Asia-Pacific Forum on Science Learning and Teaching, Volume 13, Issue 1

FOREWORD

Preservice teachers learning about teaching for conceptual change through slowmation

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Abstract

This study reports on research into the use of Slowmation in a general science methods program in teacher education as a productive way of teaching student teachers how to recognize and respond to students' alternative conceptions in science. The preservice teachers first experienced Slowmation themselves as modelled by their lecturers in their teacher education program, they then used Slowmation during their school practicum with their school students. On returning to the university after their practicum they reviewed their learning about teaching with Slowmation in ways designed to encourage deep reflection on their practicum experiences in relation to their students' conceptions of science. The results of this study show that as a consequence of teaching Slowmation that these student teachers came to recognise and respond to students' alternative conceptions.

Introduction

In their review of learning to teach science, Russell and Martin (2007) noted that while, "[t]eaching for conceptual change has been a dominant theme in the science education literature for several decades … only a small fraction of that research considers how individuals learn to teach science in preservice programs" (p. 1152). Russell and Martin's concerns become all the more important when considering understandings of, and pedagogical responses to, conceptual change in preservice science teacher education. Complicating this challenge is the fact that teachers tend to teach the way they were taught (i.e., are shaped by what Lortie (1975) described as an Apprenticeship of Observation), and that student teachers often enter preservice education with an expectation that learning to teach is relatively straight forward. These factors combine to create a learning about teaching expectation whereby gathering a 'bag of teaching tricks' can become a student teacher's learning about teaching goal to the detriment of developing deeper understandings of the complexity of teaching (Loughran, 2006).

As the above suggests and the literature continually demonstrates, teacher change is a major issue in education. Teacher change therefore attracts the attention of professional developers, science teacher educators and policy makers, because, despite knowledge of new and different teaching procedures and approaches, teachers do not necessarily embrace such changes in their own practice. There are countless examples of programs of professional learning designed to encourage teachers to implement new practices and teacher education programs are no different. In fact, science teacher educators in particular have long drawn attention to the need to promote student teachers' understanding of conceptual change as a special area for attention. However, doing so is not as simple as it may appear. For example, Duit and Treagust (2003, p. 687) cautioned that, "…What research on conceptual change has to offer classroom practice cannot be set into normal practice to a substantial extent. Of course, teacher development programs are essential in order to change teachers' views of teaching and learning and their practice. However, it appears to be also necessary to make these theories more simple and describe conceptual change strategies in such a way that they may become part of teachers' normal routines". Clearly then, science teacher education stands out as an important starting point for confronting this issue and beginning to address the oft bemoaned nature of traditional school science teaching.

One response to this situation is for university science education courses to initiate new ways of engaging preservice teachers in learning about teaching science in ways that might engender confidence, and better prepare them for challenging stereotypical approaches to school science teaching and learning. However, despite extensive research into a range of issues confronting science teaching and learning, it is clear that changes in practice are slow in coming; not only in schools but also in science teacher education programs. There is a need for teacher education programs to teach in ways that are consistent with the approaches that teacher educators are advocating for science learning in schools and in ways that are manageable for neophytes to the profession. Yet despite a plethora of studies illustrating the range of conceptions that students bring with them to their science classes (Tanner & Allen, 2005), ways of addressing these alternative conceptions have not generally been developed or documented in ways that speak to science teachers.

Hammer (2000, p. S52) in particular noted that, "misconceptions and difficulties are limited ... they provide no account of productive resources students have for advancing their understanding ..." Moreso, if such resources are available, they tend to expect more from teachers than may be possible in light of the demands of the 'busyness' of teaching (Loughran & Northfield, 1996) i.e., they are overly complicated with multiple steps to be followed in distinct order (e.g., Olenick, 2008) or based on approaches that are not effective (Wenning, 2008).

This paper focuses on responding to this challenge (as briefly outlined above) through a focus on Slowmation. Based on the theoretical underpinnings of Slowmation (described later in this paper), it could well be argued that Slowmation offers real opportunities for student teachers to become much more sensitive to their students' science conceptions and engage and challenge their learning. As a consequence, Slowmation can make a difference to the way science is understood and taught in teacher education programs and in school science classrooms. The following sections of the paper consider important aspects of conceptual change and Slowmation in respect to the research purpose of this study.

Conceptual change and students conceptions

> The best known conceptual change model in science education, based on students' epistemologies originated with Posner, Strike, Hewson & Gertzog (1982) ... and applied to classroom instruction by Hennessey (1993) ... In this learning model, resolution of conceptual competition is explained in terms of the comparative intelligibility, plausibility and fruitfulness of rival conceptions. (Duit & Treagust, 2003, pp. 673 - 674)

A central tenet of learning as conceptual change is that knowledge cannot be transferred during teaching; that existing thinking influences outcomes. This is one of the reasons why, for some, aspects of science are difficult to learn. A learner's personal understandings must be uncovered and brought to the surface in order for the teaching activity to contribute to the reconstruction of prior knowledge and ideas (Pringle, 2006). Teaching therefore should, "provide opportunities to probe students' developing understanding in a formative way, allowing subsequent teaching to be responsive to students' learning" (Scott, Asoko, & Leach, 2007, p. 38).

Although various meanings have been attributed to the term conceptual change, it is typically associated with constructivist perspectives, "In a general sense, conceptual change denotes learning pathways from students' pre-instructional conceptions to the science concepts to be learned" (Duit & Treagust, 2003, p. 673), and therefore focuses attention on the ability of teachers to identify such pre-instructional conceptions. To do so requires a change not only in perspective but also in practice from transmissive to constructivist understandings and approaches to teaching.

Many teachers are not aware of their students' pre-instructional conceptions, and even when they are, "Some teachers are aware that students' pre-instructional conceptions have to be taken into consideration but usually they do not explicitly see them as 'goggles' that guide observation and interpretation of everything presented in class by the teacher or the textbook" (Duit & Treagust, 2003, p. 683). Therefore important in conceptual change is first to recognise that students bring conceptions of scientific phenomena into class with them, and as a consequence, teachers need to see how these conceptions act as a lens through which students learn science.

There is also a social and affective dimension that is important to take into account for conceptual learning to occur and "teachers who ignore the social and affective aspects of personal and group learning may limit conceptual change" (Duit & Treagust, 2003, p. 679). As the literature demonstrates, knowledge about conceptual change abounds, however, the ability of teachers to know how, or to be able to, teach in order to facilitate such change is not so vast. In many respects, the teaching and learning situation in teacher education programs is not that different to that of school science classrooms.

Student teachers' learning about science teaching cannot be conceptualised as a process of transference, their prior experiences have important consequences for their expectations of, and approaches to, their students' science learning. Therefore, finding ways to help student teachers recognise this is important if teacher preparation is to genuinely impact student teachers' understanding of teaching and how it influences their students' learning.

The conceptual change literature highlights a number of important issues that impact teacher education. For example, to raise, confront and reconstruct students' thinking is often difficult to implement in classrooms. There are few specific examples of how to do this documented and accessible to teachers and it is time consuming for teachers to develop such materials themself as they can be quite complex (see Berry & Milroy 2002). Further to this, the 'dissatisfaction with existing ideas phase' of conceptual change approaches can create difficulties for teachers when challenging students' views, and for the students, can be very confronting as they experience the affect of having their views challenged. Given the well documented difficulties that student teachers often experience in terms of their content and pedagogical confidence (Appleton, 1992; Garbett, 2007; Parker & Heywood, 2000), the idea of teaching for conceptual change based on the examination of students' views adds another layer of complexity and difficulty to student teachers' learning about teaching science.

A pertinent example of this situation is offered through the work of Berry and Milroy (2002) when, as teacher researchers, they sought to do something about the alternative conceptions that they had uncovered in their students' understandings of the science topics they were teaching.

> It was clear that telling students the answer did little to change their views ... From the outset we were keen to draw on research to inform our teaching. Our … University experiences had been significant in influencing our views and we saw value in accessing the possibilities that a conceptual change approach might have on students' learning ... However, when we turned to the research literature to find a context for teaching about atomic structure or practical classroom assistance for dealing with the particular conceptions we had uncovered and wanted to challenge, we found little.
>
> This frustration persisted throughout many of the units we taught. Probes of children's conceptions of scientific phenomena and descriptions and analyses of the shortcomings of much classroom science teaching were abundant, but there was little to support a conceptual change approach … for dealing with the variety of individual conceptions – how to challenge; what to do with those students who already had a coherent view of the phenomenon; what the likely response to various situations might be; good teaching procedures targeting particular concepts ... (pp. 107 - 201)

As Berry and Milroy (above) make clear, although the research literature abounds with knowledge about alternative conceptions, practical advice for teachers about what do as a consequence of uncovering them is not so plentiful. Clearly, if this situation is difficult for experienced teachers it carries great import in terms of implications for science teacher education programs. Although student teachers may be taught about alternative conceptions and even encouraged to confront and reflect on these ideas in terms of the impact of such thinking on their subsequent practice, there is a major difference between recognizing a situation and actually doing something productive about it in practice. For student teachers, that prospect is both challenging and demanding.

The problematic aspect of finding pedagogical approaches that might be implemented to advance learning beyond knowing likely conceptual starting points and barriers is clearly apparent and the literature has very little, "to say about how to shape instruction in order to help students come to terms with the scientific point of view" (Scott, et al., 2007, p. 51). Yet, while it is important to acknowledge the context specific nature of teaching some instructional approaches may in fact be more helpful than others because they "involve a motivating activity for students, or challenge students' thinking in an engaging way, or allow students the opportunity to articulate their developing understandings" (Scott, et al., 2007, p. 51).

It is this need to examine productive ways of recognizing and responding to students' alternative conceptions that can create real opportunities for science teacher education programs to respond to these issues in teaching for conceptual change. One such purposeful approach is through Slowmation. However, it cannot be that Slowmation is a solution per se, rather that it is through understanding the theoretical underpinnings that its impact on learning can really be understood and inform student teachers' developing knowledge of their own professional practice. Through concept construction and representation created through Slowmation, real gains in student teachers' learning about teaching for conceptual change are realized. Hence, making the pedagogical purpose of Slowmation strong and explicit by creating situations through which student teachers personally experience learning as both students and teachers is the key to moving beyond 'activities that work' (Appleton, 2002).

Slowmation: Theoretical framework

Slowmation (an abbreviation of slow animation) is a pedagogical approach that enables students to create their own animations of science concepts in a relatively short period of time using simple hardware and freely accessible software (for a full explanation see Hoban, 2005, 2007, and 2009). Slowmation has proved difficult to explain through text as it is often misunderstood as being a software program or some form of technology that 'does the work' for students; neither of which is the case. Perhaps an easy way to visualise Slowmation is through comparison to the low tech, childhood cartoon 'flip book'. Each page of a flip book has an image that changes in small ways from page to page so that when the pages are quickly 'flicked through' it creates the impression of a moving scene. Slowmation works in exactly the same way. It is based on taking a series of individual digital photographs of scenes that been have created by the learner and that change in small increments (one small change per photograph) and animating them through a simple format that combines them in a sequence. Putting the photographs together (just like the pages of a flip book) and playing them creates what is more commonly known as "stop-motion animation" (for examples of slowmation see http://www.slowmation.com/).

Slowmation offers an innovative approach for teachers of science not only to recognize, but also begin to respond to, learners' conceptions in science. Slowmation involves a process of: conceptualizing what the theme to be constructed needs to contain (e.g., phases of matter); developing the artifacts (e.g., particular features important to constructing representations) to demonstrate how the concept can be visualised and incremental changes made for photographing; review of how the product demonstrates that which was intended; and, reconstruction (where needed in light of review). Slowmation then can be conceptualized as comprising four distinct phases: *planning; chunking & sequencing; constructing; and, reconstructing*. Each of these phases help teachers see into their students' thinking about a science concept, and at the same time, invites learners to consider their own understanding of that science concept as the phases challenge their understanding of the concept itself. The Slowmation product (the short animated film) is the end result, but the process that led to that product is what matters most; especially in terms of issues of conceptual change outlined earlier.

Hoban et al. (2011) described the theoretical framework underpinning studies of slowmation as being that of semiotics. Semiotics is concerned with how meaning is made when a sign is used to represent an object. Pierce (1931/1955) described such meaning making as involving: (i) a referent of the concept or content being represented; (ii) a *representamen* (more commonly known as a representation); and, (iii) the *interpretant* (the meaning generated from the sign). Together they comprise an interrelated "semiotic system."

> For example, a high school student who wanted to learn about the solar system (the referent or content), might draw a 2-D sketch of the planets positioned in orbits around the sun (the representation) and during the construction process learn about the order of the planets and how they rotated and revolved around the sun (the interpretant). Clearly this is not a linear process, but dynamic as the student makes meaning by iteratively checking

> the content whilst creating the sketch ... Although from early last century, the theory of semiotics explaining how learners make meaning by interpreting representations still has currency in science education research (Gilbert, 2007; Prain, 2006; Prain & Waldrip, 2006; Tytler & Prain, 2010; Tytler, Prain, & Peterson, 2007). According to 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. (Hoban, et al., 2011, p. 991)

Because the learner creates the representations in Slowmation, multiple opportunities for thinking about the referent (content) and the representation being constructed emerge and that is important because "transformation among multimodal representations has the greatest potential in promoting learning and depth of processing" (Yore & Hand, 2010, p. 96). As Hoban et al. (2011) explain in detail, the value of learners creating multiple representations of the same concept becomes all the more powerful because it forms that which has been described by other researchers active in this field of representations as a semiotic chain (see for example, Bezemer & Kress, 2008; Hand & Choi, 2010; Waldrip, Prain, & Carolan, 2010) through which understanding of the concept under consideration is enhanced.

Briefly, Slowmation begins with a *planning* phase in which the learner develops a plan for representing a science topic or concept. This may mean that the learner needs to conduct research on the particular topic in order to gain sufficient information to identify a sequence that will involve sufficient change to be demonstrated through a series of phases. The purpose of the planning phase is for the learner to develop a big picture representation of the relevant concept.

The second phase involves both *chunking* and *sequencing* which involves developing and laying out the story. In this phase, the concept must be broken into chunks or scenes which need to be sequenced to bring the anticipated actions, explanations and 'story' into line. Chunking and sequencing involve an analytic phase important in creating a deeper understanding of the complete depiction of the concept. Through analysis, appropriate sequencing can be experimented with so that the learner can question the representation in relation to that which was abstractly anticipated in the planning phase. The chunking phase provides the teacher with an opportunity to recognize and respond to students' conceptions in ways that are perhaps not so likely through more traditional approaches to science teaching.

The third phase, *construction*, involves the learner in thinking about the chunks of the concept in concrete ways as representations, and the way these chunks are organised into a sequence and brought to life through model construction. The construction phase invites the creator to question the ideas being developed in more personal ways as the concept becomes 'real' through the artifacts developed and that which they concretely depict. This is an important aspect of learning because in typical teaching situations (and as is certainly the case in traditional science classes), teachers tend to "ask students direct questions pertaining to theoretical principles, [that] risk getting responses that mirror verbatim learning only" (Hallde´n, 1999, p. 56). This phase therefore prompts more personal questioning of the representation in ways that go beyond simply mirroring verbatim learning.

The fourth phase, *reconstruction*, involves reassembling the concept into a coherent whole. It is at this stage of learning through the Slowmation process that the learner has an opportunity to review the different levels of representation that have been created and portrayed. At one level this phase serves as a review of the individual chunks, while at another level, it provides a big picture view of the whole concept. Reconstruction is an important element of learning because it offers a meta-level of analysis of the concept whereby the synthesized account of the representation may be viewed, reviewed and evaluated in relation to the learner's understanding of the concept. At this stage, it is possible that personal recognition of aspects of uncertainty or cognitive dissonance (again an important aspect of conceptual change) might be grasped; if so, the learner may be motivated to refine the representation in order to address the situation. Importantly, reconstruction maintains (and in fact consolidates) ownership of the learning as the representation is finalised.

Slowmation is highly engaging for learners because they are the designers and creators rather than the passive consumers of information supplied by others. As Chan and Black (2005) noted, moving away from being a passive consumer is an important shift that is clearly facilitated through the production of animations. Further to this, as Bransford, Brown and Cocking (2000) argued, making and manipulating models of concepts is valuable for learners because they "develop a deeper understanding of phenomena in the physical and social worlds if they build and manipulate models of these phenomena" (p. 215).

In essence then, the overall Slowmation process offers a real opportunity to address issues associated with teaching for conceptual change outlined at the start of this paper as well as doing so by helping student teachers see beyond it as just another activity to add to their bag of teaching tricks.

Outline of the study

The focus of this study is on the use of Slowmation (as an explicit method for development, manipulation and reconstruction of representations) to determine the impact of the process on the ways in which student teacher participants recognize and respond to students' alternative conceptions. Slowmation offers a new and exciting pedagogical approach to sensitising participants to their learners' alternative conceptions.

Context

This study was situated within the context of a University preservice science teacher education program, qualifying students to teach General Science (that includes topics from Chemistry, Physics, and Biology) at the secondary level (Years 7-10; students aged 12 - 16). Student teachers entering the program had either an undergraduate qualification and so were completing the 4th year of a Bachelor of Education double degree (e.g., B.Sc./B.Ed.) or were post graduate students completing the one-year end-on Postgraduate Diploma in Education (Grad. Dip. Ed.).

The design of the science methods course in which this study was conducted is underpinned by a constructivist orientation. As constructivist studies have demonstrated for some time, learners bring their own prior views of science to the classroom based on the ways in which they conceive of particular concepts and ideas (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Teaching informed by a constructivist perspective relies on the teacher acknowledging and identifying learners' prior conceptions and creating experiences and opportunities for them to experience conceptual change. The expectation being that students might then develop deeper understandings of concepts as they move from their informal prior views toward the "accepted school view" of science (Fensham, Gunstone, & White, 1994).

Within the program, considerable emphasis is placed on preservice teachers coming to understand these perspectives through experiencing them – rather than simply being told about them by their lecturers. Hence, the lecturers aim to make explicit the practices they advocate their students use in their classrooms through modelling. They also actively provide opportunities for their student teachers to use the teaching approaches used in their program in their practicum and to reflect on their experiences post practicum, both individually and collaboratively, with their lecturers and peers.

De Jong, Van Driel and Verlop (2005) distinguished between preservice teachers "learning from teaching … in an active way involving real situations, to make learning more meaningful to themselves, and learning of teaching … learn[ing] in a mainly passive way how to teach" (p. 952). The principles underpinning the science methods course at this institution are consistent with this view of learning from teaching.

Research Design

Data collection for this study was based on three crucial aspects of participants' learning experiences:

1. Program based sessions associated with learning about Slowmation in which two classes of participants (N=38/N=34) worked in small groups (34 student teachers) together to develop their own representations of particular science concepts (data set 1).
2. Student-teachers' presentation and review of their school students' Slowmations (produced during their practicum) to their student teacher peers in sessions post practicum (data set 2).
3. Interviews with volunteer student teachers (N = 5) at the end of the academic year using a semi-structured interview protocol of approximately 45 minutes duration (data set 3).

All data sets were captured through audio-recordings which were later transcribed. Signifiers for each of the data sets were labelled as follows:

1. Data source 1 (DS1), with participants' in transcripts listed by number (S1, S2, etc.) and group number (Grp1, Grp2, etc.)
2. Data source 2 (DS2), with participants listed by number (e.g., S1, S3, etc.)
3. Data source 3 (DS3) with each individual interviewee allocated a pseudonym (e.g., Sharon)

Transcripts were coded and analysed using the QSR NVivo 8 software. Nodes were progressively determined as a consequence of reading through each transcript and coding text in relation to the particular topic/issue/idea being discussed in the transcript. After coding all transcripts, 9 free nodes (i.e., stand alone separately coded instances of themes/issues without sub-coding) had been developed and 2 tree nodes (i.e., nodes with sub-categories that involved differentiation of ideas associated with the particular node; see nodes 4 & 8) had been developed (see Table 1 below). Alternative conceptions is the particular focus of analysis for this paper, hence, those nodes that do not directly relate to alternative conceptions have not been included in this paper. All quotations used in this paper are drawn from alternative conception node data sets (as per Table 1) and are offered as indicative quotes of given situations.

Table 1. All nodes coded across all transcripts

1. Alternative conceptions
2. Assessing slowmation
3. Difficulties with doing slowmation
4. Topics for slowmation
a. DNA replication
b. Day and night
c. Photosynthesis
d. Solar system
e. Tsunami
5. Introducing looking for alt conceptions
6. Introducing slowmation to teacher education class

7. Learning about student learning
8. Learning how to do slowmation in teacher education
a. Looking at cell division
b. Looking at DNA
c. Looking at survival
9. Possible changes to how to do slowmation
10. Students' views on slowmation
11. Why slowmation works (students' views)

All quotations used in this paper are drawn from the data sets for each theme and indicative quotes are used to illustrate prevailing views.

Results

Pre Practicum Learning Experiences

An important aspect of teaching about Slowmation to preservice teachers was to help them begin to see possibilities for focusing on students' science conceptions and see beyond Slowmation as simply 'a fun activity'. In this case, working collaboratively with peers in developing Slowmations helped these preservice teachers begin to recognise and respond to the range of conceptions that they held, not only in terms of what they are, but also how they might arise, and how they might be used in a classroom to generate discussion about that science idea. In the pre-practicum workshop, a major focus of discussion in some groups emerged around the use of language, and the ways in which everyday language can promote misconceptions in science. For example, one group decided to create a Slowmation on the topic of day and night. Through their discussion in the planning stage, there was evidence that some participants were coming to recognise problems associated with using the everyday terms, 'sunrise' and 'sunset':

2: When it's day it's light and when it's night it's dark which it's not always.
1: Yeah like we say the sun ...
2: Rises [but] we're [Earth is actually] moving.

1: The sun stays still. So the everyday language that the kids hear is that the sun rises. We tell kids every single day from when they're little kids from when they come to school as if the Earth stays still. And at night ..
2: Goes down.
1: …sun sets but it doesn't actually does it, it's not as if the sun moves ...
2: Sunset is still and it's actually the Earth that moves
(DS1: Grp 1).

In developing their Slowmation, these participants also discussed how they might respond to this problem of a 'static earth'. As a consequence, they were pushed to elaborate their thinking around a range of ideas including the earth's tilt and the time taken for light to reach Earth from the sun. In this case, the process of planning and then manipulating the materials for the Slowmation acted as a stimulus for this conversation.

1: So what would be the main thing to address here?
2: Rotating Earth …
3: Yep.
2: Not moving sun.
1: That's exactly it.
3: So you'd want that in the middle so that they don't get a false conception. If we have the Earth in the middle they assume it's you know, the centre of the universe.
2: Yeah that's true.
1: Great idea. So now how ... to pictorially display that point ...
2: Well if you've got the sun in the middle or even to one side and Earth to the like equal sides wise you can maybe turn the Earth around the sun?
1: Does it turn around the sun?
2: Well no no, the sun sort of stays where it is and then you've got the Earth here but the Earth is like moving around while the sun stays still.
1: So what's the Earth doing? It turns around ...
2: An axis. ... So yeah, you've got your sun and then you've got your ball of the Earth with its axis and it's just moving.
1: So well let's … grab a few things and we can start playing around with it ...
2: Rays of light coming out of …They move at the speed of light.
3: They take about 5 minutes to get there. Do we have 5 minutes?
1: Well for this [slowmation] speed doesn't really matter ... but what does

matter? What direction? Do they move in all different types of direction?
2: I'm gonna say yes but I'm not sure.
3: They go in sort of straight lines.
All: Yep
(DS1: Grp1)

While planning and making Slowmations offered a productive context for recognising and discussing science conceptions, a further opportunity was created through whole class viewing and discussion of a completed Slowmation. In the following example, preservice teachers' use of the expression, "survival of the fittest" was questioned by their peers after viewing a Slowmation on the topic of survival, and a discussion ensued about the meaning of the term in a biological context.

5: ... our slowmation is on 'Survival of the fittest'.
6: So maybe I should talk it through, it's a little bit hard to see. So beautiful scenery, along comes a beetle …Happens upon a frog, is eaten. Along comes a bird, eats the frog. Then there's a snake that eats the bird and then a cat eats the snake and then a person kills the cat and in case you didn't see the caption: 'human-1, animal-none.'
7: That's your first misconception.
8: So basically you've taken survival of the fittest to mean the survival of the biggest, strongest top of the food chain rather than survival of the fittest as in the process involved in evolution.
7: So yeah…instead of looking at it as an evolutionary process you've kind of mixed up survival of the fittest with the food chain in that yeah it's just a bigger animal or a scarier animal kills the other one and then humans (who clearly aren't animals) end up wining in the end because we're the biggest and the best.
6: I think [the word] strongest is leading to this [misconception] but it's more a favourable characteristic that's becoming more favourable in a changing environment.
3: So as a science teacher you'd probably use the words 'best suited' and get rid of the word strongest 'cos that's what the kids are …
5: And we might just also want to address that ... they introduced it as survival of the fittest, they should understand that that term isn't survival of the biggest and the strongest it's the survival of the most appropriate to an evolutionary

> pressure type of thing.
> (DS1)

As the data above illustrates, Slowmation offered these science student teachers a way in to deeper consideration of the science concepts being examined. Their need to think through the science concept influenced their thinking about that which was portrayed, how and why. In the above examples, the role of language in creating misconceptions/alternative conceptions was highlighted and translated knowledge of alternative conceptions into personal and practical examples.

Post-Practicum Learning Experiences

Slowmation helped participants to bring to the surface their (school) students' conceptions of the topic/theme under consideration. The first two examples (below) highlight how Slowmation allowed these preservice teachers to study their students' understanding of the particular content. These examples, illustrate how a teacher deals with recognising and responding to students' alternative conceptions. There is also the issue of whether the finished product (the Slowmation film) is an accurate representation of student thinking – and how the different parts can help the teacher gain access to students' thinking.

> *Whole class discussion of a Slowmation about DNA replication created by school students*
> 18: I think they'd need to have a little section on what DNA actually looks like; the little bits of it by themselves, ladders and the other bits you don't have them joining at different parts, like …
> 12: Yeah like they are the separate… the size of the ladder, whereas the nucleotides themselves make up the base.
> 23: But I mean part of that can just be an artistic [issue] like you know, I'm bad at art and so doing something like this might make it look like they [students] have misconceptions they don't actually, just because I'm not skilled in …
> 15: I think that might be when you ask them …
> 23: Yeah, absolutely but just in looking at it you know, it's sometimes hard to show. In your mind it's clear but it's hard to show what you think.
> 15: I think that's where the chunking sheet comes in. Like if for example you get them to do the chunking sheet and then you collect them and you can say, "what did you mean by this?" and like speak to the group …

12: Would you edit their work on the chunking sheet or would you just sort of take a note and let them continue and then address it when it's all over?
32: I reckon you'd question them, "What happened there?"
Lecturer: And so you might do that as you're walking around and they're making their chunking sheets?
32: You should address it I think, misconceptions as you see them.
(DS2)

The following transcript offers strong examples of not only how Slowmation helped to highlight alternative conceptions for teachers, but also how responding to alternative conceptions can become an important facet of learning to teach about science teaching and learning.

Whole class discussion of slowmation about photosynthesis created by school students
Lecturer: What did you think of that one?
13: I think this one shows a better idea of it than the other one did.
16: We're not supposed to call it 'dark reaction' anymore. …trust me! ... my [school based] supervisor got me for that one.
6: And they shouldn't use that name because of the misconception of dark reaction …
16: Because the students were thinking it only happened at night. So they assumed because of the 'dark reaction' that it only happened at night in the dark ...
Lecturer: What about this bit? H2O splits? Where did they get this idea from? What did you think?
17: It's interesting. Can we see it again?
18: But what would you say when they presented things like this because you wouldn't want to tear them [students] down and they've spent this much time on it you can't exactly say "that's wrong"?
Lecturer: That's a good point, what would you say? ...
6: Could you tell them upfront that in their first run they may have errors because of misconceptions and that you'd like them to draft one and say the work is great but needs extra work on electrons and stuff like that?
Lecturer: Ok so you could give them the opportunity to go away and perhaps take a few extra photos or add something to it you think?

6: Yeah.
16: I was going to say perhaps outline that you would keep your eye out for misconceptions at the start so they know what to expect.
33: Could you pick up on these misconceptions before they do the photos?
Students together: On the chunking sheet.
Lecturer: On their chunking sheet ... you might tell them on their chunking sheet and then what might happen?
Students together: They'll still do it.
Students together: They won't take any notice of it.
33: I was going to say as you're moving around if there is something glaring [out at you] you should be able to see it ... you learn a lot as you do it more [it] is a really good opportunity to look inside kids' heads and see what they understand.
(DS2)

Building on the transcript (above), the following transcript illustrates how, by viewing their students' Slowmations and discussing aspects of the alternative conceptions apparent, that the problematic nature of science teaching emerged for participants which helped to challenge transmissive views of teaching science. In the transcript (below) the preservice teacher comes to understand that simply telling students what they 'should know' does not have the desired effect on students' understanding of a concept. Hence, responding to students' alternative conceptions becomes an important pedagogical challenge that is recognized and accepted in a meaningful way.

Whole class discussion of Slowmation created by school students
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.

Lecturer: The other thing they do is once they feel confident with it, and you tell them something that they don't understand ... they will stick with what they know. So if your explanation is more confusing than what they understand then they won't take it on board.

3: Or what they do is they split their brain into 2 halves; they've got the teacher understanding that they'll regurgitate on a test and they've got what they believe. So they hold 2 models. So they give you what they think you want and then they believe what they want, "This is the truth for me, and this is the stuff that you want me to say."
(DS2)

Discussions derived of these experiences (as per the indicative quotes above) illustrate well that these student teachers viewed Slowmation as much more than an "activity that works" (Appleton, 2002). Seeing beyond "activities that work" is an important shift for student teachers in beginning to better understand the complex nature of teaching for conceptual change. (It also highlights positive ways of working with students' alternative conceptions and begins to address the frustration of attempting to work with students' alternative conceptions as reported by Berry and Milroy earlier in the paper.)

Post Program: Learning about Teaching and Learning of Science

It has been well documented that preservice teachers often reproduce the teaching approaches that they experienced as school students, thus unwittingly maintaining the status quo of school science teaching as the transmission of information. As we argued earlier in this paper, introducing Slowmation through science teacher education programs is one way of positively disturbing preservice teachers' understanding of practice. This view is commensurate with that of Segall (2002), who argued the need to break the cycle of reinforcing the status quo of school teaching and learning.

Superficially, Slowmation can be seen as an innovative teaching approach that engages students (and teachers) in a variety of ways. However, the real issue is about encouraging teachers to recognise, and begin to work with, the range of conceptions that students hold about particular science ideas. In that respect, the preservice teachers in this research project clearly saw their experience of learning and teaching through Slowmation as an educative process – as opposed to the simple acquisition of 'another activity' to add to their 'bag of teaching tricks'. Data from the interviews with volunteers at the end of the program supported the view that Slowmation helped participants in this project to articulate their thinking in a methodical way. As the data in this section illustrates, the importance of chunking for recognising and then responding to students' ideas, and that teachers and students developed explicit awareness of their own thinking in relation to the science concepts under consideration, is clearly apparent.

> Sarah: I think sometimes in science things can be really dry and boring and really theory based and I think slowmation brings out … there's a creativity base to it, students get to use their hands and what not. And I think … well anyway the way I found going about it, doing the chunking sheet I think students got time to clarify their ideas and really think, "ok what is the next step?" and, "what are the important parts of whatever the topic you're learning about?" What are the essentials? What do we need to include? What is not so important? And I think that's … sometimes when you do other teaching strategies or what not I think it's just like 'here's a lot of information, go through it yourself' whatever other strategies are used, but I think, yeah, slowmation really allowed them to clarify their ideas …
> (DS3)
> Interviewer: Was there anything you learnt about teaching using Slowmation?
> Sharon: Ah teaching, I found that 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 so I was just kind of a guide walking around the classroom rather than someone up the front continually talking to these students. So I learnt that.
> (DS3)

Helping preservice science teachers look into their teaching and their students' learning in new ways was facilitated by the ways in which the elements of constructing a Slowmation worked together to highlight different aspects of the content/topic under consideration. The science student teachers used the chunking sheets as a way of opening up a discussion about alternative conceptions.

> Interviewer: Tell me how you used the chunking sheets?
> Sharon: Ah we used the chunking sheets at the start so we got all the students in groups and they chose their topics and from that topic each group had to come up with a chunking sheet. I collected their chunking sheets at the end of that lesson, had a look over them and just highlighted some areas where they might need to go back, just to try to avoid the misconceptions that they might put into

> their slowmations, and then we spent another 20 minutes where the students went back, looked at my corrections and then changed some of the stuff that they were going to produce in their slowmations and then I had a look at that again and then they went off and completed their slowmations
> (DS3)
> Interviewer: So you found the chunking sheets really important?
> Sarah: It [chunking sheet] points out if there are any misconceptions cos 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 speak to them you know highlight and say, "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 to add 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.
> (DS3)

These preservice teachers used Slowmation in ways that suited their teaching contexts. Just as experienced teachers often use their professional judgement to unpack a teaching procedure and then adjust and adapt it to suit their needs, so too these preservice teachers were able to work with Slowmation in ways that demonstrated their ability to move beyond the procedure as a 'recipe' or interpret it as 'one right way' of using Slowmation.

> Sarah: I decided that I'd use slowmation to pull it all together in a way because they had all these separate ideas of how, you know 'this is light' and 'this is sound' and I wanted to sort of pull the processes together, they're all different forms of energy and what not and they didn't have those connections so I started off doing the chunking sheet and I thought that was one of the most valuable tools. … I took up their chunking sheets and I put them into groups of what sort of processes they did. So like say 4 or 5 of them did echoes so I said, "Ok you guys do echoes together and work it out and do a new chunking sheet." So they then had another group chunking sheet and they went and made their movies and they really enjoyed it. A few groups actually changed their

> chunking sheet when they made them[their movie]. They said, "Oh, you know, we haven't included this step" or, "this wasn't included" or, "it's really important to include this part." And that lasted 2 other periods and then the next one when we put it all together on the computer.
> (DS3)

As the data demonstrates, by paying careful attention to alternative conceptions these preservice teachers recognized the value of Slowmation in offering insights into the relationship between teaching and learning in new ways. Their focus shifted from the delivery of information to that which students brought with them to the classroom (prior knowledge) and the ways in which they interpreted the science content under consideration.

> Interviewer: You said earlier that you thought that Slowmation makes the students think.
> Enid: Yes. It's that whole breaking down the concept idea because it's easy enough for them to rattle off a definition or say, "step 1: you do this, step 2: you do this" but to actually have them show you and show how it happens then it's really easy for them to show it or it might be really hard depending on their knowledge and then you can see where they need to improve or where your teaching has a flaw or something like that.
> (DS3)

As these preservice teachers reflected on their use of slowmation, their learning about students' alternative conceptions became a major shaping force in their learning about teaching.

> Interviewer: So with the Slowmation movies when they presented, did they talk to their movies?
> Sharon: We [class] watched them throughout and then another time they stopped and actually explained what was going on in the parts of the movie just because they kind of had a little one about pulleys and it was a whole little story about a car being crashed into a tree and the pulley coming along but then actually to get more of the science side of it we watched it once throughout which the kids really liked and then we watched it together and they started pausing it and saying, "This is what a pulley does and how it works" and I think that way I got to see [their thinking] because they were speaking orally I got to

> see how much they knew and we got each member of the groups to speak as they were doing it because sometimes they're making it but you don't actually know if what [they're thinking], but when they produce it you can see the misconceptions but actually getting them to speak about it. So I could actually see where the misconceptions actually lay and who had the misconceptions in the group and if the whole group thought that or just one student ...
> (DS3)

As the data (above) illustrates, preservice teachers and their students found Slowmation to be a new and different way of learning about science in line with Hoban's (2005) original claims. However, as the present study illustrates, when the focus of Slowmation moves beyond a view of 'an activity that works', the participants' learning through the Slowmation process dramatically impacts the ways in which they are able to recognize, respond and work with students' alternative conceptions in productive ways.

Conclusion

It has been well recognized in the literature that teaching for conceptual change is an important component in quality learning in school science (Scott, et al., 2007). Therefore ensuring that teaching for conceptual change becomes an integral aspect of science teachers' practice is crucial if genuine change in school science is to occur (Mortimer & Scott, 2003). It stands to reason then that a beginning point for such change is teacher education. By purposefully addressing understandings of, and approaches to, teaching for conceptual change in science teacher education programs, the likelihood of challenging the status quo of school science teaching becomes a real possibility.

As the extensive elaboration of the theoretical framework underpinning Slowmation described by Hoban et al. (2011) makes clear, the semiotic system that underpins the representational influence on learning central to the pedagogical power of Slowmation offers a clear breakthrough in teaching for conceptual change. Hoban et al. described those underpinnings as being important because:

> ... each representation [is] a semiotic system ... making meaning (the interpretant) as they made decisions about which modes to use (the representation), as well as thinking about how to integrate them to best explain ... the referent. Furthermore, the final semiotic system is a multimodal

> digital animation that the preservice teachers designed by aligning the modes of slow moving images, still images, text, and narration to complement each other ... Another feature of the making process that distinguishes it ... is that the creation process involves the preservice teachers in ''translating'' ... the content five times through a progression of representations. This sequence of interrelated semiotic systems, involving a transfer of meaning from one representation to the next culminating in the final narrated animation, we call a semiotic progression. [Importantly], this progression of meaning is not strictly linear, because in the construction of each representation, there [is] a good deal of recursive checking of information ... with previous representations ... [Therefore], each representation [has] a role or affordance that focuses the preservice teachers' thinking about the concept in a particular way. ... the affordance of the final representation is that the preservice teachers use technology to integrate the four modes of writing, moving, and still images and narration. Constructing each representation therefore allows the preservice teachers to revisit the content for different purposes ... [and in] creating a slowmation to explain a science concept produces a digital artifact that can be shown publicly, which may illuminate ... alternative conceptions and in so doing, the conception may be modified in light of discussion or further research. (Hoban, et al., 2011, pp. 1001 - 1003)

Genuinely teaching for conceptual change in teacher education requires preservice teachers to not only be aware that students carry conceptions that influence their learning of science ideas (i.e., move beyond a 'nod' to the research literature), but to be better equipped to pursue approaches to responding to the situation in their own practice. Therefore, at the very least, student teachers need meaningful opportunities to see such conceptions in themselves, and in their students, in order to seriously consider taking that knowledge into account in their own teaching – something that has been called for in the literature for a long time (see for example, the extensive research based claims of, Wandersee, Mintzes, & Novak, 1994).

Through the learning about teaching for conceptual change made possible through the theoretical framing of Slowmation (briefly revisited above), real opportunities for impact on preservice teachers' practice becomes possible. As Hoban et al. (2011) have argued, and the data in this project illustrates, through Slowmation (as a process of representation), student teachers not only recognize, but also begin to respond to learners' alternative conceptions. Through the four distinct phases of making a Slowmation, teachers are given different ways and different times of seeing into learners' alternative conceptions which creates multiple opportunities for pedagogical responses.

This research highlights how, in teacher education, there is great value in sensitising student teachers to their own and their students' science conceptions through Slowmation. In so doing, teacher education can make real gains in helping science teachers teach for conceptual change in meaningful ways.

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