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Enhancing Preservice Teacher Learning through Slowmation Animation*

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This paper is an exploration of conceptual change. It reports on a study which utilizes conceptual status elements, and explores the unique contribution of Slowmation Animation in the conceptual learning of preservice science teachers. 15 short animations were created by 55 participants in a single two hour tutorial class as a part of their methods training. Conceptual change was found to occur when their animation topic challenged their understandings of the processes within the scientific concept. The preservice science teachers reported an enthusiasm for Slowmation Animation as a method for learning how to learn, as well as for highlighting what they thought they knew, but didn't really know.

Keywords: conceptual change; slowmation animation; secondary science; preservice teacher education

1. Introduction

1.1 The use of Wed based and ICT technology for learning

There have been many calls in secondary and higher education for increased use of Web based and ICT technology in teaching to improve the learning of students. The education of prospective Engineers is no different [1–6] with several special issues of IJEE dedicated to Web and ICT inclusion in engineering courses. Many of these studies use web based or program based animation software [1, 2, 7, 8] to build and/or consolidate the knowledge of students.

Park et al. [4] investigated using 3D simulations instead of 2D visual aids in teaching industrial design to manufacturing engineering students. The results revealed that students were initially impressed with the novelty of the 3D simulations but it had little lasting impact on the students' learning. The researchers offered several reasons for this, the mode of instruction did not change, the knowledge learnt was not tested for, and the "attentive newness" [4, p. 847] decreases rapidly over time. It seems novelty engages in the short term but has no lasting impact on learning.

Lundgren and Jonsson [1] used specifically designed animations to consolidate the knowledge of engineering students about the semiconductor operations, particularly *drift* and *diffusion*. These concepts had been found to be difficult for students to understand correctly. The authors were surprised to find ". . . that what is intended to be shown in the animation is not automatically perceived by the user. Even those properties of the animation that seemed rather obvious to the interviewer were not at all obvious to the user" [1, p. 13]. The way the animations were used revealed alternative conceptions that the students contained that were unexpected to the researchers which hardly consolidated the knowledge as anticipated. In evaluating this study, for their own research, Donnelly et al. [8] suggested that part of the problem was that the students had no input into the creation and design of the animations. They concluded, ". . . using the materials did not change one of the students' incomplete conceptualization-given what is known about the intractability of misconceptions, this is not a surprise" [8, p. 159]. What is portrayed here is that students 'see' what they believe in the simulation, reinforcing their own alternative conceptions of the phenomenon, consolidating 'their understanding' not the understanding of the animation creator.

This work and others like it, is in contrast to the authors of this paper and researchers such as Church et al. [3] who advocate using student made slow animations or stop animation (called Slowmation, see slowmation.com.au for full explanation and examples). Church et al. explain the reasons why slowmation is appropriate for engineering students and particularly high school students aiming for an engineering degree in the future:

> It has been shown that students who are interested and motivated (manifestations of engagement) think more critically, become more excited in furthering their knowledge, develop greater conceptual mastery of the domain and retain the material better than students

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> who are taught in traditional content-delivery environments [9–11]. To maximize these benefits, learning environments that provide multiple representations of content, multiple forms of expression and multiple means of engagement are essential. Engineering as a pedagogical vehicle in the classroom provides for exactly these traits. The process of design, construction and testing (whatever the content or material) creates an active learning environment where students can construct knowledge. Such engineering-based environments satisfy the need for multiple modes of access to content and at the same time provide students with alternative ways to demonstrate their knowledge. Currently, we are keen on developing a process parallel to engineering design, one where students define a problem and work toward generating animated solutions based upon solid mathematical and physical modelling. The process under consideration is stop-action movie making [slowmation]-an approach that embodies the qualities of an effective learning environment. [3, p. 861]

The difference between slowmation and watching pre-constructed animations is that in small groups, students discuss their understanding of engineering or science concepts and through a cycle of multimodal representations work together to demonstrate their understanding of a complex abstract scientific idea. It is in the interactions between the learners during the transformations between modes that learning is challenged, remodelled and consolidated. There are also several opportunities for the lecturer or teacher to monitor and counter alternative conceptions. But addressing Donnelly et al.'s [8] concerns, here the students not only have input to the animations, but ownership of the knowledge they are presenting.

1.2 Monitoring and countering alternative conceptions in preservice teachers

To ensure a constant flow of high school graduates entering university engineering courses, we need to ensure they are exposed to the best pedagogies and learning opportunities in the sciences when at high school. We cannot ensure this if the teachers are not competent to teach not only the content, but the analytical and processing skills also. It is therefore vital that preservice teacher education methods courses are creative, that they offer Web based and ICT learning opportunities, using technologies familiar to the learning [7]. However, it is a difficult call to expect a preservice teacher to have complete conceptual knowledge across astronomy, biology, chemistry, earth science and physics when their typical university degrees are quite narrow. Many preservice and newly qualified science teachers have gaps in their knowledge, and being able to identify and fill these gaps is half the battle [12]. In addition to meeting conceptual knowledge requirements in the classroom, the preservice and newly qualified science teacher is required to be technologically literate and able to integrate computers into science activities. It is reasonable to assume that gaps in preservice and newly qualified science teacher technological knowledge is partially responsible for Songer's [13] finding that "computers and network technologies are often under-utilized and poorly integrated into core science education activities" [13, p. 471]. This paper aimed to explore conceptual change in preservice science teachers as they investigated abstract scientific concepts through the creation of Slowmation Animation movies. The preservice teachers were "learning with technology" [14, p. 1]. Jones distinguishes between learning with and learning from technology, in that learning from technology involves passive learning from a web page, a video or an audio recording as described above by Lundgren and Jonsson [1]. Learning with technology is "when the learners are actively engaged in a learning problem while using technology to solve that problem" [14, p. 1; 3]. Instead of watching a video, the learner creates a video. The purpose of this paper, then, was to explore the "learning with technology" by preservice science teachers when the technology is 'Slowmation Animation'.

1.3 Slowmation animation and science learning

'Claymation' involves the use of clay to create characters, scenery and props. These are then used to create a video in a stop motion format using a digital camera. Minute changes to the characters and props between each photograph create the appearance of movement on the screen. 'Slowmation Animation' is a simplified version of 'Claymation' that uses many of the same learning processes—"researching information, planning and writing a story, storyboarding, designing models, taking digital photographs, using visual literacies, using technology, evaluating and, most importantly, working collaboratively as a team" [15, p. 27].

This paper aims to drill down into the research on slowmation to investigate more fully how the learning processes interrelate when learners are engaged in making such animations. Further, Hoban, Loughran and Neilsen [16] state "It is clear that further research is needed to study how learners in different contexts use their own technology to design and make multimodal animations to represent science concepts" [16, p. 1004]. Yore and Treagust [17] also note that there is a need to investigate "the enhanced cognition that occurs during the transformation from one representation to another representation or one mode to another" [17, p. 208]. Author 1 uses slowmation to "explore the science conceptual learning of preservice teachers as they create their own understanding whilst moving between representations. Kidman [18] explained that her purpose is to probe secondary preservice teachers "learning through technology" rather than "learning from technology" when creating slowmations. According to Howland, Jonassen and Marra [19], for learning that is supported by technologies, the learner will inquire, experiment, design, communicate with others, build models, write and visualise. This combination of skills enables deeper levels of thinking and reasoning. Our purpose, with secondary preservice teachers, has been focused on the learning and understanding of the science concept being examined within the processes of creating a slowmation rather than the finished product. As Howland and her colleagues point out: "technologies are lousy teachers, but they can be powerful tools to think with" (p. 17). We have added the emphasis to 'think', as we consider it essential for the creator of a slowmation to think about the science concept they are representing in order to gain any understanding of that science concept.

The question arises, how can learning with technology be used to effect conceptual change in preservice science teachers? More specifically, the research questions addressed by the current project were three fold: (a) How did the preservice teachers use the 'Slowmation Animation' to represent their conceptual knowledge? (b) To what extent did the preservice teachers demonstrate conceptual change? And (c) In what ways did the 'Slowmation Animation' support preservice teacher learning during the project?

2. The design/procedure

The overall approach to the project was based on the "constructionism" theoretical framework promoted by Papert [20, 21]. Papert first used the term "constructionism" in his 1987 US National Science Foundation grant (award number 8751190) entitled "Constructionism: A new opportunity for elementary science education". In the abstract for this NSF grant application he explained the term: "The word constructionism is a mnemonic for two aspects of the theory of science education underlying this project. From constructivist theories of psychology we take a view of learning as a reconstruction rather than as a transmission of knowledge. Then we extend the idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing a meaningful product" [21]. Papert contended that students engage in deep learning when they research, design and construct an artefact or model as a representation of their knowledge. This theoretical framework has evolved from Information and Communication Technologies but has not been widely used in science education because of the lack of a process that is simple enough to enable learners to use technology to create artefacts to represent science concepts.

In the project, 55 preservice secondary science teachers formed groups of four, to jointly develop short Slowmation Animation videos during a 2 hour tutorial class. The preservice teachers had previously self selected into three tutorial classes as a part of their methods course. Within each tutorial class, small groups of four were formed by the participants on the basis of friendship. Each tutorial class was shown a short segment of a Wallace and Gromit video as an example of a Claymation movie, and given a short verbal and text description of the Slowmation Animation process. The tutorial class then spent about 1 hour familiarising themselves with their self selected scientific concept (approximately 45 minutes with access to the Internet and an assortment of secondary school and tertiary science text books), the plasticine materials and the Slowmation Animation processes (approximately 15 minutes). The aim of this process was to enable those with no Claymation experiences to gain some knowledge, though limited, whilst they researched their topics and planned their video. The tutorial class then proceeded to create their video. A digital recorder was placed in the centre of the work space for each group in order to record the conversations. These recordings were later transcribed for analysis. Additional data collected was in the form of planning artefacts and a completed video from each group, and a video recording of each group's verbal explanation of their video to the class.

3. Findings/analysis

3.1 Background knowledge and chunking

We have identified key stages for the preservice teacher to move through in working with slowmation. The first stage is the prior knowledge or background knowledge that the learner brings to the task. The learners often begin slowmation with the knowledge they have. This initial stage of learning is the deconstructing of the Background Knowledge of the learner. The learner identifies their background knowledge, and makes it explicit with the intention of sharing it with the group. This is called the Chunking stage, and whether it is done as a chunking sheet, storyboard or dot points, the purpose is to bring to the group each learner's understanding of the concept. Using Peirce's model of Semiotic Systems, Kidman et al. [22] considered background knowledge to be the object (referent), the chunking task is the representation and Making Meaning (Fig. 1) is the meaning. However, how is learning informed here? We propose that at this initial stage, the group can choose to accept one representation of the chunks (surface learning) or through discussion and planning agree by consensus on the key 'chunks' that need to go in their slowmation (deep learning). For the individuals in the group to make meaning of the concept, they move through Vygotsky's Semiotic Mediation, intermental thinking (sharing prior knowledge as a group) becomes intramental thinking (internalized knowledge) through the signs the group use (their discussion, diagrams, and planning). This represents the "recursive checking of information" [16, p. 1002).

Once the 'chunks' are agreed to, the group needs to reconstruct the knowledge. At the second stage, the group constructs the models, takes the photos and then builds and edits the animation. By taking the chunks as the object, and creating representations in the form of models and the animation, the learner makes meaning of the concept. The learning at this stage occurs as the learners are involved in Vygotsky's Semiotic Mediation—they discuss their ideas and understanding, grapple with production as they translate chunks into models, and reconstruct the chunks into a coherent process as they construct models and animate these.

The intermental thinking is based on the chunking concepts they have developed, as the preservice teachers build models and animate them, they are individually involved in thinking and problem solving (intramental thinking). Their learning is mediated through the discussion, constructing the models and creating the animation. In this model,

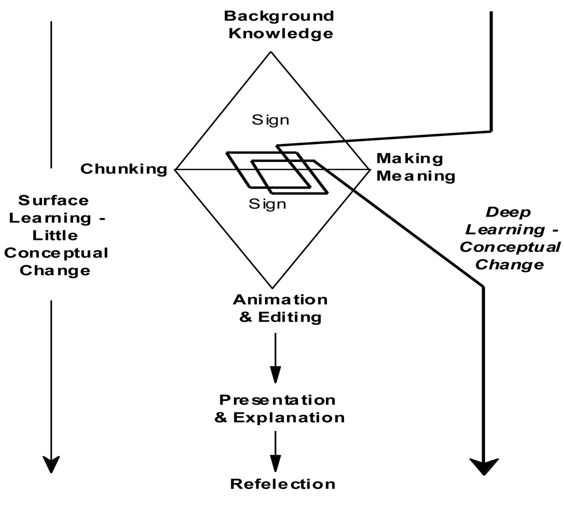

Fig. 1. The Learning MMAEPER model (modified from [22]).

learning occurs when background knowledge is socially chunked allowing individual's "making meaning"; the MMAEPER (pronounced mapper) is the part of the model, that through signs, an agreed external representation is released to reveal the learning. The left hand side of the Learning MMAEPER model represents surface learning.

3.2 Surface and deep learning

In the third stage of the Learning MMAEPER Model, the learners present their animations and explain them. Learners present their animations and explain the scientific process to their peers. Typically the teacher/lecturer will ask questions (and often peers as well) to ascertain the accuracy of the representation. Often these slowmations are not polished pieces, rather they are an artifact of the process of the learner's knowledge construction from the prior knowledge they brought to the task, compared to that which they had at completion. This explanation stage is critical as it is an opportunity for the learner to talk their way to understanding as they stand in front of their peers and show their slowmation.

While the above explanation of the Learning MMAEPPER Model represents the learners deeply engaged in both their own learning and the slowmation task, there are those who only surface learn when creating a slowmation. A group may move down the left hand side of the Learning MMAEPER model and rarely engage with the kinds of discussions that help learners internalize or enhance their understanding of the knowledge—undergo very little conceptual change. They may feel they are expert and the ideas need no further explanation, or they may feel out of their knowledge comfort zone and feel they know little about the topic or concept. There may be a dominant member in the group who takes control and the group has to follow them.

To tease out the difference between surface and deep learning along with conceptual change that may occur when creating a slowmation, the authors of this paper employed their "Model of Translation between Representations" [15]. Fig. 2 presents this model which is useful in recognizing the processes learners engage in so that creating a slowmation involves learning for the learners. The authors believe this to be a useful model to allow teachers to recognize deep learning from surface learning as it identifies the key elements of learning in slowmation and could be a useful guide to move their learners towards deep learning by asking key questions. When learners reconstruct the knowledge using their own representations and are satisfied with their explanations of the links between their

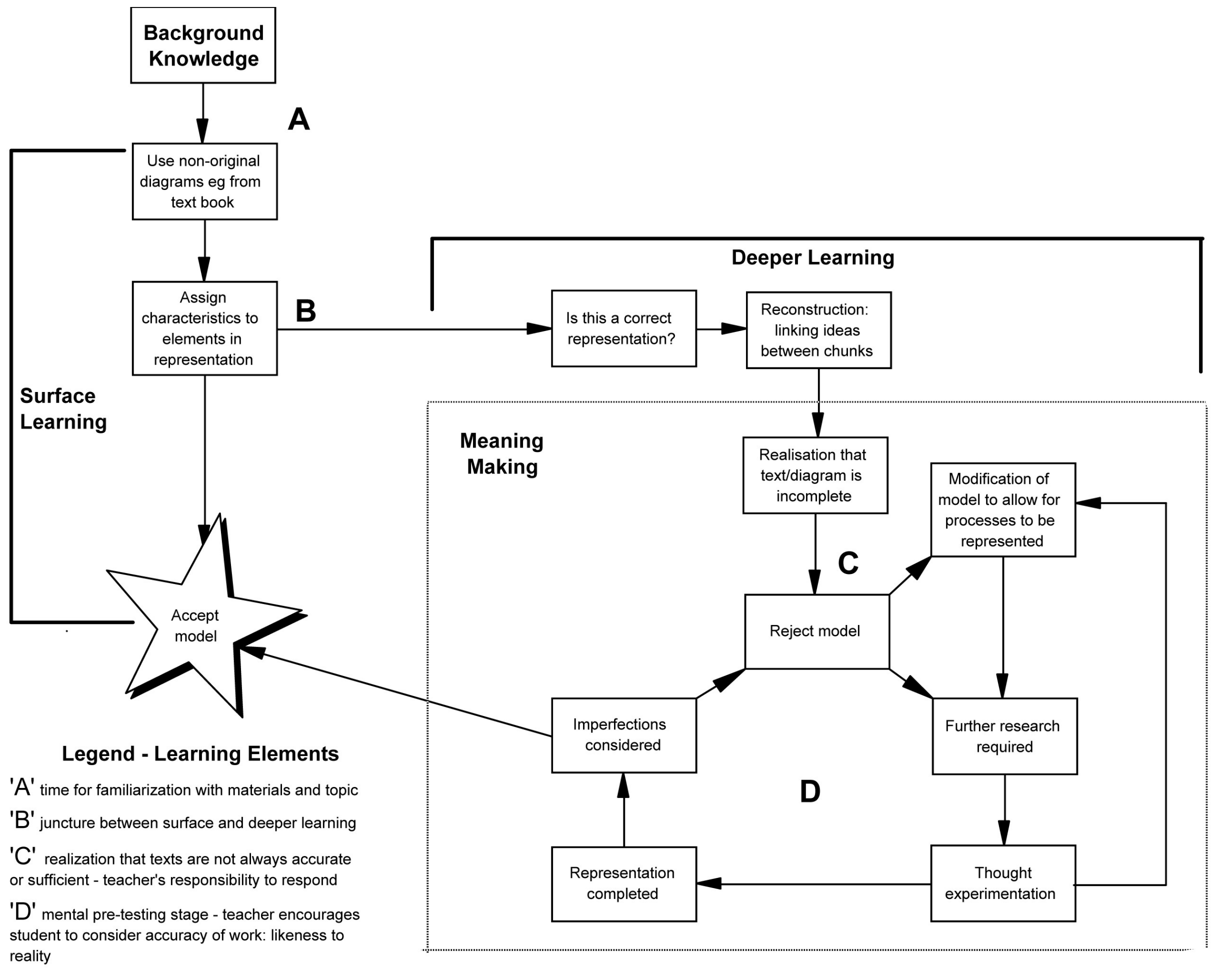

Fig. 2. Model of learning and relearning through slowmation (Source: [22]).

chunks, it is a good indication of the process of deep learning.

In the Learning and Relearning Model, there are two pathways and four learning elements. An initial recall or copying of a diagram is often used to familiarize the learner with the concrete model making materials. Should the learner simply accept this diagrammatic representation, or perhaps just change a few aspects of representation by adding in information from a separate source, the learner can simply create their movie and be "done". Very little analysis of the visual representation is made. This is best considered as surface learning with low conceptual change. The focus or purpose is on the production of the movie, and not on the quality, accuracy or originality of the science concept presented in the movie. Tell tale signs that surface learning is occurring in the learner were found to involve them making comments like "It was there in the book, all the stages, so we just made them. I don't know how we would have gone if we had no diagram to begin with. It is interesting we found it easy and quick to do, while the others took so long" (Kimberley). If allowed, it is easy for the learners to get caught up in making pretty presentations rather than focusing on the accuracy of the scientific explanation. The teacher needs to continually push the learners to think about the science. The learning of science needs to occur as part of the process of creating slowmation, and this needs to be the focus, not the summative assessment—that of producing an animation. Surface learning tends to occur when the slowmation replicates the representations in the text/s.

Should the learner be more inquisitive about the science processes involved, and have a desire to produce an accurate and perhaps original movie of the science concept, then the learner moves into the deeper learning section of the learning and relearning model. Deeper learning occurs in those who explore the science by engaging with the abstract science concepts and processes as they move between representations. For deeper learning, there is a need to check and double check the scientific processes being represented. This recursive checking of information may be via referring back to support material and will manifest itself in the classroom as discussion and negotiation among group members. Another indicator of deeper learning is by contemplating the concept and reconsidering the processes against background knowledge. Kidman [18] likened this to Justi and Gilbert's [23] thought experiments where the model is tested in a mental state—"I imagine it actually happening. Like, I twisted and turned our model in my mind to check it was doing what we needed it to do. If it was misbehaving, I would suggest changes to my group" (Simon).

Unfortunately for some learners, especially those creating a slowmation from a reduced background knowledge relating to the concept; they flounder in the actual task of creating a movie. Sometimes groups are unable to produce a final product. Understanding and making meaning may take precedence over all other activity: "It is all very good to draw the bits of the cell at various phases of division, but nothing is telling me how it moves to a next phase. I mean, is there a hormone? Or a chemical or a a a . . . like a brain structure sort of thing that governs it. Nothing happens in isolation. There has to be driving force, but what is it and where is it?" (David) "Until we can find that missing force, we are stuck. We don't know how to proceed, and interestingly, the biology and chemistry folk don't know either" (Mark). David, a preservice physics teacher saw there was a link between conceptual knowledge and pedagogy: "this is a scary awakening for me. I know I don't have to know it all, but have the skills to figure it out at an appropriate level. But today I failed terribly. I could not let go of the need for an answer. If that was in the classroom, I would have a disaster lesson". For the preservice teacher, the creation of a slowmation allowed them to experience deeper learning from two complimentary lenses—that relating to the scientific conceptions, and that relating to pedagogy.

3.3 Learning elements

In addition to highlighting surface and deeper learning, the model of learning and relearning through slowmation presents four learning elements—each is crucial if learning is to occur: 'A' indicates time needed for the familiarization with the concrete materials and topic. 'B' indicates the juncture between surface and deeper learning. By becoming aware of surface and deeper learning through slowmation, the preservice teacher can see it is possible to teach from a surface learner perspective. That is, a teacher can supposedly 'teach' something that they have 'learnt' via surface learning, and this is a concern: "That is not going to be good enough if we have to teach it. What if a student is actually thinking about how it works, like a deep learner, what do I do then?" (Suzie). Learning element 'C' relates to the realization that publicly obtained texts and or diagrams are not always accurate or sufficient, and that it is the teacher's responsibility to respond accordingly. This element blends conceptual knowledge with pedagogical knowledge as described by Mickey, a chemistry preservice teacher: "It's funny. The text book uses all nice colours, but logic tells me it is impossible to see these colours because we needed to use a blue stain. It all looked varying shades of blue. How do I deal with that in the classroom?" Learning element 'D' is a mental pretesting stage where the accuracy of the model is considered—to consider a likeness to reality: "You know, like I need to check my answers in maths, I need to get the kids to check their ideas in science too. I want to tell them to remember all they did, and to sort of relive the experiment to see if the answer makes sense. I do the same here. I ask myself if my representation is the same but different—an improvement—from what is shown in the book. It is important for teaching that I get it right" (June). The teacher can use this mental retesting in the classroom by not having to reteach ideas, but to ask key questions and let students work through their ideas towards a better understanding.

3.4 Conceptual knowledge

Pre-service science teachers were able to represent their conceptual knowledge through Self Generated Questions (SG), Argumentation (A) and, via a need for Attention to Detail (AD).

Group conversations revealed self generated questions which indicated that the preservice science teachers were intellectually engaged with the science topic at hand. Many self generated questions were concerned with the real life physical appearance. Appearance, or visual image, seemed more important than the processes involved in terms of self generated questions as the following excerpt indicate: (SG 2) "We are using shapes to show different bits. What do you think the real bits look like?" Not all groups used argumentation to represent their conceptual knowledge. In one group, what initially appeared to be a simple error in the use of the word 'symmetry', quickly became an exploration of symmetry, resulting in the self generation, through argument, of meanings for symmetry, size, and congruence: (A 1) "No not symmetry. That is a maths topic not science. It means if you cut it in half each half matches the other." (A 2) "A maths topic? No, not just a maths topic. It is everywhere, so there will be symmetry [here]. But you are using a wrong word. You don't want symmetry in the shape sizes. You mean size." (A 2) "Yea that's what I said, size." (A 3) "But you said more—the symmetry bit.

Symmetry is different. It is not relevant to what we are doing. You need to say the word that means "all the same size, shape, dimensions" sort of thing. Congruence? Maybe? There is another word though. (A 4) Congruence triangles. I remember them. We have triangles and they SIMILAR. SIMILAR is the word. We need similarity in our shapes." The need for attention to detail was present in all groups. Appearance was important but so was a need to be attentive to terminology. The creation of a slowmation video is very kinaesthetic. There appears to be a hidden visual learning component. The participants needed to get the appearance right according to their common understanding of the topic. Alignment, scale size and similarity were issues openly discussed in all groups, for example: (AD 1) "Is there a size ratio thing between say the length and width? and thickness?" Occasionally a group would also focus on the scientific processes involved as shown in the following excerpt: (AD 3) "Oh no! We didn't check the direction of the spiral. It goes clockwise . . . or is it anticlockwise when it spirals? We just unravelled it. It could be wrong!" Terminology was an important concern as it generated discussion on the need for correct terms instead of lay terms as shown by the following: (AD 2) "You mean the landmarks not bits. It is important to use the correct names or we will get confused. Keep it accurate". In addition to this, there was a very productive discussion relating to the incorrect usage, and subsequent narrow definitions of a term.

Slowmation Animation has shown to be an interesting activity enabling the exploration of preservice teacher's new conceptions from a variety of status elements. Plausibility became evident through discussions of past learning experiences and epistemological ideas: "I've done [this] a few times. In school we did it . . . and used a text to write down phases but I don't recall phases correctly. I now realise how little I know. Well it comes back to me a bit when I read it, but I don't know it. I cannot teach it from the cuff like I can some other stuff" [Arthur] and "Well I just thought that if we showed the bits moving from the middle to the ends, then it would be OK—'cause that is basically what [it] is. I didn't think about getting it accurate, but now I think about it we should not teach anything unless it is accurate or we will get the wrong ideas across. My ideas have now changed, and I think I understand this a lot more" [Michelle]. None of the preservice teachers indicated the status elements of fruitfulness during the 2 hour tutorial class. However, one student reported back after a four week school based practicum: "I did not get assigned to the class, but when I heard what they were doing, I asked to sit in. It was so cool as I had this secret little voice inside me saying 'I know this! I know this!' . . . the teacher asked me if I would like to make a comment. So I told the class about what we did last semester. The students were interested and the teacher quickly changed her lesson and let me walk the class through the storyboarding task. . . . We didn't have time or equipment to do it properly, but just doing storyboarding made the lesson enjoyable for the class. The teacher was going to have them summarise the text, but by doing it my way, the class was engaged and hopefully will remember the basics better than I did when I did a text summary at school" [Michelle].

3.5 Challenging alternative conceptions

Many preservice teachers are reluctant to participate in whole class discussions in case they offer wrong answers and suggestions. As the video is a group effort, the atmosphere during the sharing session was very supportive as it is not clear where an alternative conception originates. Arthur, a preservice teacher, felt demoralised as his group's movie was not scientifically accurate. The following discussion took place during the explanation of the video to the class: "You could make another one that is correct, so all is not lost" [David], "Yes, but this one is still a lost cause, because it needs to reflect the science concept accurately otherwise you have wasted your time, and will teach the kids incorrect stuff" [Arthur]. "Ah, but that is where you have to think 'outside the box'. You have a video with errors—do you know all the errors? . . . well? Do you?" [David] "um, no" [Arthur and Michelle]. "Good, see the teacher does not need to know everything. You could give this dud one to the class, maybe in groups or as a whole class activity, and have them identify the incorrect science" [David] "YES YES (Arthur shouted enthusiastically) I see it too. If we made another one that was accurate, we could ask them to identify which video represents the correct process. Sort of like a spot the difference and explain each difference in terms of reality. Brilliant idea Dave" [Arthur]. There were numerous examples where the activity allowed the development of a supportive atmosphere where the preservice science teachers could develop their conceptual knowledge.

4. Discussion

There is scant published research pertaining to the use of Slowmation Animation in science and engineering education— the small number of papers are mostly procedural in nature. Very few, if any investigate "the value of the teaching approach for student learning" [24, p. 2]. The MMAEPPER model presented in this paper, may prove useful for teachers and lecturers of science and engineering that use slowmation to monitor the types of learning that occur in their classrooms. What Hoban et al. [16] observed in their research occurs when individual primary preservice teachers create slowmation from their own research, moving from Background Knowledge, to Chunking, and to Animation and Editing. However, for the authors' secondary preservice teachers working in groups or observing groups, much of the learning occurs when the learners engage in Vyogotsky Semiotic Mediation, taking knowledge created socially and internalising it for themselves. The Making Meaning addition is important as it represents this internalisation of science understanding by the learner. Further, the authors found that Kidman's model of surface and deep processing adapted for slowmation was insightful for teachers and lecturers as an explanatory model of learning when creating slowmation. As a guide, this surface and deep processing could assist teachers to monitor the learning of their students and direct them to deeper understanding [3] of the science concepts.

This study relating to secondary preservice teacher education indicates that deeper conceptual and pedagogical learning takes place when slowmations are created by small groups of learners. This socialisation enables multiple opportunities for the discussion and questioning of understandings of phenomenon, negotiation of external representations based on the learners internal representations, resulting in making meaning of the science phenomenon. Deeper learning will not occur unless there is this recursive checking of information at multiple times during the creation of the slowmation. The authors have found that learning can be viewed through two complimentary lenses: that of conceptual status and change, and that of pedagogical knowledge. Further work is needed to explore just how deeper conceptual learning occurs via the creation of a slowmation by either preservice teachers (both primary and secondary) or by school aged learners. Likewise, further learning is needed to explore the pedagogical uses of slowmation by preservice teachers (both primary and secondary). Finally, it would be interesting to understand how conceptual knowledge and pedagogical knowledge blend for preservice teachers using slowmation as a tool in science classrooms.

An interesting observation was that as preservice teachers experience slowmation animation for the first time, they have an initial focus on the visual appearance of the concept which later moves on to include aspects of the processes and functions of the topic when considering self-generated questions. Attention to detail in terms of scientific accuracy is not an initial concern. To some preservice science teachers, accuracy becomes an all too consuming concern. In terms of measuring conceptual status and conceptual change, slowmation animation has shown to be an interesting activity enabling the exploration of preservice science teacher's new conceptions from a variety of elements. Conceptual change may be evident when a preservice science teacher becomes dissatisfied with their conception and representation of a concept. This dissatisfaction can lead to conceptual change sufficient to build enough confidence to take over a class and present the topic without any planning. On the other hand, dissatisfaction may highlight further gaps in the preservice teacher's knowledge preventing them from achieving a level of confidence sufficient to teach the topic. Further research is needed to assist preservice teachers to recognise dissatisfaction and cope with conceptual change in order to reduce the impact of gaps in their knowledge. Further research is also needed in supporting preservice "to critically evaluate and communicate their scientific ideas with others" [13, p. 464] during the use of ICT's.

The authors recommend further research work to be conducted with primary preservice teachers that explore their conceptual and pedagogical knowledge development as they create slowmations in small groups. Similarly, it would be interesting to explore the quality of teaching resources that could be created by secondary science preservice teachers that takes into account the accuracy, originality of the representations of the concept, as well as the pedagogical uses of such a slowmation. To date, an emphasis on a polished slowmation product that accurately depicts an abstract scientific process has not been used in the secondary context.

5. Conclusion

Preservice teachers were able to create models, takes photos and animate them using readily available software programs. The animations represented the preservice teachers' conceptual understanding of the scientific phenomenon they were studying. Often this process led the preservice teachers to revaluate their conceptual understanding and its scientific accuracy through semiotic mediation.

Once confronted with the inaccuracy of their animation or modelling, several paths of learning were open to the preservice teachers. Using the 'Model of learning and relearning through slowmation' to analyse the preservice teachers in this study, it was found that the level of conceptual change depended on the path taken. Preservice teachers who worked with the surface learning arm of the model, recognised their inaccuracies and accepted them with little or no change to their conceptual understanding. While preservice teachers who worked through the cyclical deeper learning structure grappled with modifications to their models and through semiotic mediation developed new understandings, recognised their limitations but continued until consensus was reached. In this way preservice teachers working within the deeper phase had their conceptions challenged, and through several iterations worked towards a better understanding of the phenomenon.

The preservice teacher learning occurred in the 'meaning making' section of the MMAEPER model and deeper learning section of the 'Model of learning and relearning through slowmation'. In answer to the focus question, learning with technology does not necessarily help preservice science teachers to learn. Using technology to produce animations that requires them to engage in semiotic mediation and deeper learning does have the potential to challenges their conceptions of scientific phenomenon in ways that encourages rethinking their conceptions and this leads to conceptual change. It has been established in this paper that slowmation can produce cognitive dissonance the precursor to conceptual change when preservice teachers work together on making a model that they recognise is not scientifically accurate. What happens from this point determines the level of conceptual change in the preservice teacher.

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