not always be immediately evident to teachers confused because of that which Appleton (2002) described as a teacher's pursuit of 'activities that work', i.e., the need to have activities that appear fun and keep students busy. Therefore, seeing slowmation through the frame of visualization allows for a deeper understanding of the learning possibilities inherent in slowmation (as both a process and a product) and captures the learning aspects important to meaning making (i.e., interpretant).

4.3.2 Slowmation: Multiple Forms of Visualization

As noted earlier in the chapter, visualization has been described as encompassing two important aspects – the 'what' and the 'how' (Bishop 1989). It is not difficult to see the 'what' of slowmation as there is a clear product (the animation created) which also equates with Vavra et al.'s (2011) notion of a visualization object. The 'how' though needs more careful consideration as it touches on the other two aspects that Vavra et al. described, that of *introspective visualization* (mental objects pictured in the mind) and *interpretive visualization* (making meaning from visualization objects or introspective visualization of existing networks of beliefs, experiences and understandings). The next section explores these aspects of visualization in relation to both the product and the process of slowmation.

4.3.3 Slowmation as a Product

Slowmation as a product is a low tech animation. It is easily created and is an engaging, creative and enjoyable task for students. However, just as Linn et al. (2006) noted in their description of TELS (Technology Enhanced Learning in Science), so too slowmation needs to be understood as valuable because it "enable[s] students to connect scientific visualizations to their understanding of complex scientific ideas [and] help[s] guide students to make sense of visualizations rather than viewing them as amusing movies" (p. 1050). Slowmation is able to do this because beyond constructing the (simple) physical models and contextualizing them within a background (scene), there is also the need to manipulate the objects in order to, through the individual photographs taken of the incremental changes being performed, create the illusion of movement. When all of the photographs are combined in sequence, the animation comes to life and a clear product becomes immediately tangible.

At the simplest level, slowmation visually represents the idea/concept (referent) under consideration as conceptualized by the author. However, that product can be enhanced through the addition of narration, the use of music, signs, symbols, text or messages, or more sophisticated forms of display (e.g., moving from two-dimensions to three-dimensions and/or the use of commercial models and more complex approaches to depiction). But the important point is that the ‘control’ of development and depiction rests with the author – an important element of meaningful learning – and something that encourages teachers to pursue student centred learning in their science classrooms.

A valuable feature of slowmation is the combination of two forms of visualization: the individual photograph(s); and, the development of a ‘movie’. From the storyboard that sets out the plan for the slowmation, a number of scenes are depicted and so, in one sense, the storyboard is a big picture overview that comprises a number of visual representations (each scene in the storyboard). These scenes can be regarded as individual representations which depict the author’s perspective on the particular features of the concept/theme/process under consideration and how they come together to illustrate the author’s conceptualization of the idea as a whole. As static constructs the storyboard scenes convey the author’s understanding of the data (e.g., elements, phases, aspects) that comprise the concept attempting to be portrayed. That static form is transformed when each scene is brought to life through the expansion via the individual frames (photographs) necessary to simulate movement using the models. Hence the slowmation itself leads the author to change a static visualization (storyboard) into an interactive visualization – which is dynamic as a consequence of the data sequencing across changing scenes – creating time lapse from once individual static objects.

> … computer-based visualization appears to be particularly well suited to visualization for understanding. This is so because the computer lends itself so naturally to representations with text, sound, and visual displays. The possibility of combining language and a dynamic visual display while allowing for the user to control speed and other presentational factors underwrites much of the current enthusiasm for computer-based visualization. (Phillips et al. 2010, p. 81)

The change from a static to interactive visualization illustrates a transformation of data from an abstract to a concrete representation; the success of that transformation is often dependent on the extent to which the ‘data changes’ adequately capture and portray the ‘markers’ anticipated by the author as conveying particular meaning (initially for the author in conceiving the slowmation but ultimately for the audience when viewing the final product). In terms of visual representation, it is not only the model(s) but also the background that helps in cueing the viewer to intended features for more focused attention. Hence, such things as colour (in models and background) impact a viewer’s attention and can enhance recognition and visualization of data; especially so as changes in scene and various markers emerge through the movements depicted when brought to life through the movie itself.

The effectiveness of the illusion of movement created through taking the static photographs and combining them in sequence is influenced by the number of frames (incremental changes) and the speed with which the frames are viewed. As noted earlier, two frames/second is the common form used for slowmation, and the rate of data flow (speeding up, constant rate, slowing down) can be important in further portraying the concept under consideration and attracting the viewer’s attention to particular features of the slowmation. Through the use of narration and/or annotation, the viewing experience may be enhanced as different elements of the visualization emerge across the time sequence and are visually cued to aid interpretation and understanding of that which is being depicted.

As all of the above suggests, although thinking about slowmation as a product might initially appear to be a simple way of conceiving of it as a visualization tool, for the author, there are a multitude of decisions and possibilities inherent in constructing the product as the original abstract conceptualization of the animation and the concrete form of product are compared and contrasted. As opposed to more sophisticated commercially developed animations constructed by experts for students to watch, slowmation allows multiple points of learning for the author as the actions of designing, constructing, creating and displaying all invite creativity and innovation through the direct control possible in the process of developing and refining the author's personal final product. When teachers understand these crucial underpinnings of slowmation, the importance of the teaching-learning relationship becomes all the more real and the superficial view of slowmation as 'an activity that works' is able to be challenged in meaningful ways.

Slowmation as a product is obviously a valuable visualization tool because it offers a depiction of the author's understanding of the concept under consideration in a tangible fashion through the nature of the narrative being displayed through the final product. Learning from the product is then available to an individual audience (the student-author and the teacher) and collective audience (class as a group). Learning though is not limited to the notion of slowmation as a product, there are many interlinked processes within design and construction that contribute to this form of visualization being educative at a number of levels; all of which impact teachers' understandings of their practice, the way it is structured and the influence it might have on students' learning.

4.3.4 Slowmation as a Process

> Science education is a domain in which teaching methodologies have often relied on matches between learning activities (i.e., external presentations) and the knowledge we wish students to acquire from their lessons (i.e., internal representations). Lab-based activities, active learning assignments, and task-driven coursework all help students learn about scientific topics through active participation rather than passive viewing or listening. External representations ('visualizations') have emerged as a methodology that, in many ways, relies on similar principles to facilitate learning. A visualization can be thought of as the mental outcome of a visual display that depicts an object or event … the need to assess the effectiveness of 'visualizations' in science classrooms has led to increased interest in the impact of their use. (Rapp and Kurby 2008, p. 30)

An important aspect of developing a slowmation revolves around the nature of the knowledge to be represented. Typically in the teaching of science, the teacher is perceived as knowing the subject matter content (breadth and depth) in ways that goes beyond that of the majority of students in their class and so the archetype of science as the delivery of propositional knowledge routinely arises. However, another way of thinking about this situation is that teachers may have become so comfortable with their understanding of the subject matter knowledge, that the manner in which they have 'chunked' (White 1989; White and Gunstone 1992) that information masks the complexity and intricacy of what it takes to assemble the ideas in a coherent way for learning in order to better understand the idea as a whole. Therefore, the teacher has fewer (but larger and richer) chunks of knowledge on the topic (e.g., particle model as an all-encompassing way of understanding states of matter) than students who may have numerous smaller, less connected and poorly integrated chunks that they might struggle to bring together in a coherent way (e.g., if solids, liquids and gases are only propositional knowledge it can be challenging for a student to make sense of such things as sublimation or colloids). Therefore, the nature of the representations that teachers carry (and/or construct), influences their understandings of subject matter knowledge, and the nature of their chunking inevitably influences the complexity of the representations they need to illustrate their understanding; which inevitably impacts the manner in which they teach those ideas.

As noted earlier, the first phase in developing a Slowmation is that of research: researching the topic/theme under consideration. For a teacher, this step encourages them to tap into students' prior knowledge and how it is influences (or not) their developing understanding of the topic. Through this process, students are not controlled or bound by the teacher's chunking but are open to various forms of chunking from the different sources on which they draw – something which through didactic approaches is often difficult to achieve. The process then encourages the development of representations that aids in knowledge building and is not only open-ended but also derived of a sense of creativity and innovation – two highly prized features of learning that teachers often consider difficult to encourage and support through 'typical' approaches to science teaching.

Storyboarding is a process that encourages, questioning of the referent and the representations (individually and as a group) as consideration of the congruency between mental models and anticipated products acts as a key organizing principle. Refining the storyboard is an active process through which the synchronization of movement and the chunking through scenes offers feedback about the adequacy of the representation as a coherent whole. This process is further reinforced when the storyboard is 'made real' through the development and use of the models that comprise the third phase of Slowmation production. Again, comparison between that which was envisaged and the physical representation created through the models is able to be compared to the understanding of the referent (idea/concept/theme) from the author's perspective – thus giving a teacher an ability to see into students' developing understanding of the concept in ways that allows prior knowledge to be recognized and challenged in less threatening ways than public classroom questioning.

The fourth phase of slowmation is taking the digital photographs of the incremental changes made with the models as the static forms become dynamic. Through the simulation of change over time, an overall understanding of the referent is able to be tested in ways that encourage the author to consider not only the chunks that are captured and portrayed in each scene, but also the overall adequacy and accuracy of the depiction of the temporal dimensions conceived through the introspective visualization that is at the heart of the process as a whole. Importantly, this aspect of slowmation then allows teachers to see that learning goes beyond the much bemoaned 'school science learning' as the student is genuinely shaping, challenging and constructing conceptual knowledge in ways that are very different from 'guess what's in the teacher's head' depictions of school science.

The fifth and final phase of constructing the slowmation is downloading the digital photographs then uploading them into a movie-maker program to turn the still photographs into an animation. At this stage, interpretive visualization comes to the fore as existing understandings are confronted as a consequence of viewing the slowmation and considering how it depicts, negates or challenges the conception of the referent. Thus meaning making (interpretant) is likely to be catalyzed as there may be satisfaction with the product, or a desire for further refinement to better align the product with the prevailing mental images of the referent. Again, for a teacher, this phase offers something very different to typical science classroom practice, satisfaction/dissatisfaction with the product is driven by students' understandings not imposed by a teacher's directive.

As this section highlights, product and process come together to encourage learning through visualization in ways that are based on independent and active learning but are fundamentally driven by slowmation as a valuable pedagogical tool. How teachers understand these elements of slowmation and how that understanding impacts their practice is considered in the next section of this chapter.

4.4 Understanding Slowmation: A Teacher's Perspective

As the above suggests, understanding Slowmation as visualization involves a process of representation, deconstruction and reconstruction, in order to examine the nature of the science concept (referent) under consideration.

Keast et al. (see, 2009, 2008) conducted a series of studies with pre-service science teachers designed to examine how beginning teachers came to understand the value of slowmation as an approach to science teaching and learning and how that impacted their practice. Data from those studies was drawn from many sources including interviews about their experiences of learning to do slowmations, teaching using slowmation and evaluating their students' learning from making slowmations.

The research was conducted in a preservice science teacher education program qualifying students to teach General Science at the secondary level (Years 7–10; students aged 12–16). Preservice teachers entering the program had either an undergraduate qualification and were therefore completing the fourth year of a Bachelor of Education double degree (e.g., B.Sc./B.Ed.) or were post graduate students completing the 1-year end-on Postgraduate Diploma in Education (Grad. Dip. Ed.).

Data collection was based on three aspects of participants' experiences with learning about, and using, slowmation. The first was in creating their own representations of particular science concepts through their own slowmations (in small groups, 3–4 participants) and discussion of the process with their peers. The second was derived of participants' presenting and reviewing with their peers the slowmations their students constructed when these teachers taught using slowmation as a pedagogical approach in their science classes. (Data for both of these aspects was collected through audio recording and video recording group work, presentations, reviews and discussions). The third aspect involved participants' reflections on their learning as a consequence of the first two aspects with a particular focus on the impact that learning had on their thinking about their science teaching (data for this aspect included semi-structured interviews with volunteers at the end of their program).

The following section considers indicative data from these projects designed to illustrate participants' experiences in learning about and teaching using slowmation.

4.4.1 Learning About Slowmation

It is well recognized that in order to understand an approach to teaching, it is helpful to experience that approach as a learner. Slowmation is a good example of an approach that, once it has been experienced as a learner, creates a greater sense of confidence in being able to implement it as a teacher and to grasp the pedagogical underpinnings of the approach. The data drawn from the slowmation projects presented in this chapter generally support the view that making a slowmation before attempting to teach using slowmation is important as stated by Sarah.

> It's different doing slowmation [yourself] than actually teaching it with your class, [not doing it myself] what would have put me off … I wouldn't have felt confident. (Sarah)

As noted earlier, all participants created their own slowmations in small groups and considered their learning from that process as important in shaping in their understanding of the structure of the procedure.

> I thought it was good that we were able to do our own [slowmation] because it kind of, you know, got us used to making it and how to put it onto the computer … and we knew if we had any problems we could [get help] so I think that was good [doing that]. (Sue)

Concepts/topics selected by participants were those that they had been teaching in schools and were commonly listed in curriculum documents (e.g., DNA replication, Day and Night, Photosynthesis, Solar system, States of Matter, Life cycles, Chemical reactions, etc.). However, despite participants' perceived knowledge of the topics, doing a slowmation highlighted their need to think beyond the content alone.

> Ah, I needed more practice with it before implementing it … more practice in making more slowmations, not just myself making them but actually presenting the concept … until I actually tried it I wasn't really sure what were the key things, I had no idea what the most important components of a slowmation were. (Wayne)

In making a slowmation, a teacher becomes attuned to key technical and pedagogical issues for using slowmation that might otherwise not be so clear. On the surface, slowmation can appear to be technically challenging and time consuming, both of which can be barriers to implementation. Participants were conscious of these issues and consistently raised them as difficulties that might impact at the personal as well as the curriculum level.

> … all these computers and laptops and digital cameras which I'm probably not [so good with] I thought, "oh my gosh what am I going to do if I get into the classroom" I didn't even know how [I'd do it] … (Sue)
>
> I really liked it but I thought it took a lot of time to set up and get going in class, it might be a bit too long for some units and schools, it takes a lot of classes to do and some people might think that it's, you know, they could do other things that are shorter and might achieve the same result or something similar. (Ellen)

For the large majority of participants, despite their recognition of the likely 'pitfalls' in teaching using slowmation, they were enthusiastic about that which was achieved when they implemented the procedure in their science classes as illustrated in the next section of this chapter.

4.4.2 *Teaching Using Slowmation*

As noted earlier, slowmation could easily be viewed as a fun activity. However, when teachers observe their students' carefully whilst constructing their slowmations much more emerges about the nature of their learning than superficial views of fun or hands on activities. Much of the learning is driven by two important aspects of teaching, the first is the move away from teacher dominated practice, "it was a lot more student driven which I really enjoyed as a teacher because you know the students don't like a teacher up there dominating the class all the time" and the second is offering students genuine opportunities to pursue their own understanding and to capitalize on the questions created in their own minds through visualization as both a process and a product.

> Kids learn in different ways, kinaesthetic modelling is a really good way of learning in science rather than just seeing a diagram or a series of steps or something, slowmation is a good way of showing you how something happens … that the diversity of thinking and kids need to have that ability to work on different tasks and different projects, it has a lot to do with the visual aspect and actually doing something, actually seeing the thing happen, actually seeing the process on the screen was good for all the students not just the ones who made it. We had their movie moment where we showed all of them [slowmations] and discussed them and that sort of thing and that helped the whole class, not just that small group. (Ellen)
>
> Interviewer: You mentioned before that you saw something in the class where 'they didn't understand that before' …
>
> Sarah: Yeah, one of the boys, they were doing levers and they did one on different types of levers and there were speed multipliers and force multipliers and I think when he was actually in the group he didn't understand the difference between what a speed multiplier did and what a force multiplier did but there were 2 other boys in his group that really grasped that concept and so they did one with a tennis ball I think, and for a speed multiplier the tennis racket hitting the ball and I can't remember what they did for a force multiplier but anyway when we actually came back to watch it I could tell that he didn't really understand it, so we started

talking about it a little bit and then you know, he said he got it but then I think the light bulb moment for him was when we started watching back the other videos and we started going through examples of what a speed multiplier was and a force multiplier and he was like, "oh I understand it now!" and then because we'd watched it [he got it] … and then a couple of lessons later we watched his video again and he's like, "now I understand how that acts as a force multiplier and that acts as a speed multiplier" and I think for him because he wasn't strong in science at all he was like, "wow I actually learnt something" and he'd never passed a science test before … he's like, "normally we just sit down and write things in our text books and learn science from doing experiments." [He normally] doesn't understand [science], but slowmation actually, like using the technology and the plasticine, making it actually helped him understand what he was learning.

As the quote above suggests, slowmation offers teachers new ways to see into, and respond to, students' developing ideas of concepts. In particular, it is helpful for drawing attention to alternative conceptions in new ways. Loughran et al. (2012) examined how teachers became more sensitive to students' alternative conceptions when using slowmation. They explained the uncovering of these as being catalyzed in two ways. The first was through the learning as a consequence of the classroom presentations of students' slowmations – teachers began to recognize alternative conceptions in their students' finished products. The following transcripts from a discussion by preservice teachers following viewing their students' slowmations illustrates this first point.

Lecturer: So what are they showing here?

Participant 15: Oxygen

Participant 12: Watering

Participant 17: And water into the leaves, which is a bit of a misconception as in it's brought up through the roots not into the leaves.

Participant 18: I think they're bringing the water through the veins of the leaf rather than carbon dioxide and oxygen just coming out of the green parts.

Lecturer: Yeah it's a bit hard to know isn't it? This is where you might want them to explain it.

Participant 19: They're not saying what the sun's doing there apart from looking pretty.

Participant 20: And what's the major alternate conception that they miss here? 'Cos in primary school the major thing that they're learning, the major alternative conception with plants is that they don't realise that plants respire. You know 'cos plants photosynthesize and respire … and that's the number one alternative conception and they don't show that at all do they?

Lecturer: The light and dark reactions

Participant 19: … instead of respiration?

Participant 20: Plants do both at the same time the thing is though that they photosynthesize more than they respire and that's one thing that they're not showing here and so they've actually got an alternate conception.

Participant 3: And most alternative conceptions cannot be spoken through so you'll find that you cannot debunk an alternative conception by speaking to it and that's the number one thing. How do you 'break' an alternative conception? Because you've got to remember that these students have had a lifetime of thinking this way or if they've learnt something they've got it from what they consider a legitimate source, text book or something like that, and you in 2 seconds cannot break that.

The second way that they came to recognize and respond to alternative conceptions was through the careful observation of their students' thinking and 'chunking' through their story boards. Commonly, the participating teachers came to see that simply telling their students about a concept did not necessarily alter their thinking about the concept in any appreciable way. Hence, through using slowmation, these teachers were personally confronted by the limitations of transmissive approaches to teaching and developed a greater sense of the value of creating conditions to help students confront their own thinking in productive ways. They began to implement different ways of responding in their practice beyond simply restating the facts.

> In the chunking sheet yeah, I didn't actually say that's a misconception, I didn't want to say you know, "that's wrong" so I just said you know, have you ever thought about that, maybe this could be done in this way and they would be like, "oh ok maybe" and I said "look in your text books and see what that says" I didn't want to take it up and be like "that's wrong, fix that up" it was kind of like, "have you thought about this? What do you think?" I wasn't going to give them the answer I gave them the opportunity … still if they were adamant that that's what it was, that was ok for them … It wasn't about me saying "that's wrong, your slowmation has to be perfect". (Sarah)
>
> Interviewer: So do you mean would you use the chunking sheets without making the movie?
>
> Sharon: Um, I think, I would if there was an idea that a lot of students were a bit mixed up or there seemed to be a bit of like one student believed this but then another student believed this so I think there would be another form of assessment of students' beliefs or misconceptions and then going to a chunking sheet, using that and then getting them to clarify their ideas again. So yeah I think you could probably use it without making the movie … it points out if there are any misconceptions because they're putting their own ideas on to the paper and as I said I collected them after the first one and I was looking at them and I have to say the ones I did most of them were pretty spot on with their ideas. But it allowed me to look at them and go, "ok this student here has got this idea a little bit confused" so maybe [I'd] speak to them you know highlight, "maybe include this information" or "this isn't quite correct" and then I think getting the students into groups and doing the same process and making another big group chunking sheet was good because each of the different students had maybe one little [bit of an idea] and extra step, or they've included a little bit more information to this part and I think that was good that it allowed other students to go, "Oh ok, I didn't think of that" and then they could build on each other's ideas as well.

4.5 Conclusion

Through the theoretical framework of semiotics, slowmation illustrates well how the notion of visualization is helpful in understanding the ways in which slowmation can enhance students' science learning as a consequence of it being thoughtfully implemented in a teacher's science practice. As I trust this chapter illustrates, understanding slowmation as an important pedagogical visualization tool can be a catalyst for teachers to become more informed about science teaching and learning.

As the chapter attempts to make clear, that which a science teacher can see and learn from both the process and the product of slowmation offers insights into the value of visualization and draws serious attention to why an explicit focus on visualization in teaching and teacher education is helpful. At a time when science teaching and learning is increasingly questioned, criticized and scrutinized as a consequence of national and international testing regimes (e.g., TIMMS, PISA, ROSE), it is important to be reminded of the pedagogical underpinnings of practice that are crucial for valuing science teachers' professional knowledge of practice. Slowmation offers a way to help teachers work with scientific concepts so that students internal representations can become public. As Gilbert suggests, "It is entirely possible that, once a series of internal representations have been visualized, that they are amalgamated/recombined to form a novel internal representation that is capable of external expression" (Gilbert 2008, pp. 4–5). I think it is fair to suggest that Slowmation does that, and does so in a creative and engaging way.

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