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Learning Science through Creating a 'Slowmation': A case study of preservice primary teachers

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Learning Science through Creating a 'Slowmation': A case study of preservice primary teachers

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Many preservice primary teachers have inadequate science knowledge, which often limits their confidence in implementing the subject. This paper proposes a new way for preservice teachers to learn science by designing and making a narrated stop-motion animation as an instructional resource to explain a science concept. In this paper, a simplified way for preservice teachers to design and make an animation called 'slowmation' (abbreviated from 'slow animation') is exemplified. A case study of three preservice primary teachers creating one from start to finish over 2 h was conducted to address the following research question: How do the preservice primary teachers create a slowmation and how does this process influence their science learning? The method of inquiry used a case study design involving pre- and post-individual interviews in conjunction with a discourse analysis of video and audio data recorded as they created a slowmation. The data illustrate how the preservice teachers' science learning was related to their prior knowledge and how they iteratively revisited the content through the construction of five representations as a *cumulative semiotic progression*: (i) research notes; (ii) storyboard; (iii) models; (iv) digital photographs; culminating in (v) the narrated animation. This progression enabled the preservice teachers to revisit the content in each representation and make decisions about which modes to use and promoted social interaction. Creating a slowmation facilitated the preservice teachers' learning about the life cycle of a ladybird beetle and revised their alternative conceptions.

Keywords: *Slowmation; Technology; Animation; Semiotics; Multimodal representation; Conceptual change*

One reason for the lack of science teaching in primary schools is that teachers often have limited content knowledge, which decreases their confidence in implementing

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the subject (Bennett, 2001; Davis, Petish, & Smithey, 2006; Lee, Wu, & Tsai, 2009; National Academy of Sciences, 2006; Tytler, 2008). For example, some primary teachers have difficulty in understanding scientific concepts such as day and night (Atwood & Atwood, 1997), phases of the moon (Trundle, Atwood, & Christopher, 2002), the water cycle (Stoddart, Connell, Stofflett, & Peck, 1993) and energy (Trumper, Raviolo, & Shnersch, 2000). One way to address this problem is to engage preservice primary teachers in experiencing new ways of representing science knowledge during their teacher preparation programmes.

Using technology that is readily accessible can sometimes be a catalyst for such engagement, especially if the tools help preservice teachers to represent their knowledge in innovative ways (Kim & Reeves, 2007; Lee, Linn, Varma, & Liu, 2010). According to Prain (2006), 'student manipulation of computer-generated texts, where students integrate imagery, sound, mathematical symbols, diagrams, and writing, alters the role of written language as the major or dominant medium of learning' (p. 180). In particular, getting preservice primary teachers to design educational resources to explain science content may help them to develop personal knowledge (Gamache, 2002). According to Jonassen, Myers, and McKillop (1996), when students design technology-based resources to explain content, 'they reflect on that knowledge in new and meaningful ways' (p. 95). With the rapid advancement in personal digital technologies, it is becoming easier for students such as preservice teachers to design media products such as animations and videos, which may be a way to support their conceptual understanding of science concepts that are typical in the primary school curriculum.

Learners as Animation Designers in Science Education

Many studies have involved animations made by experts to assist students in learning science concepts (Clark & Jorde, 2004; Metcalf, Krajcik, & Soloway, 2000; Roschelle, Kaput, & Stroup, 2000; Sadler, Gould, Brecher, & Hoffman, 2000; Schank & Kozma, 2002; Soloway et al., 1997; Stieff & Wilensky, 2003; Wilder & Brinkerhoff, 2007). However, studies researching the value of these animations for learning have produced mixed results. For example, some studies have shown that watching animations to explain science concepts has improved the knowledge of high school students (Marbach-Ad, Rotbain, & Stavy, 2008) and college students (Williamson & Abraham, 1995), especially with regard to learning about challenging concepts such as molecular genetics and chemistry. In contrast, other studies have found that there has been little improvement in learning when students watch animations that explain science concepts (Sanger & Greenbowe, 2000; Yang, Andre, Greenbowe, & Tibell, 2003). The mixed value of animations for learning has been confirmed by three reviews of literature involving over 80 studies on the relationship between students' learning and viewing expert-generated animations (Berney & Betrancourt, 2009; Sperling, Seyedmonir, Aleksic, & Meadows, 2003; Tvertsky, Morrison, & Betrancourt, 2002).

It is possible, however, that animations could provide a motivation for engaging with content if learners became the designers and creators rather than consumers of information as in expert-generated animations (Chan & Black, 2005). However, the possibilities for learners to design and create their own animations have been limited because the process is usually too complex and time consuming and requires sophisticated software. However, a few studies in which the software has been specially designed to enable learners to manipulate computer-generated images to produce animations have been conducted. For example, a software program called *Chemsense* was designed to enable high school students to construct their own representations of molecular level animations in chemical systems by viewing, manipulating and interpreting visualisations in chemistry (Schank & Kozma, 2002; Stieff & Wilensky, 2003; Wilder & Brinkerhoff, 2007; Wu, Krajcik, & Soloway, 2001). More recently, a software program called *Chemation* has been specially designed to enable school students to create animations about the particulate nature of matter and to document their explanations (Chang, Quintana, & Krajcik, 2010). The pre- and post-test results obtained from working with seventh-grade students ($N = 271$) revealed that there was a significant effect on the students' learning, especially if they also peer-evaluated the animations produced. In a third study, 12 computer science undergraduates used another specially designed program, *Carousel*, to animate three different algorithms involving text, pictures, video, animations and speech, which could also be shared with other students on a website (Hubscher-Younger & Hari Narayanan, 2008). Although the number of research studies on student-generated animations is small, each of these studies noted the educational value of students creating their own animations to learn concepts. These programs, however, are limited to the topic that is the focus of the specially designed software. It seems reasonable to suggest, therefore, that an easier way to make animations would enable students to engage with science content through the process of making them.

Slowmation: A Simplified Way of Making Stop-motion Animations

Because of advances in the capacity of personal digital technologies, it is becoming easier for preservice teachers to make their own animations as representations to explain science knowledge. But even with access to this new technology, making an animated mini-movie to explain a science concept could be difficult for preservice teachers because science models do not move by themselves unless they are motorised. However, making a movie using a traditional stop-motion animation technique is feasible, because it is the creator who manually moves the objects while taking each digital still photograph, thus eliminating the need for complex mechanisms to provide movement. Having preservice teachers take digital still photos one by one, instead of a continuous 25–30 frames per second as in video, also allows them to check, manipulate, think about, discuss and reconfigure the models with each movement and photograph (Hoban & Nielsen, 2011). Yore and Hand (2010) contend that getting students to make stop-motion animations is a good way for teachers to introduce content as 'students take a series of still photographs and produce a time-series or time-lapse collection or a flipbook to illustrate relative motion' (p. 99).

'Slowmation' (abbreviated from 'slow animation') is a simplified way for preservice teachers to make a narrated stop-motion animation that is played slowly at two frames per second as an instructional resource to explain a science concept (Hoban, 2005, 2007, 2009). Preservice teachers can learn the process in 1–2 h, creating models made out of everyday materials such as Plasticine, cardboard and paper, or use existing plastic models and take digital still photos as the models are moved manually. The creation process integrates features of clay animation, object animation and digital storytelling and involves the preservice teachers in designing a sequence of representations (Hoban & Nielsen, 2010): (i) research notes; (ii) storyboard; (iii) models; (iv) digital photographs and (v) the narrated animation. In short, a slowmation displays the following features:

- *purpose*—the intention is for preservice teachers to engage with science content by making a narrated stop-motion animation as an instructional resource to explain it; the design can include a range of enhancements to assist in the explanation such as narration, music, photos, diagrams, 2-D and 3-D models, labels, static images, repetitions and characters;
- *timing*—slowmations are usually played slowly at 2 frames per second, not at the usual animation speed of 20–24 frames per second, and thus need 10 times fewer photos than required in clay or computer animation, hence the name 'slow animation' or 'slowmation'; this slow speed enables the designers to narrate the slow-moving images to explain the science;
- *orientation*—models are made in 2-D and/or 3-D and usually manipulated in the horizontal plane (lying flat on the floor or on a table) and photographed with a digital still camera mounted on a tripod looking down or across at the models or by a hand-held mobile phone, which makes them easier to make, move and photograph;
- *materials*—because models are usually made flat on a table and do not have to stand up, many different materials can be used such as soft play-dough, Plasticine, 2-D pictures, drawings, written text, existing 3-D models, felt, cardboard cut-outs or natural materials and
- *technology*—students use their own digital still cameras or mobile phone camera (with photo quality set on low resolution) and free movie-making software available on their computers (e.g. iMovie or Stop-Action Motion (SAM) Animation on a Mac or Windows Movie Maker on a PC).

In summary, slowmation greatly simplifies the process of creating a stop-motion animation by enabling preservice teachers to (i) make or use existing 2-D or 3-D models that may lie flat on a table or the floor; (ii) play the animation slowly at 2 frames per second requiring 10 times fewer photos than required in normal animation and (iii) use widely available technology such as a digital still camera, a tripod and free movie-making computer software. While previous research on learner-generated animations has identified their value for learning (Chang et al., 2010; Hubscher-Younger

& Hari Narayanan, 2008; Schank & Kozma, 2002), the research field could benefit from investigating whether making this simplified form of animation influences learning. The purpose of the present paper, therefore, is to study how creating a slowmation influences the science learning of preservice primary teachers to address the following research question:

> How do the preservice primary teachers create a slowmation and how does this process influence their science learning?

While most research studies on animations have used either cognitive or situative theories as their focus (Russell & Kozma, 2007), our theoretical framework for this study draws on a language-based theory—semiotics—because it focuses on the representations or artefacts produced from the construction process to help explain learning.

Theoretical Framework

Since making a slowmation involves preservice teachers designing and making a sequence of language-based representations using modes such as writing, sketches, models, images and voice, a suitable theoretical framework is semiotics—the study of signs or representations and their relationship to meaning-making. In semiotics, a sign is something that stands for something else, such as the sign K stands for potassium in the periodic table. Peirce (1931/1955) was one of the pioneers in the field and identified three terms that help explain how meaning is made when a sign represents an object: (i) a 'referent' or 'object' is what is being represented; (ii) the sign created is called a 'representamen' and (iii) the meaning generated from the sign is called an 'interpretant'. He explained the relationship between the three terms that act as a triad as follows:

> A sign, or *representamen*, is something which stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign, or perhaps a more developed sign. That sign which it creates I call the *interpretant* of the first sign. The sign stands for something, its *object*. . . . that is to have a like content. (Peirce, 1931/1955, pp. 99–100) [italics in original]

Lemke (1998) also explained how a representation is a semiotic system involving the interplay of three influences, especially when learners use a range of modalities. Both Peirce's (1931/1955) and Lemke's explanations of a semiotic system, however, refer to a representation that has been constructed by experts for learners to interpret and thus make meaning.

Recently, the terms in Peirce's semiotic triad were interpreted for science education by Jamani (2011), who called the 'representamen' a 'representation', the 'referent' the 'science content' and 'interpretant' the 'meaning made'. As Peirce explained, these three influences on meaning-making—the referent, the representation and interpretant—do not act independently, but instead form an interrelated whole as a semiotic system. Previous studies have also revealed that understanding may be enhanced when learners are exposed to more than one representation of the same concept (Donovan & Bransford, 2005; Norman, 2005; Prain & Waldrip, 2006). Learners have additional opportunities to engage with content if they design multiple representations using single or multiple modes (Hand, Gunel, & Ulu, 2009; Kress, 2010; Lemke, 2000; Prain, 2006). According to Yore and Hand (2010), 'the transformation among multimodal representations has the greatest potential in promoting learning and depth of processing' (p. 96). A feature of slowmation is that it is the learners who are designing and making multiple representations of the same concept that culminate in the final representation, which is multimodal.

With any learner-generated representation, however, there exists the possibility that the content could be misrepresented or misinterpreted because the learners may hold intuitive conceptions (Babai, Sekal, & Stavy, 2010), alternate conceptions (Sequira & Leite, 1991; Trumper, 2001) or misconceptions (Driver & Erickson, 1983; Gilbert & Watts, 1983). Such alternative conceptions are often deeply held and highly resilient (Cobern, 1996; Driver, 1983; Howes, 2002; White & Gunstone, 1989). According to Tytler and Prain (2010), conceptual change can be supported when learners negotiate meaning through creating representations as 'conceptual change strategies have long advocated opportunities for students to engage with, explore and negotiate ideas. … This representational focus offers the possibility of a more active and engaging approach to teaching and learning' (p. 2075).

Our goal in this study, therefore, is to research whether preservice primary teachers learn science through creating a sequence or progression of representations that results in a slowmation. Previous research has labelled this process as a *semiotic progression* (Hoban, Loughran, & Nielsen, 2011); however, no previous study has documented the actual science learning during the creation process. It is possible that slowmation requires preservice teachers to develop a sequence of representations of a science concept and thus provides multiple opportunities for them to confront their own prior conceptions and possibly develop more intelligible, plausible and fruitful conceptions (Duit & Treagust, 2003; Hewson, Beeth, & Thorley, 1998; Posner, Strike, Hewson, & Gertzog, 1982).

Methods

Participants and Data Collection

This study was conducted in November 2009 and used a case study design (Merriam, 1998; Stake, 1995; Yin, 2003) to map the learning of three preservice teachers as they created a slowmation over a time period of 2 h. We base our study in a social constructivist paradigm (Cobb, 1994; Johnson & Gott, 1996; Mintzes, Wandersee, & Novak, 1998), where we assume that social interaction between learners involves conversation that may both reveal and develop conceptual understanding. We used this framework to guide data collection, analysis and interpretation. The preservice teachers were allocated a topic, 'Life Cycle of a Ladybird Beetle', at the beginning of the study, a topic about which they had no prior knowledge. We chose this topic because insect metamorphosis is a common curriculum topic in primary schools and, hence, represents science knowledge that primary teachers should understand. Furthermore, the study offered a chance to perhaps challenge the preservice teachers' prior conceptions, since the case students had already completed their mandatory science methods subject and, thus, had encountered all the science content that they would as part of their teacher education programme.

Our case students, who were in the third year of their Bachelor of Primary Education programme, were given the task of creating a slowmation as an explanatory resource for primary school children. We used a range of qualitative methods to study the creation process. As soon as the preservice teachers were allocated the topic, individual interviews were conducted to ascertain their prior knowledge. In addition to being asked about their science backgrounds, they were each asked to reflect on their own knowledge of the ladybird life cycle, through questions such as What do you know about the topic? Where will you look for information? How will you learn about the topic? Additional probing questions sought elaboration of aspects of their background knowledge.

During the actual slowmation construction process, which took 2 h, the preservice teachers as a case group were video- and audio-recorded. Artefacts that they produced were also collected as data (e.g. notes, storyboard, models, photos and the narrated animation). The three preservice teachers who volunteered for the study, Jackie (J), Elettra (E) and Alyce (A), were audio- and video-recorded as they talked aloud during the construction of their slowmation from start to finish on the allocated topic. Immediately after the animation construction was completed, the preservice teachers were again interviewed individually about how their knowledge had changed, through questions such as What did you learn that was new? What was helpful to you for your learning? Were you surprised by anything? Thus, through the interviews, the preservice teachers were asked to reflect on what they knew (pre-interview) and what had changed (post-slowmation construction). The research period was 3 h including the time for pre- and post-data collection. The audio-record was transcribed verbatim and annotated with video data.

It should be noted that there was some previous preparation for the case study: (i) the three primary preservice teachers were in the third year of their programme and had previously made a slowmation in their first-year science methods course, so they were familiar with the creation process and use of the technology and (ii) a week before the study, the preservice teachers completed a 1-h workshop in which they were encouraged to 'think aloud' and articulate their thinking as they made a slowmation on a different topic. Furthermore, in order for the case study to finish within 3 h (including the pre- and post-interviews), the preservice teachers were given a plastic model set of the four stages in the life cycle of a ladybird beetle, but no other information was provided. Construction materials, such as assorted colours of Plasticine and construction paper, were provided in order to make any other models that they thought to be necessary.

Data Analysis

The goal of this research was to examine how the process of making a slowmation influences the preservice teachers' science learning. We scanned the interview data about the preservice teachers' background knowledge of the life cycle of the ladybird beetle, which alerted us to areas of possible conceptual development *as identified by the preservice teachers.* The preservice teachers made reference to details of the life cycle, including colour changes, and the role of aphids as a food source for the ladybirds in the pre-interview.

To analyse possible changes to the preservice teachers' conceptual understandings during the process of slowmation construction, we adapted a discourse analysis framework developed by Simon, Naylor, Keogh, Maloney, and Downing (2008), whose coding system identified different types of utterances when a teaching resource (in their case, puppets) was used in a primary school science lesson to promote discussion. Simon et al.'s (2008) coding scheme was developed inductively through a process of open coding to capture the types of utterances generated when teachers encourage discussions among students about science concepts using the puppets as a resource. In the current study, we were also interested in the type of discussion generated as a result of the preservice teachers constructing a teaching resource as well as any evidence of conceptual change, including argumentation and reasoning. Although Simon et al.'s scheme did include one code for 'argumentation', we replaced this with three more specific categories suggested by Toulmin (1958) (proposition, backing and claim) to be consistent with the definitions used by Furtak, Hardy, Beinbrech, Shavelson, and Shemwell (2010). Furtak et al. were interested in school students' reasoning at a conceptual level, and in another work, conceptual discussions where student thinking developed were examined (Shemwell & Furtak, 2010). Thus, while our work focuses on preservice teachers, we are likewise interested in how discussions during the slowmation creation process indicate thinking and possibly learning. We also omitted Simon et al.'s category of 'story and character' as it did not apply to the current study. The modified analytical framework based on the work of Simon et al. (2008) and Furtak et al. (2010) is presented in Table 1.

Inter-rater Reliability

Following advice from Miles and Huberman (1994), we conducted a 'checkcode' on the 100+ page transcript of discussion during the 2-h construction process that served the dual purpose of refining the working definitions and testing the reliability of the coding system. Together, we identified all transcript sections that made specific reference to life cycle details, colour changes and the role of aphids. The 'aphid' data represented approximately 10% of the whole transcript. We independently coded these data, using the adapted analytical framework of Simon et al. (2008).

By reviewing our coded data together, we realised inconsistencies in the respective unit for coding we had each used. Once we clarified this through discussion, we achieved 73% intercoder reliability for our first attempt at using a coding scheme,

Table 1. Discourse analysis framework

Type	Code definition	Code	Example
Reasoned question	Question that presents a problem or requires a reasoned answer	Q	J: What's an aphid, did we say that?
Non-reasoned question/statement	Question or statement that does not require a reasoned answer. Closed, rhetorical or non-science questions	N	A: Do we feel like we have a good idea now?
Language	Features of language: focus on the use or meaning of words rather than on ideas and concepts, for example, correcting grammar or clarifying vocabulary	L	E: Emergence, that was the word I was thinking of
Feedback	Offers a response to someone else's comment on some aspect of the content	F	E: yes, near aphids
Encouragement	Offers praise or positive endorsement at a social level	E	A: Oh, good idea
Recall	Recalls information from memory or accesses previously learned knowledge	R	J: I said in my interview that they eat plants
Observation	Describes something in the classroom. Reads from worksheet or the board	O	J: The storyboard says lays eggs next to aphids
Procedure	Gives information or instruction or discusses things that relate to the order or procedure to be followed	P	J: This part could be the head part and these could be legs
Proposition	Tentative statement that needs clarification or evidence	PR	E: I think the larvae might come out of the egg
Backing	Supporting statement in the form of data, information, evidence or a rule. It could be reading from the internet or from a book to explain or clarify a relationship in the data to support a claim	B	A: It says here they change colour because its wet
Knowledge claim	An assertion/insight/conclusion about what exists. This includes either what something will do in the future (prediction/presumption) or what is happening in the present or past (conclusion or outcome)	C	E: See the wings dry, I knew that happened, the wings' casing dries out

which is within the expected value suggested by Miles and Huberman (1994) for a first attempt at using a coding scheme. We then tallied our disagreements, identifying which codes had been assigned by each of the two raters. We reviewed each disagreement, discussing our respective interpretations of the code definitions and refining the definition for each code. As noted in other research, we likewise experienced difficulty in distinguishing between Toulmin's (1958) categories such as backing, claim and proposition (Furtak et al., 2010; Sampson & Clark, 2008). So, while we added detail to our coding scheme by replacing Simon et al.'s (2008) 'argumentation' code with three of Toulmin's categories, this resulted in a need to retest our interpretations and revise definitions over two more cycles. By coding a different portion of data together, we had further discussions to refine the overall process of analysis and produced an intercoder reliability of 90%. The entire transcript was subsequently coded using the adapted coding scheme given in Table 1.

Results

This section is presented in three parts to address the research question. First, we present data concerning the preservice teachers' prior knowledge about the allocated topic of the ladybird beetle life cycle. Second, data are presented to explain the process of the preservice teachers creating a slowmation based on each of the representations created. For each representation, a discourse analysis identifies the type of utterances fostered from creating the representations. The section concludes with data from individual interviews collected after the slowmation construction to show if learning occurred and if any alternate conceptions changed.

Individual Interview Data before Animation Construction

The three case students in this study, Elettra, Jackie and Alyce, were interviewed individually immediately following the allocation of the topic and before the commencement of the slowmation construction. During the interviews, we probed the preservice teachers' backgrounds as science students and their prior conceptions about the life cycle of ladybird beetles. Jackie revealed a positive attitude towards science, having enjoyed studying biology in her final two years of high school, but she felt that she needed to improve her background knowledge in order to effectively teach science in a primary school classroom. She described her attitude towards science as positive but felt that she lacked content knowledge about particular topics and so 'when I do have to teach a topic, I know that I will have to go away and research it all'. Elettra had also studied science through high school including biology in her final two years. She described her attitude as 'quite positive, I enjoy it. I think that it's great for children to do because it is fun and they're constantly learning'. Alyce, however, had only studied science up to grade 10 and did not continue with the subject in her final two years of high school because she did not like the subject at school. However, she changed her attitude after completing the compulsory science methods course in the first year of her BEd degree as she was interested and scored high marks and 'found it interesting and primary science is a lot different to high school science because I tend to look at it very differently'.

Data from the individual interviews revealed that none of the three preservice teachers could explain the ladybird beetle life cycle in any detail. Jackie did know that adult ladybird beetles could be of different colours such as red, yellow and orange and that they lived under bark and leaves, but she knew very little about the life cycle stages, 'I don't know anything about the life cycle at all, I'm wondering if they start off as lav [*sic*], I can't even say the word. . . . I only know about them when they're a fully fledged ladybird'. Similarly, Alyce realised that adults can be of different colours such as red, yellow and orange, but she knew 'very little about the ladybird life cycle. I know the colour of the ladybeetle [laughing]. I don't think I know anything. I can guess that maybe they lay eggs, but that could be wrong'. She also noted that the ladybird beetles fly with wings, mate in spring and live on plants and flowers but did not know about the life cycle stages. Consistent with the other two preservice teachers, Elettra also could not explain the ladybird beetle life cycle stating that 'I don't even know if they come from eggs, I can't remember . . . . I'm pretty sure they have wings, something about they come out of something and then their wings dry but I don't know what they come out of'. She was unsure if ladybirds came from eggs or not, but she knew that they had wings and were yellow at one stage and then changed to red. She could not recall the name of any phases of the life cycle or how often they occur stating that 'I don't really know anything'. She did recall that adults have wings with flaps to protect them and that ladybird beetles were insects with six legs and an exoskeleton, perhaps drawing upon her background knowledge from high school biology.

An interesting point revealed in the individual interviews is that two of the preservice teachers held alternative conceptions concerning what ladybird beetles eat. Jackie expressed an alternative conception that ladybirds were similar to caterpillars in eating leaves, 'they possibly eat leaves I think, like caterpillars walking along a leaf and munching little holes'. Alyce, held a similar alternative conception: 'I think they eat plants but I don't know what sort of plants. . . . yeah, they eat leaves'. Elettra, however, did not mention an alternative conception and revealed later that she did not know what ladybirds ate and so made no comment in the pre-interview.

To explain how making a slowmation influenced the preservice teachers' learning, the next section presents a discourse analysis of their discussions during the construction of each representation. Using the categories given in Table 1, we present excerpts of data and analysis collected during the construction of each representation selected from the 100-page audio transcript of the 2-h slowmation construction. We analysed three main threads of conceptual development during the slowmation creation process: (i) ideas about the life cycle stages; (ii) what ladybirds ate as a food source and (iii) colour change during the life cycle. Aphids as ladybird food were chosen as the focus for data presentation in this paper because the role of aphids was a recurring topic in each of the five representations created by our preservice teachers and both Jackie and Alyce had expressed an alternative conception about what ladybirds eat.

Discourse Analysis of Discussion about Aphids during Animation Construction

As mentioned previously, it is recommended that preservice teachers design and make five representations when creating a slowmation: (i) research notes; (ii) storyboard; (iii) models; (iv) digital still photos and (v) the narrated animation. A discourse analysis of the utterances during the construction of each representation is now presented.

Representation 1

As soon as the individual interviews concluded, the three preservice teachers sat around a table with their laptops open and began creating the first representation of 'research notes' about the ladybird beetle life cycle. They sought information from two sources. First, each did a Google search on the topic from which notes were taken, which included reading a Wikipedia site. Second, the preservice teachers viewed a YouTube video about the life cycle of the ladybird beetle. Below, we present a discourse analysis of their discussion regarding aphids as a food source for ladybird beetles, which shows that the preservice teachers exchanged a variety of utterances in making the first representation of research notes:

Jackie:	What's an aphid, did we say that? (Q)
Alyce:	An aphid. It's like a little green guy that ... eats ... I don't know much about them but I know that they eat rose leaves and stuff, roses I think because people that grow roses don't like them. (R)
Jackie:	OK. (E)
Alyce:	Oh, and they eat aphids. (E)
Jackie:	Yeah, so that's why she lays her eggs there ... 'the female lays the cluster of eggs near an aphid colony'. [reading from Wikipedia] (B)
Elettra:	Near aphids (F)
Alyce:	So what happens to the egg ... it turns into? (Q)
Jackie:	The eggs just stay there until the larva comes out and then the larva eats the aphids that are nearby. (C)
Elettra:	Sorry, aphids are plants aren't they? Some sort of flower? What's an aphid? (Q)
Alyce:	It's like a little ... yeah, we need more information than what I'm saying about aphids. (N)
Jackie:	Are you saying it's an animal or a plant? (Q)
Alyce:	No, it's a little bug. (F)
Elettra:	'Plant-lice ... aphids are plant lice ... small plant-like eating insects, members of the superfamily Aphidoidea. Aphids are among the most destructive insects pests on cultivated plants in temperate regions'. [reading from Wikipedia] (B)
Elettra:	So they're plant lice, aphids are plant lice. (C)
Elettra:	So basically it says, 'also known as plant lice .... Small plant-eating insects, members of the super family Aphidoidea. Aphids are destructive insect pests on cultivated plants in temperate regions. The damage they do to the plants have made them enemies of farmers and gardeners. There are 4400 species and ten families known'. OK, so aphids are those little bugs, they look like that. [reads and points to Wikipedia] (B)
Jackie:	OK, and that's what larvae eats. (C)
Alyce:	That's a really good picture, yeah. (F)
Elettra:	Yeah, and so the female lays her eggs near a cluster of them. (C)

Given the students' limited prior knowledge about ladybird beetles, it is not surprising that most of the discourse involved social interaction where they asked questions and then sought answers using information from the internet as backing. This included four reasoned questions (Q), three examples of feedback (F), three examples of backing (B) and two knowledge claims (C) (larvae come out of eggs and they eat aphids). For example, Jackie's initial question 'What's an aphid, did we say that?' draws the attention of the other two, who are also viewing websites about ladybird beetle life cycles. In response to this, Elettra asks if an aphid is a flower and reads from Wikipedia that aphids are 'small plant-eating insects'. In summary, the preservice teachers generated a half page of notes for the first representation containing nine points that summarised key information about the ladybird life cycle. Of particular interest is the fourth point written in the notes by Elettra: 'larvae eats aphids—as larvae grows rapidly it sheds its skin several times'. It might be assumed that this statement also clarified Alyce and Jackie's alternative conception concerning what ladybirds eat, but as we shall see, this was not the case. The first representation, generated in the form of nine points in a half page of notes, was then used to guide the construction of the next representation.

Representation 2

Elettra used the research notes to create the second representation of a 'storyboard' by splitting the nine dot points into six sketches adding labels to represent the different life cycle stages. The labels for the six sketches were as follows: (i) mating in spring; (ii) laying eggs next to aphids; (iii) larvae crawl out of eggs and eat aphids; (iv) larvae attach to plant stem, shed final skin and pupa comes out 1 week later; (v) emergence from pupa as an adult, yellow with no spots, 24 h later wings dry, and changes colour and (vi) colour develops over 24 h, red with black spots, eats aphids and other small insects, looking for a mate straight away. In creating the storyboard, the preservice teachers checked the content they had previously documented by reading their research notes, the Wikipedia site describing Ladybird Beetles and the YouTube video they watched. As such, the storyboard was a plan to re-represent the content they had accessed on the internet by reading text, looking at still photos and a video:

Jackie: All right, so we'll just have the first slide is going to be about the mating in the spring and then summer. Okay. (P)
Elettra: Okay, so starting off with that, then the next one. [Elettra draws first sketch] (P)
Jackie: Yeah, the next sequence would be laying the eggs. (P)
Elettra: What do they lay them on? (Q)
Elettra: It says near aphids. [reading from Wikipedia] (B)
Jackie: Well it'd be near the aphid colony, so I guess it would be on some part of the plant. (PR)
Elettra: Yeah. (E)
Elettra: So, but they show the aphids on a stem, didn't they? (Q)
Jackie: All right, so put them maybe like right near the stem . . . it'd be where they join. (P)
Elettra: There's the little aphids. (P)
Jackie: Yeah, so we can draw a little plant stem if you want and have the ladybird just come hatch the eggs there, yep. (P)
Elettra: Okay. (E) [Elettra draws second sketch]
Jackie: Beautiful. (E)

Elettra: So laying eggs next to aphids. Then, the eggs hatch. (P)
Jackie: Yep, into the larva. So we can just kind of have this larva crawling out of the eggs and then the eggs disappear. (P) [Jackie manipulates the model]
Elettra: Larva crawls out of the eggs. Off . . . no and the eggs. (P) [Elettra draws third sketch]
Elettra: Is the larva going to crawl off the screen? (Q)
Elettra: No, because it eats . . . (F)
Jackie: It eats the aphids. (C)
Elettra: 'out of egg . . .' So we might have to make some. [Elettra writes third label]
Jackie: So well we can just have him sitting on the leaf eating the aphids and then during them we say, 'Oh you know it eats aphids for three weeks. It grows rapidly and then it sheds its skin several times'. (P)

The discourse analysis about aphids while creating the storyboard shows that the utterances consisted of seven procedures (P), two reasoned questions (Q), one backing (B), one proposition (PR) and one claim (C). It is not surprising that the predominant utterance was procedures as the preservice teachers needed to make decisions about planning the animation as they translated their research notes into a sequence of events shown in the storyboard. The claim made by Jackie that ladybirds eat aphids is the same as that made by Elettra while constructing the first representation. In their discussion, they revisited concepts from the research notes stating that the female ladybird lays her eggs near an aphid colony and Elettra recalled images she had seen on the internet that showed the aphids on a plant stem. In summary, the preservice teachers designed a storyboard to break the content into six 'chunks', each with a sketch and a label used for planning the rest of the slowmation. Creating a storyboard is thus the second representation and facilitates discussion about procedures (P), but also raises questions (Q) that need to be clarified. The storyboard produced then became the basis for the next representation.

Representation 3

The preservice teachers used the storyboard to design the third representation, which involved making or selecting 'models'. Alyce and Jackie made a 'mate' for the plastic model of a ladybird, since the kit we provided included just one, while Elettra gathered stems and leaves from the garden and made model aphids from Plasticine, which were not supplied. Their discussion involved Elettra talking her way through creating models of aphids as Jackie and Alyce made a model of a ladybird beetle. Elettra's statements are emblematic of this stage of creating the slowmation as making models raises questions about the physical dimensions and appearance of aphids and ladybird beetles as well as how they move in relation to each other, which is a key affordance of this representation. The range of utterances demonstrates social interaction in the form of questions and discussion:

Elettra: Look, there is our stem and leaves. (N)
Elettra: Oh, what can we have for little aphids? (Q)
Elettra: Let's make them yellow, oh, but the paper is yellow. (P)
Jackie: Can this part be, what's this part? [holds up the model] (Q)

Elettra: Aphids can be orange. (P)
Elettra: These are the aphids. (F)
Jackie: We have to have them [ladybird beetles] mating first. [Jackie makes a mate] (P)
Alyce: What do you call them? [looking at the ladybird beetle] (Q)
Elettra: Antennas. (F)
Elettra: Is that what you are trying to get at? (Q)
Jackie: There you go, look how good our ladybug looks. [holds up ladybird made out of Plasticine] (N)
Alyce: All right, so what else do we need to make? (Q)
Elettra: Well I'm making aphids now. [from Plasticine] (P)
Elettra: It's what he [ladybird] eats .... (PR)
Alyce: We've got the leaf, well done. [arranging plant stem and leaves on a project cardboard laying flat on a table] (E)
Elettra: Yes, we have the leaf, we have the stem, we have the pupa. (P)
Jackie: Yeah, so these two will just walk along the screen, join together for a second and then he disappears and then she lays her eggs. (P)
Elettra: And then this is what they eat. Okay, well let's have a few of them [aphids] disappear at a time. (C)

When making models for the third representation, the preservice teachers discussed the size of the aphids in relation to the ladybird beetle and how the ladybird beetles move in relation to each other. There were a range of social interactions that included six procedures (P), five reasoned questions (Q), one proposition (PR) and one claim (C). As we have seen in the earlier representations, the interactions continued between the preservice teachers, seeking clarification about procedures and concepts as new questions were asked and answers sought. Planning for the final animation, therefore, continued because the representations (e.g. models) need to be realistic, relatively sized and able to demonstrate the concept that the case students are seeking to illustrate. Once the 3-D models were made, and the backdrop (yellow project sheet) and props added (real stem and leaves), they were ready for use in the next representation.

Representation 4

As soon as the models were created, they were used in the fourth representation of taking 'digital still photos'. In this representation, our case students set up a digital camera on a tripod looking down at the tabletop where the yellow cardboard project sheet was placed flat on the table as background with a stem and leaves that Elettra had gathered in the previous stage. Figure 1 shows the set-up with one of the preservice teachers being responsible for moving the models, one for taking the photos and another for accessing the internet on a laptop computer to check the content.

According to planning in the storyboard, the models were moved manually in small increments (1–2 cm at a time) as the photos were taken. Discussion for this representation included consideration for how the models are to be moved step by step in order to take the still photographs, consistent with a stop-motion technique:

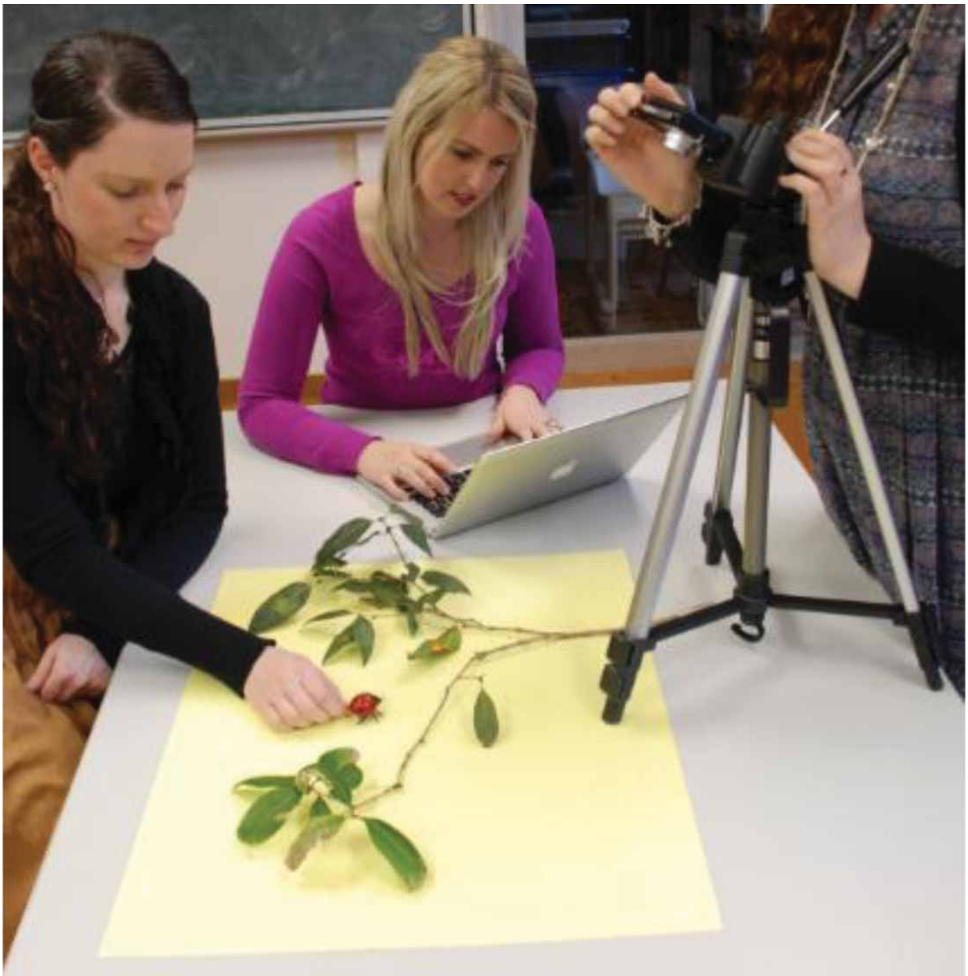

Figure 1. Set-up for making the slowmation. Image reproduced here with permission. © 2010 Wiley Publications. Cover image from *Journal of Research in Science Education*, Vol 48, Issue 9.

Jackie: So where is she going to lay her eggs? (Q)
Elettra: Oh we have to have our little thingy's [aphids]. Let's just have a few disappear, every time she gets a little bit closer, because they're meant to be the aphids. (P)
Elettra: On the thing [cardboard sheet]. The aphid colony is meant to be there. [points] (P)
Jackie: Did we maybe want to label it with a little arrow to 'aphid colony'? (Q)
Alyce: We could do that with the photo on the computer. (P)
Alyce: Do you know what I mean? (Q)
Jackie: Oh, okay. (E)
Alyce: Like put a label, put labels in it? That'd save you having to be more technical. (P) [two minutes additional discussion of ladybirds, colour scheme and timing of phases]
Jackie: So he can like kind of . . . we'll do a few shots of him walking off and then the eggs disappear and it's just him [ladybird], eating the aphids. (P)
Elettra: Yep. Two to five days. (P)

Jackie: Can we get him with those? (Q)
Alyce: So its going to start eating the aphids, is that what it does? (Q)
Jackie: Yep. Eats aphids for three weeks. (F)
Jackie: So maybe we can just slowly take away some of the aphids? (Q)
Elettra: Yeah. (F)
Alyce: That's a good idea, yep. [taking a few aphid models away] (E)

Much of the discussion focused on questions about the movement of the models in relation to each other, the props of the stem and leaves, and the cardboard backdrop. For example, the discourse analysis concerning the discussion about aphids shows a variety of utterances consisting of six procedures (P), six reasoned questions (Q), two encouragements (E) and one example of feedback (F).

Even though the sequence of chunks had been planned previously and the models constructed, new questions were raised as the preservice teachers were preparing to take the photographs. Jackie's opening question 'So where is she going to lay her eggs?' is an opportunity for the case students to synthesise their thinking about the relative position and size of the eggs in proximity to the modelled aphid colony. They also considered how to explain the life cycle sequence with the moving 3-D images and photos of labels identifying the name and time length of each phase. In summary, taking the digital still photographs provided the preservice teachers with an opportunity to clarify misunderstandings about the timing and detail for each life cycle phase by asking questions (Q) and checking their decisions about procedures (P).

Representation 5

The final step of the slowmation process involved downloading the still images onto the computer desktop, uploading them into a movie-making software program and aligning the modes of slow-moving images with text and recording the narration. After importing the images into the SAM Animation software program, the preservice teachers made decisions about which photos were to be 'copied and pasted', providing static images to align with key aspects of the narration. Elettra then wrote the narration during a discussion with the other two preservice teachers:

Elettra: 'Ladybirds mate in summer and spring. Ladybirds lay a cluster of eggs up to 300 near an aphid colony. After 2–5 days the eggs hatch into a larvae state. This state can last up to three weeks. Larvae eat aphids and grow rapidly shedding its skin several times. When the larvae is full size it attaches itself to the plant stem. The larvae splits and exposes the pupae'. [rehearsing the narration] (R)
Jackie: So we're up to the pupa did you say? (P)
Alyce: So the pupa lasts one week. (R)
Elettra: 'After this week the ladybird emerges as an adult. It is a pale yellow colour with no spots. Over 24 hrs as the wings dry it is a pale yellow colour with no spots and over 24 hours its wings dry' and umm ... 'its colour darkens into red with black spots.' [writing and rehearsing narration] (R)
Jackie: Yep, darkens to become red. (F)
Elettra: 'darkens to become red with black spots. Adult ladybirds eat aphids and other small ...'[writing narration] (R)
Jackie: Plant types. [Jackie finishes Elettra's sentence] (F)

Elettra: No, small insects, they are carnivores, I didn't know that. (C)
Alyce: That's something interesting. (E)
Elettra: That was an 'ah ha' moment. (E)
Alyce: Definitely. (E)
Elettra: Guys, ladybirds are carnivores, did you know that? They eat aphids and other small insects. They don't actually eat plant life. Did you know that? (C)
Elettra: Well, there you go. (F)
Alyce: We initially thought, well I did anyway, that they [ladybirds] eat leaves. (R)
Jackie: I said in my interview that they eat plants. (R)
Elettra: Well, we thought that whatever was laying it near a colony of aphids. We're like, 'are aphids flowers? or plants?' (R)
Elettra: So, 'adult ladybirds eat aphids and other small insects and quickly search for a mate'. [completes writing the narration] (P)
Alyce: We had an 'ah ha' moment that they are carnivores, because we initially thought that they eat plants. (R)
Alyce: So even though we learnt what they ate, we still had the wrong idea in our head because we didn't really take it in, in the mode of reading. [reflecting on learning] (R)
Alyce: We're not going to forget that they are carnivores any time too soon. (R)
Elettra: Yeah. [writes last statement of narration]
Alyce: So it didn't really come through until we were discussing the narration. (R)

The discourse analysis of the excerpt again shows that there were a variety of utterances consisting of 10 recalls (R), three encouragements (E), three feedbacks (F), two procedures (P) and one claim (C) (e.g. about the role of aphids in the ladybird beetle life cycle). It was evident that there was a good deal of reflection in recalling (R) and clarifying information (F) to construct the narration. The exchange between the students that ladybirds are carnivores was particularly interesting. As Elettra wrote the narration, Jackie verbalised her alternative conception by finishing Elettra's sentence when she said that ladybirds ate 'plant types'. But then Elettra corrected her stating that ladybirds ate insects and realising herself that 'they are carnivores, I didn't know that'. This was a new insight for all three and they revisited Jackie's and Alyce's alternative conception that had been evident in the prior representations that ladybirds ate plants. Although our preservice teachers came across information that ladybirds ate aphids in the first representation of research notes and again through each representation, it was not until the fifth and final representation of making the narration that Jackie's conception changed. Alyce commented that although they had read the information that ladybirds ate aphids in the first representation, they did not 'take it in, in the mode of reading'. Hence, it was when discussing, clarifying and refining the ideas generated that new knowledge claims were made. Figure 2 presents a selection of digital still photos from the final animation along with the accompanying narration.

Individual Interview Data after Animation Construction

After the slowmation construction was complete, individual interviews were immediately held with each preservice teacher to explore what she had learned about the

"Ladybirds mate and lay a cluster of eggs, up to 300 near an aphid colony."	"After two to five days the eggs hatch into a larvae stage. The stage lasts up to three weeks"	"The ladybirds eat aphids and other small insects and quickly search for a mate."

Figure 2. Selection of still images from slowmation with narration

ladybird beetle life cycle. In her post-construction interview, Jackie confirmed some of her initial ideas in terms of colour and habitat, but other ideas were disconfirmed, including what ladybirds eat and that larvae are eggs. She was now able to explain specific details about the life cycle of the ladybird beetle, which she was unable to do in her pre-interview:

> First, the ladybird lays the eggs and they stay eggs for two to five days. I originally thought that larvae were the eggs but the eggs hatch into the larvae. The larvae stays larvae for three weeks and when they hatch they eat the aphids and grow bigger over three weeks. The skin splits and the pupa comes out. I didn't know that before. The pupa emerges and stays like this for three weeks where it grows through the changes to become an adult. … they lay their eggs in spring and summer and six generations of lady beetles can be born during those two seasons.

Jackie was also able to state that she had changed her alternative conception as is evident in her statement: 'they eat aphids and other small insects so they don't actually eat leaves'. In summary, Jackie's knowledge about the ladybird life cycle changed in three main ways since she could now explain (i) the phases in the ladybird life cycle; (ii) that larvae were not eggs and (iii) that ladybird beetles do not eat leaves but instead eat aphids.

Elettra also confirmed her prior knowledge, especially that ladybirds have six legs and an exoskeleton. Furthermore, she also confirmed that they change colour from yellow to red and they start as eggs and have flaps on their backs to protect the wings. In her post-construction interview, she was able to offer explicit details about the phases of the ladybird life cycle and what they eat:

> So they break out of the eggs and turn into larvae. Then the larvae eat aphids, which are like little bugs, tree lice, so they are carnivores. Then the larvae sheds its skin many times and attaches itself to the stem of a plant. And after the final shedding happens it then becomes a pupa and I think it stays a pupa for three weeks. Then it comes out and in 24 hours it develops and changes colour from yellow to red and develops the spots and that happens when it is drying. So it's yellow, because it's moist from being inside the pupa, so it's the adult when its red, 24 hours yellow, develops to red with spots, and the life cycle continues.

Elettra was also able to explain that ladybirds eat aphids, which was new knowledge for her: 'they eat aphids, I didn't know that, which are like little bugs, tree lice, so they're carnivores'. In summary, Elettra's knowledge of the ladybird life cycle changed in three main ways because she was able to explain that (i) ladybird eggs form larvae and there are specific phases in the ladybird life cycle; (ii) the larvae eat aphids and thus are carnivores and (iii) the colour changes when the larvae dry out.

In her post-construction interview, Alyce's prior knowledge was confirmed that ladybirds are of different types and colours, that they are insects and that they lay eggs. Similar to Jackie and Elettra, Alyce was also now able to explain specific features of the life cycle:

> It's interesting that when they first come out of the pupa stage they are different colours. They go from pale yellow to orange to red for that specific species because of their wings drying . . . They do lay eggs, they lay quite a lot of eggs. It was interesting to know that the larva wasn't eggs, which I initially thought it was. They do live on plants and flowers and trees, and they tend to lay their eggs and live where there are . . . aphids and they live there where they are and they tend to lay their eggs where the aphids are. You tend to see them in spring and summer. When you don't see them they hibernate and they live under logs and spring and summer is the time where they mate, they mate and you see them.

Similar to Jackie, Alyce changed her alternative conception that 'they don't eat leaves they eat small insects, which makes them carnivorous, and some of the insects that they eat are aphids and other stuff'. In summary, Alyce's knowledge of the ladybird life cycle changed in four main ways: (i) ladybirds eat aphids, not leaves; (ii) larvae are different from eggs; (iii) there are many different colours and the colour changes when the larvae dry out and (iv) they mate in spring and summer and are found under logs.

Overall, each preservice teacher in our case study learned about the specific life cycle stages of the ladybird beetle as well as the food of ladybird beetles through making a slowmation. Although most of the knowledge claims occurred in the first representation (and some of these overlapped), there were new knowledge claims in each of the other representations, suggesting that revisiting the concept through the construction of each representation influenced conceptual change. In her post-creation interview, Elettra summarised the process of her learning:

> The research is where you gain most of your information, that's where most of your learning occurs. In the storyboarding then, we had to go back and plan and reconfirm our ideas so they matched with our images. So our information matched, like interlinked so linking images with information text helps and then making the models and construction and taking photos . . .. and then in the narration you are learning more because you're reconfirming what you have learnt by verbalising it and then re-listening to it. It is sinking in more, so you have to write it down first of all . . .. then you have to say it, record it and then you're listening back to what you're saying . . .. So it's like sinking in because you're listening to the same information multiple amount of times.

Her statements corroborate our discourse analysis that learning occurred across the five representations by mentioning the importance of 'interlinked' information with the different modes of text and images, including revisiting the content multiple times to reconfirm what was learned, thus 'sinking in'. Elettra also highlighted the social influences on learning by constructing a slowmation with the other preservice teachers:

> I think in all the phases you learn more when you're learning with others .... so if you're on your own, I wouldn't be learning quite as much. But because I was with the girls, if they picked up on something they'd bounce that information to me and so we bounce it back to each other.

The data suggest that the learning fostered by creating the sequence of representations is iterative and is enhanced by the social influences as a result of working in a group to construct the slowmation.

Discussion

The need to find new ways for primary preservice teachers to increase their science knowledge is well established (Bennett, 2001; Davis et al., 2006; Goodrum, Hackling, & Rennie, 2001; Lee et al., 2009; National Academy of Sciences, 2006; Tytler, 2008). Encouraging preservice teachers to experience new ways of learning science in their primary science methods courses is one way to address this need. To answer the first part of the research question concerning how the preservice teachers created a slowmation, the preservice teachers re-represented text, still images and video from the internet by designing and making a sequence of five representations—research notes, storyboard, models, digital still photos that resulted in the narrated animation. Each representation was a semiotic system (Lemke, 1998; Peirce, 1931/1955) because the preservice teachers were making meaning (the interpretant) as they made decisions about which modes to use (the representation), as well as thinking about how to integrate the modes to best explain the life cycle of the ladybird beetle (the referent). The final semiotic system was a digital narrated stop-motion animation that the preservice teachers designed by aligning the modes of slow-moving images, still images, text and narration to complement each other and so it is a multimodal representation (Jewitt, 2009; Kress, Jewitt, Ogborn, & Tsatsarelis, 2001). Meaning was progressively developed from one representation to the next culminating in a narrated animation, which is designed as an instructional resource for primary children. A key feature of slowmation is that it does not involve the use of any topic-specific software as in other learner-generated animations such as *Chemation* (Chang et al., 2010), *Carousel* (Hubscher-Younger & Hari Narayanan, 2008) and *ChemSense* (Schank & Kozma, 2002).

To address the second part of the research question concerning how making a slowmation influences learning, it should be mentioned that data from the pre- and post-creation interviews and the discourse analysis indicate that there were three influences on their learning. First, each of the five representations had a specific role or affordance that focused the preservice teachers' thinking in particular ways. For example, in constructing the research notes, the preservice teachers summarised information by asking questions (Q) which were answered with backing (B) accessed from the internet. In the second representation, the storyboard, the preservice teachers 'broke down' the content into several 'chunks' and placed the chunks in a logical sequence as shown by the high number of procedural statements (P) and questions (Q). These chunks were then used as the basis for modelling, in which the preservice teachers closely examined features of the model they were making, thus motivating them to check details. Taking the digital photographs in the fourth representation then enabled the preservice teachers to focus their thinking on aspects of relative size and visualising how the models move in relation to each other. In the final representation, the preservice teachers used technology to integrate the four modes of writing and moving and still images as well as narration to create a multimodal representation. In short, each representation had an affordance to investigate the same concept but in different ways. We call this transfer of ideas a *cumulative semiotic progression*, whereby the preservice teachers revisit the content through different semiotic systems with meaning building from one representation to the next to promote learning.

Consistent with the representational framework for learning proposed by Tytler and Prain (2010), creating a slowmation is also a new way to encourage conceptual change, as multiple opportunities are presented to confront and revise alternative conceptions. In agreement with the literature on the resilience of prior conceptions (see e.g. Cobern, 1996; Driver, 1983; Taber & Tan, 2011), it is clear that the act of note-taking during the first representation did not lead to conceptual change for our preservice teachers. Although they encountered discrepant or new information in the first representation when they read and wrote summary notes about information they found on the internet, change in their conceptions did not occur until they had had several more encounters with the information in subsequent representations. The example of aphids as ladybird food illustrates this point. As prior knowledge, both Alyce and Jackie thought that ladybirds ate leaves, while Elettra did not know what they ate and so did not mention it. When as a group they first read about aphids on the internet during work on the first representation, Elettra wondered if aphids were plants. Even though the preservice teachers had read that aphids were 'plant-lice, small plant-eating insects' from a website, Elettra wrote 'larvae eats aphids' in the research notes and 'the larvae eats aphids and grows rapidly' in the storyboard in the second representation, conceptual change did not occur. Furthermore, as they made models in the third representation and moved the models while taking photos in the fourth representation, the information did not 'sink in' (Elettra) until the fifth representation when they were writing the narration and they all realised that because ladybirds ate aphids, they were carnivores. We contend that the process of slowmation facilitated conceptual change by focusing the preservice teachers' attention in particular ways through the five representations.

A second influence on learning was the making and combining of different modes of representation (e.g. writing, still and moving images and voice). In thinking about the narration, the preservice teachers made decisions about aligning the images and the explanation. The images can be copied and pasted multiple times to suit the narration and are called 'static images'. Thus, in making the final representation, the preservice teachers used technology to integrate the modes of slow-moving or static images, writing and narration to complete the multimodal representation (Kress, 2010; Prain, 2006). In writing the narration, the preservice teachers must consider how to explain the content in a way that complements the slow-moving images and static images and use language that is suitable for primary-age children. This need for a clear explanation in the narration in the final representation provoked the preservice teachers' realisation that ladybirds were carnivores. Again, affordances in each representation caused the preservice teachers to revisit the concepts that ultimately led to confirming or disconfirming their prior conceptions and to learn about ladybird beetles.

A third influence on learning was the social interaction among our preservice teachers as evidenced by the variety of utterances across all five representations. Making each representation caused the students to interact through a range of discussions as they asked reasoned questions (Q), sought backing (B) and feedback (F), discussed procedures (P), provided encouragement (E) and made claims (C). We can see social interaction as an additional benefit of slowmation, consistent with the dynamic relationship between meaning-making, the representation and the referent. Social interaction is facilitated by the technique of making a stop-motion animation, whereby the creators can stop, discuss, check and edit as they go to confirm or disconfirm their developing knowledge (Hoban & Nielsen, 2011). In summary, the process of creating a slowmation in 2 h by constructing a sequence of representations caused each of the preservice teachers to learn about the life cycle of the lady beetle and resulted in two of them changing their alternative conceptions.

Implications

There is a continual search in science education to find new ways to engage preservice teachers in learning science knowledge. We also note the resilience of alternative conceptions held by potential primary teachers. Teacher education courses need to help preservice primary teachers unpack their prior conceptions and develop more robust conceptual understandings; otherwise, there is a possibility that knowledge may be misrepresented in their own teaching or they may avoid teaching the subject altogether. Importantly, slowmation offers two key advantages: (i) the simplicity of the process as preservice teachers can learn the technique within one class of 2 h and (ii) allowing the use of accessible technology such as a digital still camera and a computer, which many of them own. One way to organise its use in a science methods class is to allocate each preservice teacher a different topic and then have him or her upload the slowmations to a website to share as resources and/or to peer review.

While this paper focused on learning as revealed through dialogue as the preservice teachers made a progression of five representations, the research studies conducted so far have not focused on the decision-making concerning how or why different modes are used within each representation. It is clear that further research is needed to study how different types of learners use technology to design slowmations about different concepts including the decision-making regarding which modes and representations are to be used. We also acknowledge that a limitation of this study is that it involved three adult learners, all with some science background who displayed a positive attitude towards science. The confirmation of the value of slowmation for learning would require additional studies using a range of students across a range of topics. Follow-up research could also determine if the learning was stable. Our next research study will use a quasi-experimental design to generate data to compare the quality of the learning with that of other forms of construction activities. This comparison may use expert-generated animations or other forms of learner-generated media such as posters.

We also hope that the engagement of preservice teachers in learning how to make a narrated animation in science methods classes may transfer to their own teaching practices in schools. Although beyond the scope of this study, we are aware that many preservice teachers in our courses have used slowmation while teaching on practicum in school classrooms. In most cases, they have shown the slowmation that they had made to their class or have encouraged school children to create their own in some cases. When they get children to make one, the most common use has been as an assessment task at the end of a science topic. The slowmation is an indication of what children have learned, and in some situations, showing these to other children has revealed alternative conceptions and has generated discussions about how to improve the slowmation or what is missing from the explanation. It is feasible that the research area of student-generated representations, such as slowmation, will increase as new personal technologies such as more advanced mobile phones are developed. For example, some learners can access the internet, take digital still photos and make a narrated animation all on their hand-held mobile phone as well as upload them to an internet site for public viewing and possible peer review. As science educators, we need to encourage our preservice teachers to use technology they have access to for the purpose of learning science.

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