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Creating a narrated stop-motion animation to explain science: The affordances of "Slowmation" for generating discussion

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HIGHLIGHTS

- The discussion enabled the preservice teachers to resolve a resilient misconception.
- Slowmation enables preservice teachers to create a narrated stop-motion animation.
- Slowmation has four affordances for generating discussions about science.

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ABSTRACT

This case study investigated the nature of the discussions generated when three preservice primary teachers made a narrated stop-motion animation called "Slowmation" to explain the science concept of moon phases. A discourse analysis of the discussion during construction demonstrated that the preservice teachers posed many questions, propositions and ideas facilitated by four affordances of the process: (i) a need to understand the science in order to explain it; (ii) making models; (iii) stopping to check information; and (iv) sharing personal experiences. Slowmation is a simplified way of making animations that has four affordances to promote discussion resulting in scientific reasoning.

1. Introduction

There are increasing opportunities for students in schools and universities to use technology and create different forms of media to promote digital literacies (US National Research Council, 2012). In particular, access to personal technologies such as mobile phones are increasing students' capacity and portability to create media anywhere and anytime (Cochrane, 2011; Jones & Issroff, 2007). According to Traxler (2010), mobile technologies provide users with more ownership of knowledge and responsibility for learning since "mobile devices demolish the need to tie particular activities to particular places or particular times … mobile technologies have converged with the wider user-generated movement associated with Web 2.0 rhetoric and technologies" (p. 151–155). A consequence of students' improved capacity for creating media, particularly when using mobile phones, is that they are increasingly taking still images and videos, but mainly for the purpose of uploading to social media sites such as Facebook and Instagram. Teacher educators could thus draw upon the disposition of their preservice teachers' for making digital media and promote the use of these skills for sharing ideas about teaching and learning.

For example, the process of creating digital media could provide a context for generating discussions, especially if the media is created as a group activity. According to key theorists, discussion is a vehicle for thinking and learning (Scardamalia & Bereiter, 1993; Vygotsky, 1978; Wenger, 1998). Parker and Hess (2001) noted that "discussion widens the scope of any individual's understanding of the interpretations and life experiences of others. Shared inquiry, results, therefore, in shared understanding" (p. 275). For science learning in particular, discussion has been viewed as a key process to promote students' learning of concepts (Lemke, 1990, 1998). Discussions about science concepts are most fruitful when students are encouraged to declare their beliefs, whether correct or incorrect, listen and respond to different perspectives and evaluate and refine their ideas. Discussion amongst peers is key to these processes, especially if learners propose their ideas in ways that are understandable by others.

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Chin and Osborne (2010) analyzed the science discussions of high school students and found that an important influence on the quality of the discussion was the way in which the discussions were framed: "the initial focus on questions prompted students to articulate their puzzlement; make explicit their claims and (mis) conceptions; identify and relate relevant key concepts; construct explanations; and consider alternative propositions when their ideas were challenged" (p. 883). A systematic review of 89 studies evaluated how discussions are used in the teaching of science in schools (Bennett, Lubben, Hogarth, & Campbell, 2005). Bennett et al. showed that discussion was usually part of a broader strategy such as collaborative learning, conducting an experiment or developing an argument. Furthermore, the quality of discussion was related to how the task was framed and the timely introduction of new ideas to scaffold the discussion. Berland and Hammer (2012) confirmed the importance of "framing" a discussion in which students need to be encouraged to ask questions, state their beliefs, argue a point of view, evaluate evidence, reason with ideas and revise their own claims and the claims of others. In short, appropriate framing is key to scaffolding students' discussions and reasoning about science to support learning.

Preservice teachers should also "learn by experience" (Munby & Russell, 1994) in the teacher education program by participating in the type of discussions that they will expect of their future students in schools. For example, when preservice teachers read and discuss case studies, their individual experiences can be elaborated as ideas are shared (Levin, 1995; Richardson, 1991). This is also important for collective knowledge building (Bereiter & Scardamalia, 1993). Mathematics educators have used classroom video episodes to frame professional learning discussions (Borko, Jacobs, Eiteljor, & Pittman, 2008) and technology educators have analyzed discussions in online teacher education forums where the focus was development of ICT skills and knowledge (Prestridge, 2010). In the current study, we investigate whether the disposition of preservice teachers for creating digital media could be used as a context to promote reasoned discussions, especially in regard to making animations to explain science concepts.

1.1. Slowmation: a simplified way of making a narrated stop-motion animation

Animations have been readily available for learning in many content areas, but in nearly all cases these have been expert-generated with students interpreting the information presented (Gilbert, 2007; Phillips, Norris, & Macnab, 2010). If students become producers rather than consumers of information in animations, then they may develop meaning and in the process generate informative discussions. However, there have only been a few studies in which students have created animations as a way of learning science and in each of these studies, specific software was designed that included access to learning objects to support the construction process (Chan & Black, 2005; Chang, Quintana, & Krajcik, 2010; Schank & Kozma, 2002). Even the traditional stop-motion animation process known as "claymation", which was a term coined by Will Vinton in 1975 to describe the stop-motion technique of animating clay models in his movie *Closed Monday*, has been rarely implemented in science teacher education. This is because claymation is a tedious process needing an expensive animation stand to hold a camera perfectly still to photograph small manual movements. Hence, traditional claymation is rarely used as a teaching approach in science teacher education because it is time-consuming and the clay models dry out and easily break apart.

With current digital technology (hand held cameras and mobile phones), however, stop-motion animation in the form of *Slowmation* (Hoban, 2005) has become a simplified way for students to create animations in school classrooms and in teacher education courses. Slowmation evolved in a preservice teacher education course at an Australian university as a way for students to engage with and explain science content (Hoban & Nielsen, 2011). The animation process is simplified by laying the models flat to ease image capture and playing the images at 2 frames/second (normal animation speed is 25–32 frames/second) to create a slow-moving image and hence enable a narration by preservice teachers. In short, a slowmation displays the following features:

- *purpose* — preservice teachers or school students engage with science content to explain a science concept in 2–3 min and through the creation process, learn about the concept. The voiceover can be enhanced with narration, music, static images, diagrams, models, labels, questions, static images, repetitions or characters;
- *orientation* — 2D and/or 3D models are made and 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, a hand-held mobile phone or iPad (these can be taped to a desk). Laying models flat on a table or the floor makes them easier to make, move and photograph. See Fig. 1 for examples of two possible set-ups by preservice elementary teachers.
- *materials* — many different materials can be animated such as soft playdough, plasticine, 2D pictures, drawings, written text, existing 3D models, felt, cardboard cut-outs and natural materials such as leaves, rocks or fruit;
- *timing* — slowmations are usually played slowly at 2 frames per second, not the usual animation speed of 25 frames per second thus needing ten times fewer photos than in clay or computer animation and resulting in a slow-moving image hence the name "Slow Animation" or "Slowmation";
- *technology* — students use their own technology (digital still cameras with photo quality set on low resolution, iPad or mobile phone camera) and free movie-making software (e.g., iMovie on a Mac or Windows Movie Maker on a PC).

In the last few years, slowmation has been used in a wide variety of school and university classrooms because of its simplicity in terms of the creation process and the use of everyday technologies (free software on Mac and PC computers and the use of students' own cameras and mobile phones). A database linked to the project website www.slowmation.com shows that the site averages 10,000 requests/day resulting in over 15 million requests in the last 3 years from users in 106 different countries. An analysis of the 2000 examples on YouTube show that slowmations have been created in a range of subjects such as in science, math, history, social studies and English and in a variety of international contexts such as in North America (Canada and the USA), South America (Brazil, Chile and Peru), Europe (France, Germany, Italy and England) and Australasia (Australia and New Zealand). The adaptability of slowmation has been demonstrated by research on students creating slowmations about different topics in a range of educational contexts — in early childhood, elementary, secondary and university classrooms. In early childhood centers, there have been studies on 4 year olds in regard to the learning of science concepts (Fleer & Hoban, 2012). In the context of elementary classrooms there have been research studies on grade 4 students' understanding of equivalent fractions in mathematics (Kervin, 2007), the learning of social skills by grade 4 students with mild intellectual disabilities (Shepherd, Hoban, & Dixon, 2014) and storytelling in English (Reid, Reid, & Ostashewski, 2013). In the context of secondary school classrooms there have been studies on students' science learning (Keast, Cooper, & Loughran, 2011). In the context of university teacher education, there have been research studies on how

Fig. 1. Preservice teachers taking photos for simplified stop-motion animations (slowmations): one group is using a mobile phone and one using a camera mounted on a tripod to take photos as the models are moved manually.

creating a slowmation influenced preservice teachers in learning various science concepts (Hoban & Nielsen, 2011; 2013; Robert, Seong, & Abbas, 2011), pedagogical intent (Keast, Cooper, Berry, & Loughran, 2009) and technological pedagogical content knowledge (Vratulis, 2013).

In preparing to a make a narrated stop-motion animation, preservice elementary teachers usually make a sequence of five representations: research notes ⇒storyboard ⇒models ⇒digital still photographs and ⇒the narrated animation (Hoban & Nielsen, 2010). Steps in creating the representations involve preservice teachers making different modal choices (text, models, still images, moving images, voice) that are integrated in the final digital product. The slowmation is thus a sequence of literacy-based representations that could be examined through cognitive or situative theories (Russell & Kozma, 2007). However, given that the creation of these representations may generate discussions about producing the media product, especially if it is created by a group to explain a science concept, in the current study, we use a literacy-based theoretical framework to examine discussions.

2. Theoretical framework

Semiotics is the study of signs or symbols and according to Peirce (1931/1955), when students make a "sign" as a representation of content, which he called the "referent," it makes students think about the content and thus meaning is generated, which he called the "interpretant". Science education researchers claim that meaning-making is enhanced when students "re-represent" concepts using different modes of communication: "multiple representations refers to the practice of re-representing the same concept through different forms, including verbal, graphic and numerical modes, as well as repeated student exposures to the same concept" (Prain & Waldrip, 2006, p. 1844). This process of re-representing content using different modes is central to the literature on multimodal learning (Bezemer & Kress, 2008; Hand & Choi, 2010; Kozma, 2003; Kress, 2010; Kress, Jewitt, Ogborne, & Tsatsarelis, 2001; Waldrip, Prain, & Carolan, 2010), whereby making decisions about changing content from one mode into another (e.g. changing a text-based explanation of a science concept into the modes of models, images and speech) promotes thinking in multiple ways and further, could be a context for generating discussions.

The creation of each representation in a slowmation, therefore, (summary notes, storyboard, models, images, narrated slowmation) could promote meaning. According to Yore and Hand (2010), "the transformation among multimodal representations has the greatest potential in promoting learning and depth of processing" (p. 96). Previous research studies involving preservice primary teachers making a slowmation have focused on articulating the construction process (Hoban & Nielsen, 2011), describing the different type of modes used (Hoban, Loughran, & Nielsen, 2011), how preservice teachers use slowmation in schools (Vratulis, Clarke, Hoban, & Erickson, 2011), and the quality of the learning promoted by the construction process (Hoban & Nielsen, 2013). In these previous studies we noted that there was a good deal of discussion amongst preservice teachers as they made a slowmation and so the purpose of the current study was to analyze the discourse when students create a slowmation and to identify the affordances or features of the process that might facilitate this discussion.

For the purposes of this paper the term "affordance" refers to "action possibilities" to support or enable particular behavior (Gibson, 1979). This term has been commonly used in studies identifying the features of particular software or techniques that support desirable educational processes such as the affordances of interactive whiteboards (Maher, 2011; Warwick & Kershner, 2008), digital learning material (Kozma, 2003) and personal digital assistants (Mifsud, Morch, & Lieberg, 2013). In the current paper, we therefore investigate the "action possibilities" of slowmation for promoting discussion by addressing the following research questions:

1. What is the type of discussion generated when students create a narrated stop-motion animation to explain a science concept?
2. What are the affordances of the construction process that facilitate the discussion?

3. Methods

3.1. Participants and data collection

The current research used a case study design (Merriam, 1998; Stake, 1995; Yin, 2003) to examine the discussions generated as well as the affordances of the stop-motion animation process when

Table 1
Discourse analysis framework (adapted from Simon et al., 2008).

Type	Code definition	Code	Example
Reasoned Question	Question that presents a problem or requires a reasoned answer.	Q	A: When is it a full moon?
Non-Reasoned Question/ Statement	Question or statement that does not require a reasoned answer. Closed, rhetorical or non-science question.	N	E: Do we need to know anything else?
Feedback	Offers a response to someone else's comment on some aspect of the content.	F	E: Yes, we shouldn't laugh, this is me.
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	E: I thought it was right, that's what I said in my interview.
Observation	Describes a resource from the classroom/room. Reads from worksheet or the board.	O	A: One, two, three, four, five, six, seven, eight … [*Alice counts phases depicted by expert-generated image on website*]
Procedure	Gives information or instruction, or discusses things that relate to the order or procedure to be followed.	P	A: Let's just quickly look at the diagram
Proposition	Tentative statement that needs clarification or evidence.	PR	E: Maybe when it's completely on the side because you can see all of the sun's light is being reflected.
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: So there are eight different phases. [*looking at the expert-generated Google Image*]
Knowledge Claim	An assertion/insight/conclusion about what exists. This includes either what something will do in the future (prediction/presumption), or is happening in the present or past (conclusion or outcome).	C	E: Because the sun is huge, the sun can still light up the moon from the other side.

a group of three preservice primary teachers created a slowmation to explain a science topic to Year 6 students (aged 11–12). We used from a constructivist–interpretivist paradigm (Gallagher & Tobin, 1991; Schwandt, 2003) to inform data collection, analysis and interpretation. This design enables attention to the interactions and discussions among the group members that we analyzed through an in-depth discourse analysis.

To study discussions during the creation process of making a slowmation, three final year preservice elementary teachers, Xena, Eliza, and Alice (pseudonyms), were invited to construct a 2–3 min slowmation from start to finish on an allocated topic. The time was deliberately restricted to the length of a typical weekly science methods subject of about 3 h. They were invited to participate because they had previously made a slowmation in a first year methods subject and had previously completed a 1-h workshop in which they were encouraged to "think aloud" (Hogan, 1999; Meijer, Veenman, & van Hout-Wolters, 2006) and articulate their thinking during construction.

A topic was assigned at the beginning of a 3-h research time and had not been announced to them previously. We chose the challenging physics topic of "phases of the moon" for the study because previously we had studied simpler biology topics such as "life cycle of a ladybird beetle" (Hoban & Nielsen, 2011). The topic of moon phases exists in many elementary school curricula, but it is a traditionally difficult area for preservice elementary teachers to understand. Trundle, Atwood, and Christopher (2002, 2007) reported that preservice teachers often misunderstand the relative movement and size differences between the earth, moon and sun which leads to the common 'eclipse misconception' noting that it is a very resilient misunderstanding.

As soon as the topic was announced to our case students, they were individually interviewed before construction commenced and then again after the construction was completed. During the 15-min interviews, the preservice teachers were asked about their science backgrounds and knowledge of the topic phases of the moon. As they jointly constructed the slowmation, they were audio and video recorded. The artifacts that they produced were also collected. The audio records were transcribed verbatim and analyzed to identify the type of discussion generated when the preservice teachers were creating the slowmation.

The preservice teachers were also provided with an assortment of typical primary classroom materials such as assorted colors of plasticine, cardboard, construction paper and polystyrene balls. During the 3-h research period, we asked the preservice teachers to follow the same think aloud protocol from the preparatory workshop and after making each representation we asked them to share their reflections on the construction task. The research was approved by the university's ethics review board.

3.2. Data analysis

To analyze the nature of discussion, we used a discourse analysis framework shown in Table 1 that was initially developed by Simon, Naylor, Keogh, Maloney, and Downing (2008) to analyze discussions among school science students. Because of the nature of the discussions among these students, Simon et al. used a single code for 'argumentation'. We found this single code inadequate to examine possible changes to our participating preservice teachers' conceptual understanding about science concepts (Hoban & Nielsen, 2013) and thus adapted Simon et al.'s framework to include proposition (PR), backing (B) and claim (C) as additional coding categories to elaborate aspects of argumentation from Toulmin (1958) and Furtak, Hardy, Beinbrech, Shavelson, and Shemwell (2010). To identify the affordances of the slowmation process, interview data were transcribed verbatim and we conducted a thematic analysis on both the interview and discussion data to alert us to areas where our preservice teachers' knowledge or backgrounds indicated misconceptions or weak understandings in addition to our primary focus on how the construction process encouraged discussion. A separate research paper is currently in development that is a more in-depth study of the quality of the learning generated through the whole creation process.

3.3. Inter-rater reliability

In a previous study of preservice teachers constructing a slowmation to explain a biology topic, we used the discourse analysis framework shown in Table 1 achieving an intercoder reliability of 90% (Hoban & Nielsen, 2013). In the current study on the more challenging physics topic of moon phases, we conducted another intercoder reliability check (Miles & Huberman, 1994) and coded approximately 30% of the transcript independently and examined any differences between the two coders. In tallying and analyzing all disagreements, we noted that 11 of our 12 disagreements centered on data segments involving propositions (PR). Other researchers have also noted the challenge of distinguishing among Toulmin's (1958) categories of proposition, backing and claim (Furtak et al., 2010; Sampson & Clark, 2008), which may be why Simon et al. used only one code to capture these three aspects of reasoning. In resolving the differences of the two researchers in their respective coding decisions, we revisited the annotated transcript, paper records and video records from the study to contextualize the comments and clarified through discussion how we interpreted and coded each one. In particular, we clarified that a proposition is an example of a statement made tentatively and typically in response to encountering information, including in response to what another group member has said, whilst a backing statement draws on an external, expert source of information. Thus, we negotiated a shared interpretation of the argumentation/reasoning codes and how to distinguish amongst them. After discussing each disagreement, the intercoder reliability improved to approximately 93%.

4. Results

From analyzing the interview transcripts and the transcript from the 3-h construction process, there were several key conceptual ideas developed during the animation construction —relative movement between the earth, moon and sun; names of the phases; how orbits occur; relative sizes between the orbiting bodies; and causes of a full moon. Space limitations prevent an analysis of the development of each of these conceptual ideas and so we focus on a key question that Xena raised during the slowmation construction— "What causes the full moon?" We noted that Xena's question reflected a lack of understanding about this concept, which as noted earlier, is a typical topic in the elementary school science curriculum that is commonly misunderstood by teachers. Therefore using this example for our detailed analysis helped us to address the first research question about the nature of discussions. The next section presents the discourse analysis, with the analytic codes in parentheses "()". The subsequent section addresses the second research question about the affordances of the slowmation process to facilitate discussion.

4.1. Nature of the discussion generated

The three preservice teachers began the construction process by sitting near a laptop computer and reading information from various internet sites to gain understanding. They also watched YouTube clips about phases of the moon to gather information about the concept. They had spent 42 min collecting information when they came across a YouTube clip of an interview with a person (elementary teacher) who explained the cause of moon phases incorrectly— stating that the phases of the moon were caused by the earth's shadow:

> A: Okay, this one looks interesting, "What Causes the Phases of the Moon?" (Q)
> E: That might help. (E)
> A: This could actually be of help to us. (E)

The YouTube video showed short interviews where several elementary teachers were asked about what causes the moon phases. The first respondent articulates an alternative conception that the earth, moon and sun are aligned and so a moon phase is caused by the earth's shadow:

> What causes phases of the moon? If I had to guess, I don't know for sure, but I think it's how the earth casts a shadow on the moon. So if the moon is on one side of the earth and the sun is on the other side and so when we see a crescent on the moon, the earth is blocking out that dark area and the sun is shining on the sunny side. [from YouTube]

This triggered the following discussion partly because it resonated with Eliza's misunderstanding that there should be two new moons in the full cycle:

> A: That's wrong, is that right? [*Alice challenges the statement on the video*] (Q)
> E: That makes me feel bad for not knowing. (F)
> X: I thought that was right. (F)
> E: I thought it was right, that's what I said in my interview. (R)
> A: But didn't he say that 'Here's the earth and the moon is on one side and the sun's on the other side'? Is that what he just said? (Q)
> X: He started out saying that but then he explained it a little further. He said, yes, if there's only a crescent that means the sun is only shining on part of it and the earth is blocking the rest. (PR)
> A: Yes, but everything else that he said makes sense except when he said that. (PR)
> E: Yes, we shouldn't laugh, this is me. (F)

During this discussion, Eliza has been sketching aspects of the concept and summarizing facts about the moon phases (see Fig. 2). She adds the earth and sun sketches at the center bottom, showing a bold arrow pointing from the sun to the moon to support her explanation in the discussion. Further, she has drawn the earth and sun with the same relative size in the bottom part of the sketch that is consistent with her misunderstanding. Alice maintains her belief that contradicts the teacher's interview from YouTube as well as Eliza and Xena.

> A: But it's not about the earth blocking it (PR) it's about the sun isn't it? (Q) The earth doesn't block the sun. (PR)
> X: It does. (F)
> E: Yes, okay, because think about it – I can't do it without it being in 3D – but if the moon is here and the earth is here, if the sun and the moon go around … well the sun doesn't go around but if they're … (PR)
> A: Oh, of course. (F)
> E: Like if the sun's here … (PR)
> X: Yes, obviously. [*Xena agrees with Eliza*] (F)
> E: It blocks it in that way with the reflection and if that's completely behind the earth it's not there, but if it's sort of here you could see that half or that crescent. (C)
> A: No, I thought just then when he said that, I was assuming that he was talking about the moon being lit up already and the earth blocking it instead of the sun providing the illumination. OK, oh yes, yes, I see what you mean, which we've learned though. [*Alice now changes her view and agrees with the alternative conception argued by Eliza*] (F)
> E: OK, do we need to know anything else? (Q)
> X: This has to do, like the axis of the earth has to come into play on this because if we think back to the first video we saw, when it's the sun and then the moon and then the earth — that's when it's a new moon and you can't see it. [*Xena now thinks back to another video that contradicted Eliza's argument, gesturing with her hands to show the relative positions*]. (R)

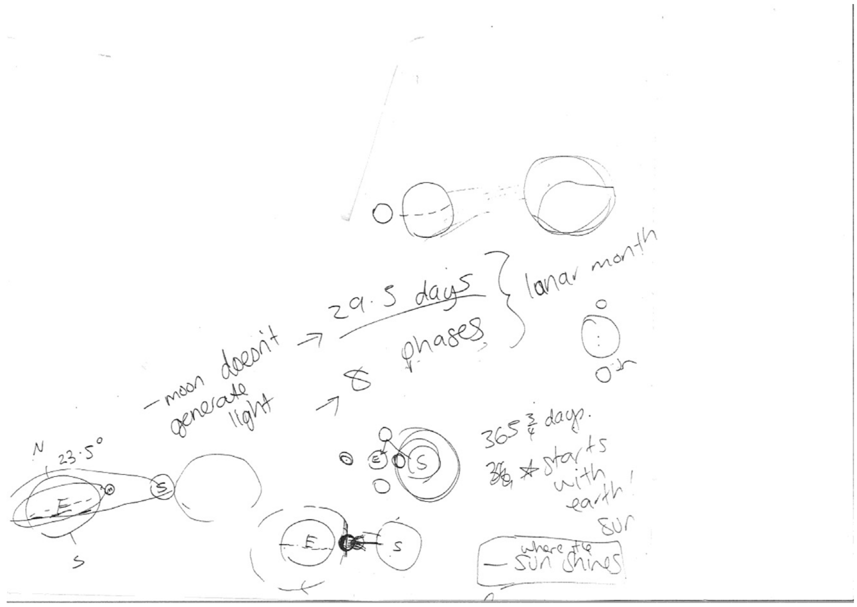

Fig. 2. Sketches by preservice teacher (Eliza) to explain her conception of moon phases.

X: So when is it a full moon then? [*Xena's key question that she returns to*] (Q)
E: Maybe when it's completely on the side because you can see all of the sun's light is being reflected. [*gesturing with her hands showing the moon on the side of the earth*] (PR)
X: So if the earth is like this, then it has to be like when the sun and the moon are close to each other. (PR)
E: Yes, yes. (F)
X: Because it has to be where the sun can reflect off of it, but it's still in the position where we can see it. (C)
A: We can see the whole thing, yes. (F)
E: So the angle of the reflection is towards earth. (F)
A: *[Alice picks up pen and adds to Eliza's sketches shown in Fig. 2 to support the alternative conception but without concern for scale differences between the earth and sun*) Because you would think that the sun would have to be there, here's the moon, the sun would have to be there to be able to see it. (PR)
X: But it depends where the earth is? (F)
E: We're seeing it, it's not when you're on the moon. (F)
X: And that's when you can't see it. (F)
A: Mmmmm! (N)
E: Yes. (F)
X: So I wonder where the earth needs to be in relation to the moon and the sun for it to be a full moon? [*Xena returns again to her key question]* What does that one say? [*plays another one-minute YouTube video*] (Q)

To answer Xena's question of where the full moon occurs, Eliza again states that there should be two new moons. This view is consistent with the common alternate conception that the earth, moon and sun line up at regular intervals resulting in two new moons per cycle, one on either side of the moon as it travels around the earth (Trundle et al., 2002). In the mean time, Alice finds an expert-generated Google Image with the eight moon phases that provides backing for her proposition that there is only one full moon per lunar cycle, which contradicts the alternative conception proposed by Xena and Eliza:

E: I don't know. There should be two new moons like here. [*again pointing to her own sketch shown in Fig. 2 of the moon phases showing the sun and earth as the same size maintaining her alternative conception*] (PR)
X: But there's only one. Isn't there only one full moon in the phases? (Q) Because there's a new moon there. [*pointing to* an expert-generated representation that Alice found on Google Images, naming all of the moon phases and depicting them in a line] (PR)
A: So there are eight different phases. [*looking at the expert-generated Google Image*] (B)
E: Why is there not two [*new moons*]? (Q)
X: Well that's what I thought. Why is there not two? [*Xena still agreeing with Eliza]* (Q)
A: That looks like there's not two. So it's right in the middle [*of the lunar cycle still looking at the expert-generated still image of the eight moon phases*] (B)
A: One, two, three, four, five, six, seven, eight … [*Alice counts phases depicted in the image*] (O)
E: And then what does it do? (Q) It goes black and then goes back to there [*pointing*] (O)
A: Yes, it goes back to this. (O)
E: It's a cycle. (PR)
A: So it's a cycle and there are eight phases. (F)
E: Why is there only one [new moon]? (Q) So okay, so it's black here and it's also black here. (O) [*looking back at her own sketch again*] Are there two phases per orbit? (Q) No, there isn't. (PR)
A: No, because there are only eight phases per cycle. (F)
X: It's not black in two spots either; it's only black in one – there's only one new moon and it's right here. [*X pointing to the sketch of the moon between the earth and the sun*] (C)
E: Then what happens on this side when the earth is completely blocking it? (Q)
X: That's when it's full. See this is what happens. (C)
E: Oh duhhhh, because the sun is massive, like the sun is huge. [*A change in Eliza's conception that there is a large difference in scale between the sun, earth and moon and so the sun can shine past the earth onto the moon thus making a full moon*]. (C)
X: Our issue is because we are not seeing it in 3D. (F)
E: Because the sun is huge, the sun can still light up the moon from the other side. (C)

The nature of this discussion included a range of utterances as the preservice teachers debated the question of where does a full moon occur in the lunar cycle. The range included reasoned questions (15), non-reasoned questions (1), feedback (17), encouragement (2), procedure (0), propositions (13), backing (2), observation (4), recall (2) and knowledge claims (6). Hence the range of statements indicate that the discussion focused on scientific reasoning to understand and explain concepts especially posing questions and making propositions leading to claims. A consequence of this discussion is that two of the preservice teachers, Eliza and Xena, resolved their misunderstanding that moon phases are caused by the earth's shadow, which is a common and resilient misconception amongst preservice elementary teachers (Trundle et al., 2002).

It should be noted that this type of generative discussion focusing on the posing of questions, stating beliefs and debating evidence leading to claims, which is typical of scientific reasoning, was also evident in regard to the other science concepts discussed. For example, at the beginning of the study none of the preservice teachers could recall the names of moon phases but they could recall all of them after the construction because they needed to know the names in order to label the different phases. Furthermore, they also came to the realization that it is the relative positioning between the earth, moon and sun that causes the phases of the moon to change. Both of these insights were not immediately clear to the preservice teachers at the beginning of the study but developed through a combination of different utterances generated in their discussion such as questioning, stating beliefs, seeking evidence and finally making claims.

4.2. Affordances of the construction process to promote discussion

While the discourse analysis helped us to examine the nature of the discussion, we were also interested in how the different features of the slowmation process promoted discussion and whether the preservice teachers recognized this in their post interviews. Data analysis of both the construction and interview transcripts showed that slowmation promoted discussion through four key affordances of the slowmation process.

4.2.1. A need to understand the science in order to explain it

The transcript analyzed in Section 4.1 is typical of many of the discussions held during the construction process as the preservice teachers sought to gain a basic understanding of the concept. This need was generated by the authentic purpose for making a slowmation — to create an explanatory resource for Year 6 (age 11–12) primary children. This purpose was clear to the preservice teachers as indicated by an excerpt from the beginning of the transcript where they initially made decisions about where to seek information:

> A: Okay, so our audience is Year 6.
> E: Yes, because we're teaching it, this is for Year 6.
> A: For Year 6, yes.
> A: All right, I'll just get us onto the internet.
> E: Could we even look up the syllabus and see, use that to guide us.
> A: That's a great idea now that you've said that. Actually, that's something I wouldn't have thought of.

This "need to know" by seeking information from the internet and the official curriculum documents is one affordance of the slowmation process because they are designing a resource for explaining science. The 'need to know' was confirmed in the post construction interviews where one of the preservice teachers stated that her understanding developed through making the different representations and thinking about the discussions:

> As we went along, people were learning from the different things we were doing. We started with the websites but that didn't really trigger our thoughts whereas different tasks triggered our thoughts. I think because we went through so many different stages – we had the planning; we wrote down our background information; then we had drawings; then we went into the 3D models. That made us reflect more on what we were doing and we had to constantly go back and think, 'Does this connect with what we were saying before?' (Eliza)

4.2.2. Making, manipulating and photographing physical models

Once the preservice teachers had conducted some research on the causes of moon phases, they made models of the earth, moon and sun (using polystyrene balls for the earth and moon and a large yellow balloon for the sun) and took 55 min to manipulate the models whilst taking digital still images. During this step the preservice teachers realized that there was still some confusion about how to model each moon phase. Hence making, moving and photographing actual models generated discussion and helped Xena and Eliza to resolve their misconception. Making and manipulating models therefore, which is essential for slowmation in order to capture still images, is another affordance of the slowmation technique. The following dialog highlights this affordance as the group members discussed whether they had depicted the model spinning in the correct direction as they tried to show the appropriate transitions between the moon phases:

> A: Can we just see what it looks like if I can get it all on the screen? [*Alice takes photo of changing shape of light to see if it shows up on the camera*]
> A: Ok so the start would be that.
> E: Should I cover this half so we've got that half rather than the other half?
> A: Well what does the information say?
> A: Let's just quickly look at the diagram – oh, that's not my computer.
> A: The diagrams, do they match on the internet? Oh, look at this, we got this bit right. [Alice confirms that the phases that they are depicting for the slowmation match the expert-generated images found on the internet].
> E: Yes.
> A: But then look at this [*at the internet*].
> A: Oh, what are we doing?
> X: We're in the southern hemisphere.
> A: Ohh!
> E: No, we did it right!
> A: Did we do it right?
> X: Yes, but we didn't get the left side.
> E: I need to get that. See how the half is like that half?
> A: Then we need to get that right.

The use of 3D models to manipulate and photograph was key to helping the preservice teachers understand the dynamic movement between the earth, moon and sun. This interpretation was confirmed in the post creation interview with Eliza as she noted how making the 3D models helped her to resolve her misconception:

> I had a misconception that the new moon happened, like it was completely black when it was behind the earth because I hadn't thought about it in 3D where the sun is a lot bigger than the earth and can shine past the earth onto the moon. I thought the shadow of the earth would block all of the sun from the front and I thought two new moons happened; one when it was behind the earth and one when it's between the sun and the

earth. So by doing it in 3D I could see and I learned that because the sun is so large and the moon is a little bit away from the earth, that the sun actually, its light goes past the earth and you can see the full moon from the other side.

4.2.3. Stopping at any time to check information

As the term, "stop-motion" suggests, each part of the animation construction process can be stopped so that information can be checked, discussed, and then construction recommenced, which is a third affordance of the slowmation process. When the preservice teachers were writing the narration, they stopped to check the direction of the earth's rotation and they sought information from Google:

A: Okay, so we've got 'The moon orbits the earth and it takes 29 days.'
E: Yes.
A: ' … as it does so … ' Okay, so the sun – this one is about the sun?
E: Yes.
A: The sun shines light on the moon.
E: So the earth goes anti-clockwise?
A: It just rotates.
E: I don't think, which way?
A: … anti-clockwise.
E: Come on. You've got this.
A: Can you just answer quickly before we Google it?
E: Oh I'll just Google it. [*Eliza does a Google search to confirm the direction of the earth's rotation so as to accurately represent it with the model*]. Which way does the earth rotate, not orbit but rotate? Okay, I'll just Google it. All I want to know is which way the earth rotates!
A: That's good.
E: I think it's anti-clockwise but I don't want to say. [*Eliza is not confident about this proposition.*]
E: All we want … counter-clockwise. So it goes that way.
A: So what did we just find out?
E: The earth goes like this … anti-clockwise.

The slowmation process is stop-motion, enabling the creators to stop the process to check intepretation or seek clarification about any point of confusion at any time. This affordance is different from making a video, which captures images at 30 (or more) frames per second and cannot be stopped frame-by-frame whilsy it is being captured.

4.2.4. Sharing personal experiences

At different times during the animation construction, the preservice teachers shared personal experiences with moon phases based on where they had previously lived. The following excerpt shows the three preservice teachers presenting different perspectives in their discussion because one of them grew up in Canada, while the others grew up in Australia:

X: The equinox thing is a bit goofy here because you guys don't follow the equinoxes; in North America, when we do the seasons, the seasons change according to the equinox and the solstice whereas here, your seasons change on the first of the month.
A: Yes.
X: So your first day of spring is September 1st whereas our first day of fall is September 21st because that's when the equinox is.
E: No way!
X: Yes, and same at December.
E: I never knew that.
E: So our seasons aren't exactly right.
X: No, your first day of summer is December 1st, our first day of winter is December 21st when the winter solstice is.
E: So whenever I'm thinking, 'Oh it will be the first day of winter in the Northern hemisphere' it's not necessarily.
X: No, because we change according to the equinox and the solstice.
E: Which makes more sense because it's actually what the seasons are not just 'This is our calendar and this is what we've chosen.'
X: I've actually found a lot of Australians don't even know what equinox or the solstice is.

In this excerpt, the three preservice teachers were sharing personal experiences about different seasons as highlighted as one (Xena) grew up in Canada and two (Alice and Eliza) grew up in Australia. Eliza identified the value of sharing ideas from different perspectives as a key part of the learning process in her post-construction interview comments:

Xena, who is from Canada has her perspective of what the moon was like in North America so she brought up concepts like the equinox and solstice because their seasons start at different times to what our seasons start. Being an Australian, our seasons just start on the first of the month, but in [Canada], it makes sense because they start on the equinox. Just by Xena questioning some of the things that I was saying made me really think about … was I saying the right thing or whether I could explain it to her.

5. Discussion

Encouraging school students to discuss their ideas about science concepts including articulating their correct or incorrect conceptions, justifying points of view, posing propositions, and making claims has been shown to be beneficial in developing science understandings (Bennett et al., 2005; Berland & Hammer, 2012; Chin & Osborne, 2010; Lemke, 1990, 1998). Similarly, the current study showed that generating discussions amongst preservice teachers was also beneficial to enhance science understandings and enabled them to experience the type of learning that would be expected of their own future students in schools (Munby & Russell, 1994).

The discourse analysis to address the first research question showed that the nature of discussion in the excerpt analyzed mainly focused on the asking of questions (15 utterances), the posing of propositions (13 utterances) and receiving feedback on those ideas (17 utterances). Importantly, this exchange and clarification of ideas contributed to scientific reasoning resulting in the making of claims (6 utterances). A consequence is that two of the preservice teachers, Eliza and Xena, resolved their alternative conception that moon phases are caused by the earth's shadow based on an incorrect idea that there is no relative size difference between the earth, moon and sun. It should be noted that this is a common and resilient misconception held by preservice elementary teachers (Trundle et al., 2002, 2007) that often needs extensive instruction to resolve. This study therefore showed that having preservice teachers create a narrated animation to explain a science concept provided a context for generating discussions and adds to other procedures used in teacher education to facilitate discussion such as using case studies in reading education (Levin, 1995; Richardson, 1991), participating in online forums in ICT education (Prestridge, 2010) and observing video of classroom teaching in mathematics (Borko, Jacobs, Eiteljorg, & Pittman, 2008). Moreover, the simplified way of making a narrated stop-motion animation such as slowmation is an achievable task within the constraints of a 3-h science education class.

Data collected to address the second research question showed that slowmation had four key affordances or "action possibilities" to support the preservice teachers in generating discussions about a science concept. First, creating a slowmation generated a 'need to know' because the preservice teachers were aware of the authentic purpose to make an explanatory resource for Year 6 children. Moreover, this affordance "frames" the task, which is so important in promoting the type of discussions that result in the sharing of correct and incorrect ideas, checking information and making propositions that results in scientific reasoning (Bennett et al., 2005; Berland & Hammer, 2012; Chin & Osborne, 2010). Thus by making their ideas explicit, our case group of preservice primary teachers made many decisions about which models to use, how to manually move the models to take digital still photographs, which images to use and how to get the narration to complement the images that resulted in their improved understanding of science. Discussion was also supported by other affordances of the construction process such as the making, manipulating and photographing of the models, being able to stop at any time to check interpretations and the sharing of personal experiences.

Furthermore, the discussions were ongoing throughout the construction process because the preservice teachers made many decisions about how to use technology to design and create physical artifacts to represent the science concept. In particular, the concept of moon phases is dependent on relative movement between the sun, moon and earth and so is a suitable topic for this type of 3D manipulation of models. For example, their first representation of research notes included writing summary notes about "phases of the moon." This led them to discuss how different types of models could be used to represent the moon's phase changes. At first they considered using 2D models (e.g. paper cutouts), but quickly realized the challenge in representing the relative movements between the moon, earth and sun in two dimensions. A subsequent discussion resulted in the decision to make and use 3D models (polystyrene balls on sticks and a balloon for the sun), because the 3D movements could more accurately depict the relative movement between the earth, moon and sun. Once they started to use the 3D models, other questions arose about how phases of the moon occurred and so the group kept checking and clarifying their understandings during the model construction. The final part of the construction process involved uploading the digital photographs into the movie-making software on a computer to edit and integrate multiple modes of communication such as speech, writing, still and moving images to produce the narrated stop-motion animation.

A limitation of the current study is that it involved only one case group of three preservice teachers and they self-selected when we asked for volunteers. But, given that previous research also involved small numbers of case group participants, the current paper adds to the growing literature on why slowmation is a valuable teaching and learning technique for particular concept areas in preservice teacher education. Concept areas could include any topic that involves relative movement such as physics topics and others that involve change such as life cycles and geologic processes. Repeating the study with a range of learners such as other preservice teachers and school students, offering wider resources and using a range of topics would confirm the findings of this study in regard to the affordances of the stop-motion animation process to generate discussion. In particular it would be useful to repeat the study with a full class or cohort of preservice primary teachers to confirm that this type of task can be conducted within the time contraints of a typical 3-h science method class. Moreover, conducting additional studies using a quasi-experimental design with groups that use different forms of representations such as expert-generated animations or other types of student-generated representations such as making a poster would provide useful comparisons to more traditional classroom activities.

6. Implications

There are several implications from this study regarding the use of slowmation in teacher education classes. First, this study shows that preservice teachers can create simplified animations as a new way to engage with and discuss content within 3 h, which is the timing for a typical teacher education class. Up until now there have only been a few studies where students have constructed animations to learn science but all have involved the use of a specially-designed software to support the process (Chan & Black, 2005; Chang et al., 2010; Schank & Kozma, 2002). Also, none of these studies involved students in teacher education classes. By way of contrast, the simplicity of the slowmation construction technique and students' common access to technology tools suggest that slowmation may provide opportunities for widespread use in teacher education classes as a technique for generating discussion. Using generic movie making software that is already on the preservice teachers' computers as well as their personal mobile phones to capture images makes the process achievable in a teacher education methods class. In particular, this study shows that the process of making a slowmation about a difficult topic such as phases of the moon may also be suitable for other topics involving change and relative movement. Importantly, preservice teachers can experience the type of group interactions that they would anticipate of students when they are teaching in schools. In addition, we suggest that it would be worthwhile for a teacher educator to make explicit to preservice teachers the type of utterances generated that leads to scientific reasoning and draw attention to what this means for their own teaching in schools.

A second implication is that the use of mobile phone cameras and electronic tablets such as iPads creates additional possibilities for using stop-motion animation in different locations. It does not surprise us, however, that getting preservice teachers to create animations to explain science concepts in their science teacher education is uncommon. We attribute this to the crowded curriculum in a science methods course and the time-consuming nature of making stop-motion animations in a traditional way. However, because of the simplicity of the slowmation technique, preservice teachers can learn how to make a slowmation during a 1 h lecture or workshop and then create their own at home. Additional educational value would be gained if the preservice teachers shared their digital explanations on a website or on a learning management system with other preservice teachers setting up the possibility of peer review.

A third implication is that slowmations can be made in subject areas beyond science. Many examples of slowmation created by preservice teachers and others can be found on YouTube, and these involve a range of concepts beyond science including the history of civil rights in the US, Aboriginal ways of knowing, Pythagoras' theorem, geographical change processes and geometry concepts. Evidence of this already exists as shown in the 2000 examples on YouTube by searching on the word "slowmation". The number of plastic models in school and university laboratories could readily enable use of the stop-motion technique as an assignment for many other science concepts, e.g. models of atoms for organic and inorganic chemistry; models of cells and human organs in life sciences or health; models of landforms in geology as well as a range of equipment in physics.

Another implication of this study is that getting preservice teachers to discuss science content may have a flow-on effect for getting school children to discuss science in schools. In our science methods courses, many of our preservice teachers have shown the slowmation they made to primary children whilst practice teaching in schools and some have developed tasks for the children to create their own. The most common use involves school children making a slowmation at the end of a science topic as an assessment task to represent what they have learned. Additional class discussions can examine the accuracy of the representations in the slowmation in peer review and make recommendations for improvement. Reviewing publicly available slowmations (on YouTube, for example) provides an additional option for classes in different settings to show and evaluate each other's digital media.

A final implication is that getting learners (university students or school children) to create slowmations as instructional resources is a new way for them to develop digital literacies and become aware of the affordances for using different modes of communication. Current literature in science education has emphasized the utility of learners making decisions about which modes to use in the process of constructing their own representations of a science concept as well as the value of re-representing these ideas (Hand & Choi, 2010; Prain & Waldrip, 2006; Tytler & Prain, 2010; Prain & Waldrip, 2006; Yore & Hand, 2010).

Whilst some people might consider stop-motion animation to be "old technology", this study has shown that it has particular affordances to foster discussion and could be the focus for further research. This could include studies to develop insights into how preservice teachers and school students might learn science concepts through the creation process with particular attention to how they use different modes to represent ideas and make meaning. Preservice teachers and school students are increasingly creating digital media to upload to web sites such as Facebook and YouTube for social purposes (Clark, Logan, Luckin, Mee, & Oliver, 2009), which will only increase with further advances in personal digital technologies and Web 2.0 capabilities. We believe that many of these same media making skills can be used for educational purposes such as explaining content using narrated stop-motion animations. Engaging with content in this way promotes discussion about key concepts and improves digital and multimodal literacies that are increasingly important in the 21st century.

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