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Exploring how creating stop-motion animations supports student teachers in learning to teach science

Abstract

This paper reports on an exploration of teaching and learning through creating rudimentary stop-motion animations set up to identify how learning opportunities involving stop-motion animations can support student learning and science teacher education. Participants were student teachers, volunteers representing both secondary and primary teacher training courses from three universities in England. Their discussions whilst making an animation themselves were recorded. Six of the secondary trainees were later interviewed after having taught using animation on placement in school. Thematic analysis of the content of the recordings and interviews showed that the student teachers view the opportunities that making an animation creates for peer discussion as the most likely to promote learning. Modelling was also seen as beneficial though no one particular activity or stage in animation creation stood out as being more effective than another. It is the holistic process of representing and re-representing one's scientific knowledge in different modes that made animation creation appear to be so useful in bringing about and supporting learning. With respect to teacher education, the student science teachers reported that making animations themselves supported them in thinking through the process of how, as teachers, they would need to communicate the underpinning science to others.

Introduction to the Problem

A key aspect of science teacher education is the need to teach student teachers how to communicate science concepts to pupils. This can be difficult as many concepts underpinning explanations of scientific processes cannot be easily observed by pupils. They may be too small (molecular structures), too fast (inelastic collisions) or on too large a scale (planetary orbits) (Webb, 2010). Teachers commonly use models such as simplified representations in diagrams, three-dimensional figures and analogies that highlight the key features they wish to draw pupils' attention to. Harrison & Treagust (2000) helpfully wrote up a typology of the many kinds of models frequently found in science teaching. However, much of science is based on dynamic processes comprising chemical and/or physical changes and interactions necessitating that science educators consider ways of modelling the stages in scientific processes and the transformations between them. Examples could include life cycles, changes of state, enzyme action, molecular bonding, planetary motion and nuclear fission and modelling these for pupils using simulations or animated sequences in two or three dimensions promptly springs to mind. Indeed showing such animations to pupils has become popular, particularly with the recent increases in availability of classroom presentation technologies such as the data projector and the interactive whiteboard (Webb, 2010). However, research into their use in teaching (Ainsworth, 2008) has centred on pupils watching them rather than creating their own.

Literature Review

The idea of using animation creation as a means of training science teachers stems from work with pre-service elementary school teachers by Garry Hoban of Wollongong

University in Australia. Hoban's (2005) innovative approach itself strongly resonates with Mestre & Cocking's (2002) conclusions developed from their application of the science of learning to the education of prospective science teachers on behalf of the US National Science Teachers Association (NSTA). Mestre & Cocking (2002) emphasise that instructional strategies that facilitate the construction of knowledge should be favoured over those that do not - these are approaches where students are discussing science, doing science, teaching each other science and offering problem solving strategies to peers. Creating animations in small groups involves all of these and enables the student teachers to discuss the ways of representing and formulating the science subject being animated that make it comprehensible to others thus directly addressing their pedagogical content knowledge as originally defined by Shulman (1986). Hoban (2005) himself found slowing up the usual process of making animations using modelling clay, known as 'claymation', particularly helpful to both his student teachers' and their pupils' conceptual learning in science. This led to the concept of 'slowmation' involving the creation of a simple stop-motion animated movie by capturing images of models of the stages in a science based process. The slow play back of around two frames per second enables a simultaneous narration explaining the science. Hoban and his colleagues (Hoban, Loughran & Neilsen, 2011) were particularly keen that the learners themselves became the animation designers and creators citing Bransford, Brown & Cocking's (2000) argument that making science models allows learners to "develop a deeper understanding of phenomena in the physical and social worlds if they build and manipulate models of these phenomena" (p. 215).

Whilst Hoban originally worked with elementary school student teachers, Keast, Cooper, Berry, Loughran & Hoban (2010) found that engaging in 'slowmation' creation could act as a pedagogical scaffold for secondary level student teachers too. They found that

their student teachers, having first learned to create 'slowmation' movies as part of their taught programme, gained valuable feedback when creating animations on placement in school science classrooms, both about their teaching and their pupils' learning. In particular seeing the pupils' animations enabled the student teachers to become aware of the range of concepts held by their learners about particular science processes such as the stages in DNA replication or photosynthesis and allowed them to employ remedial learning opportunities where necessary.

However, available time was found to be a large factor in the creation of these 'slowmations' (Keast et al., 2010; Kervin, 2007). More recently the technology has become simpler to use and freely available and it is now possible to create a short animation in a school science classroom within an hour or so using a digital or a mobile phone camera, modelling clay such as Plasticine® and freely downloadable software. It is even quicker if a tablet or a mobile device such as an iPad or iPod Touch is used as both the camera and the software are integrated in the same device. In each case the stages needed to create a stop-motion animation creation are similar: designing the planned sequence which may need research to supplement the student teacher's current knowledge, making the models, photographing them in different configurations and 'stitching together' the resulting images with software. Depending on the software used and the time available the final animations can then be enhanced with captions, narrations and sound effects.

Hoban, Loughran & Neilsen (2011) present each stage in detail, highlighting the way the different stages enable representations in different modes. For Hoban, Loughran & Neilsen (2011) these include: written notes created as the student teachers first researched the science, sketched storyboards used in designing the animations, the Plasticine® models for

the different stages, the images captured using the cameras that make up the animated sequence and finally, adding narrated voiceovers. However, Hoban and colleagues did not originally address other stages commonly found in the classroom context where student teachers working in groups will discuss their work with, and show it off, to each other. In a later paper though, Hoban & Nielsen (2014) acknowledge the importance of peer discussion and, using a case study of three primary school teacher trainees, analyse its contributions to pupil understanding. However, in the classroom, the tutor will also organise a plenary showing the class all the animations constructed in the session and orchestrate associated whole class discussion. Yet, it is not clear how much each of the different stages in the animation construction process contribute to learning. Therefore, this study attempts to shed further light on how student teachers can learn to teach science through supporting pupils in creating animations by seeking to answer the following two research questions:

- Which activities within the process of creating stop-motion animations are perceived by student teachers to promote learning?
- How can learning activities involving stop-motion animations support science teacher education ?

Theoretical framework

Hoban, Loughran & Neilsen (2011) introduce a semiotic framework to describe their approach to understanding learning through the process of animation creation emphasising the importance of the different representations at each stage and how they are interpreted, both by the creator and their intended audience. Making an animation thus involves orienting a presentation of a concept simultaneously to ourselves and to others in the same way as Lemke (1998) explains how we construct meaning. Lemke (1998) summarises this as

organizing connections between related elements of the representation and its viewers using a range of modes. Kress, Jewitt, Ogborn & Tsatsarelis (2001) also focus on different modes as routes for making meaning in the science classroom and emphasise the importance of a teacher using multiple representations and modes of communication (voice, gesture, diagrams, text, photographs, video etc.). When the teacher uses these in combination in communicating scientific concepts or phenomena they contribute powerfully to pupils' understanding.

In the case of animation creation the storyboards, models, photos and videos are the external, physical representations in different modes that signal how the modeller understands the science process that can be both shared and discussed during group work on the animations. Indeed Bennett, Lubben, Hogarth, Campbell & Robinson (2004) point out in their review of research on small-group discussions in secondary school science teaching that such discussions are a means of helping pupils explore their ideas and move from understandings that may often be naïve to towards more valid scientific ideas. Using discourse analysis of three of their primary school student teachers' discussion when making a 'slowmation' on the phases of the moon enabled Hoban & Nielsen (2014) to identify four affordances of this process that apparently enabled learning. These were (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. That it is dynamic representations that are being generated, manipulated and discussed is particularly important to Schank & Kozma (2002) who consider that high school pupils who are engaged in collaboration over producing dynamic representations such as animations can readily achieve convergent understanding through discursive interchange accompanying the changing representations. They also note the importance of the process of creating and manipulating the dynamic representations

suggesting it might support the pupils' reasoning more effectively than when merely observing an animation.

Hoban, Loughran & Neilsen (2011) see learners, whether student teachers or pupils, creating stop-motion animations as constructing meaning through a semiotic process that links these representations in different modes. In particular, this process is one where meaning-making is enhanced as learners need to translate (cognitively manipulate) ideas and information to create more than one representation of the concept being animated (Loughran, 2010). Hoban & Nielsen (2013) later go on to propose that each stage in creating an animation is important to learning the underpinning science as each stage explores the same concept but in different ways creating a cumulative semiotic progression with meaning building from one representation to the next to promote learning. This emphasis on building resonates with the constructivist approach to learning described by Good & Brophy (1994) as involving learners constructing their own meaning, manipulating knowledge by making connections between stored and new information, a process that is enhanced by social interaction and through authentic tasks. Making animations in small groups within a science classroom to be viewed by the rest of the class in a plenary is clearly both socially interactive and an authentic task with a product that can be shared within and beyond the classroom. In fact it clearly shares more with the social constructivist approach to learning which recognizes that learning involves meaning making within a symbolic world as well as the role of significant others in the science classroom (Driver et al, 1994).

Methods

Research design

As the research involves detailed investigation of the role of the different activities employed in creating stop-motion animations as opportunities for meaning making and learning, an interpretative approach to data collection was used within the social constructivist paradigm that assumes analysing discussion between learners as they created an animation will reveal how they are making meaning (Crotty, 1998). Qualitative data was sourced, firstly through observation and video recording of small groups of student teachers at work on creating animations in university teaching sessions and later through semi-structured interview once they had had the opportunity to teach animation creation themselves in placement schools. It was anticipated that this would enable the production of a rich picture of the learning process as the student teachers engage with science concepts and processes when creating their animations. This approach is admittedly limited by its small scale with 15 student teachers participating in the recorded discussions and six in the interviews and there is no suggestion that the findings are widely generalizable. The procedures and findings however, are described in detail to allow other researchers to replicate the study and assess its confirmability, transferability and credibility. These are all strategies for ensuring trustworthiness in qualitative research (Shenton, 2004).

Participants

Participants were selected at opportunity from volunteer teacher trainees attending a practical teaching session on creating animations as a means of teaching science in schools. All trainees were postgraduates following the English national one year teacher training programme, the postgraduate certificate of education. This session formed part of their taught programme for secondary science teacher trainees in one university and was offered as an option in two further universities, one training primary school science specialists and the

other secondary science teachers. In all, three groups of secondary school trainees (a pair and two groups of three) and two groups of primary school trainees (one group of three and another of four) were video recorded as they created an animation. Six of the secondary science teacher trainees were later interviewed after teaching using animation creation themselves.

Data collection and analysis

Thus in each of the five scheduled teaching sessions, whilst the students were working on their animations in small groups of 2-4 individuals, one of these groups, selected at opportunity was video recorded for later thematic analysis of their discussions. The discussion was open-ended and not triggered by any researcher led prompts. As the recordings were taking place in a teaching room where other groups were working, voice recorders were also used to capture the observed group's discussion in an effort to control for the high noise levels though, in one case, this strategy was unsuccessful. Therefore the data set comprised a) the transcribed discussions from four observed groups of student teachers and, b) for the six secondary teacher trainees interviewed, their responses to questions posed in the post-placement interview.

Both data sets, the transcribed discussions between student teachers making a stop frame animation and their answers to the interview questions following their use of animation in school were analysed thematically using an inductive approach to identify and report patterns (themes) seen within the data (Braun & Clarke, 2006). The goal of thematic analysis is to reduce the data into a set of representative themes through a process of coding. In this case the inductive approach, of coding the data without trying to fit it into a pre-

existing coding frame, was chosen as the research aimed to explore the process of making animations from the participants' perspective. However, it should be recognised that this coding will have been informed by the researcher's knowledge of some of the earlier research studies reported earlier in this paper. Other studies were published only once the study was under way. The qualitative data analysis computer program NVivo10 from QSR international was used to process the two data sets conducting a thematic analysis in each case in order to identify salient and reoccurring themes. With NVivo10, short clips of audio data that the researcher considers to be associated with a particular 'basic' theme are assigned to a 'node' and the nodes can be organized into networks through higher-level 'organising' themes in order to show any observed patterns in the data.

Instruments

Interaction and activities amongst the groups making animations was captured using a static digital video camera on a tripod and their discussions recorded on a handheld voice recorder placed centrally on the table they were working at. For the post-placement interview, a semi-structured format was chosen as the most appropriate as it allows for open ended discussion prompted by a framework of starter questions devised to ensure that the research questions are addressed. The interviewer (the sole researcher in this case) also has freedom to probe for further details of interest exploring the participants' answers to questions and the participants are given opportunities to offer related information of interest to them. The initial questions addressed whether practicing making an animation at university helped them with understanding science, the necessary preparation for, the benefits of and their concerns about teaching in this way.

Procedure

Making animations as a means of teaching and learning was introduced to the student teachers in each of the three universities in a 3 hour teaching session during which student teachers practiced making animations themselves. In one university this was an optional session scheduled outside teaching hours, in another it was scheduled as part of the teacher education programme and, in the third, it was one of several options timetabled for that day. In the universities with larger cohorts the session was repeated making five presentations in all.

The teaching session started with illustrations of children's animations made in school science lessons during an earlier research project (Wishart, 2016) and a brief presentation of Hoban, Loughran & Neilsen's (2011) ideas on why they are thought to support learning followed by an introduction to the process of making an animation. This included story boarding, model making, image capture, uploading and editing. Following this initial 30 minute presentation student teachers made a short animation (10-20 images) on a topic of their choice and one volunteer group were recorded whilst doing so. There were no suggestions made as to what they should discuss during animation creation. In most cases they used Windows Moviemaker on a laptop PC, a digital camera, Plasticine®, paper and card i.e. tools found in many UK classrooms, to create the animations however, one group used an iPhone and another an iPad, both running iMotionHD. Towards the scheduled end of the session student teachers emailed their animations to the researcher running the session so that they could be played back to the class via the data projector and discussed as a plenary. All the student teachers were then invited to report back to the researcher on any opportunities they had in their subsequent school placements to teach themselves by getting pupils to make animations. The six who did so were interviewed.

Ethical considerations

All participants were volunteers, fully briefed as to the research and their discussions and answers are presented anonymously. They were informed that this would be the case so that they would feel free to accurately report negative as well as positive perceptions of making animation as a way of learning to teach science. Whilst known as a local science teacher educator the researcher was not one of their usual tutors minimising any dual role (both researcher and teacher) effects. Finally, great care was taken to ensure that, as teacher trainees, their own professional development was not affected by participation in the project. This has impacted on this study as fewer participants than anticipated made themselves available for post-placement interview.

Findings

In all data were collected from 15 student teachers, 8 secondary trainees (3 of whom specialised in chemistry and the others in physics) and 7 primary trainees specialising in science. Two of the student teachers were over 35 years of age, three less than 25 years and the rest 25-35 years old. Three of the secondary student teachers and all seven of the primary student teachers were female. Six of the secondary student teachers volunteered for interview following their school based placement whereas no primary trainees were available for interview (only one had used animation with her pupils when on placement in school, her pupils learned only how to make an object appear to move). The chosen topics of the six secondary student teachers who went on to create animations with their classes were: the photosynthesis equation - rearranging molecules, elements, compounds and mixtures, the

different white blood cells (2 different trainees), atomic structure and lastly a free choice from fertilisation, space, photosynthesis, life cycle of plants as revision for exams.

The following charts show the organising themes resulting from the thematic analysis made using NVivo10 of the recordings of the student teachers' discussion during animation creation. In each case frequency refers to the number of comments assigned to each theme by the researcher. There is no analysis of the data for one group of 3 secondary teachers whose discussions were made unintelligible by classroom noise.

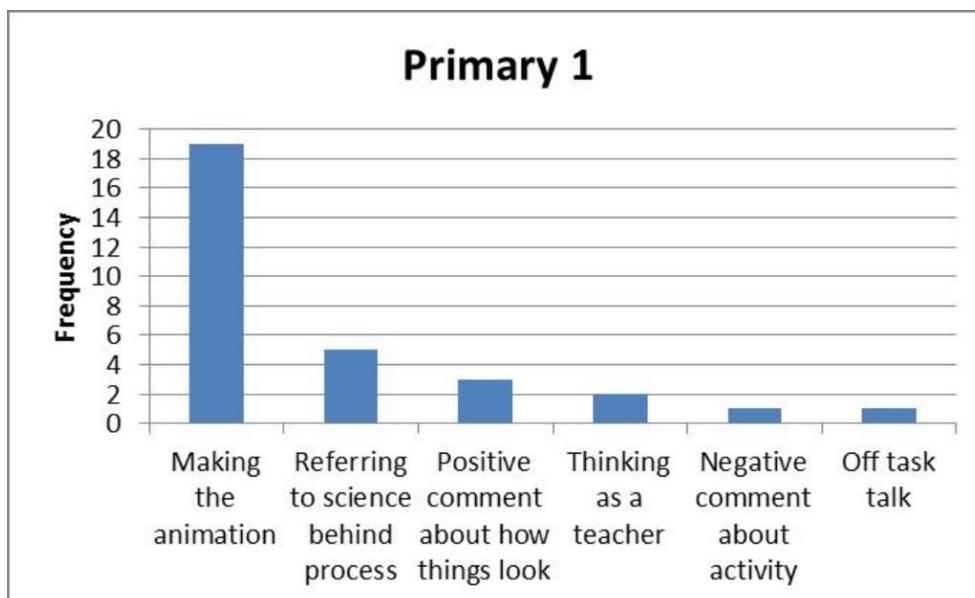


Figure 1 Four primary student teachers, recorded for 25 minutes animating the Earth's rotation to make night and day.

Here it can be seen that discussion referred overwhelmingly to making the animation itself with a much smaller subset of comments referring to the science underpinning the process. A couple of points were made about how the activity supported the student teachers in thinking about how they might teach science when in school

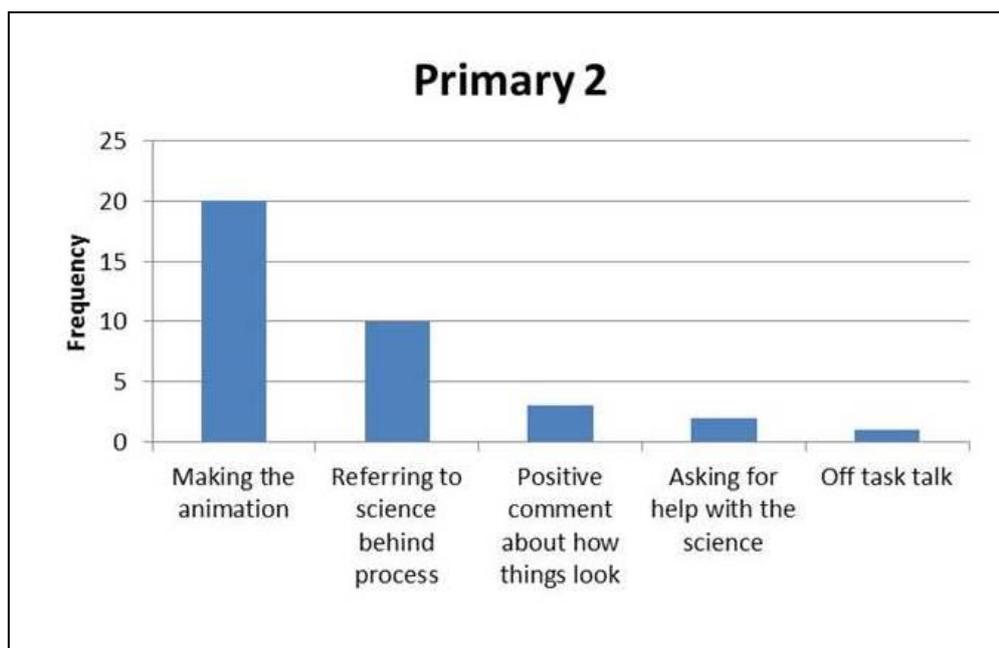


Figure 2 Three primary student teachers, recorded for 23.5 minutes animating the phases of the moon.

Again the most frequent theme appearing in the student teachers' comments are references to making the animations though this time, instances where students referred to the science behind the process being animated were more frequent. Unlike the other groups these student teachers did not appear to discuss how the activity could help them as a teacher.

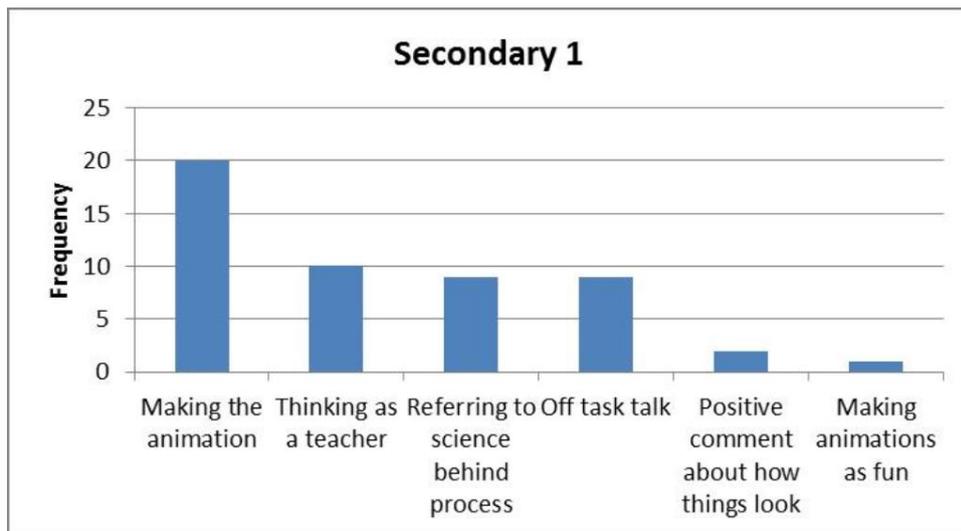


Figure 3 Two secondary student teachers, recorded for 20 minutes animating enzyme action

The balance of the student teachers' discussion here similarly includes twice the amount of talk on making the animation itself as on considering the underpinning science however, this time, how the activity helps them think about how to teach is more prominent. As is, less helpfully, off task talk.

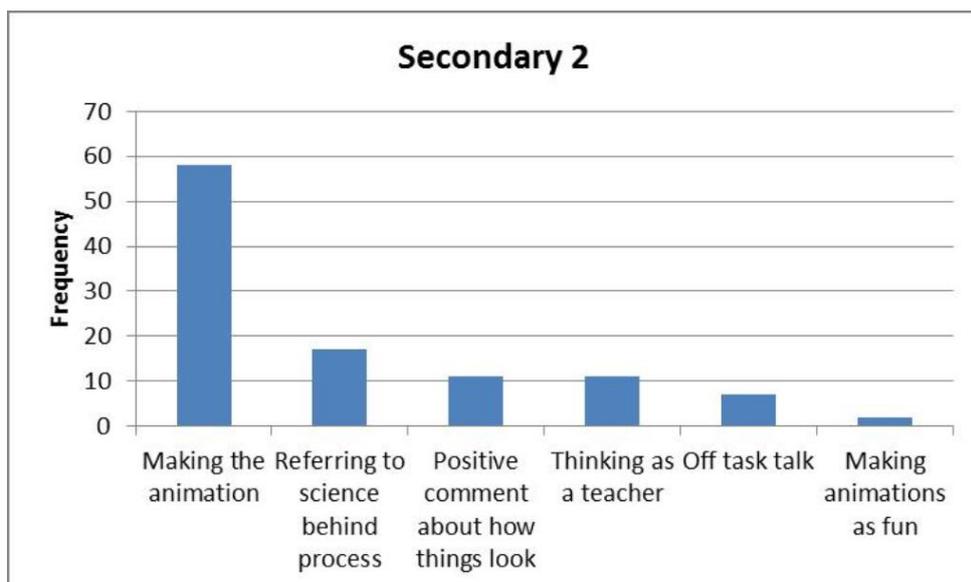


Figure 4 Three secondary student teachers, recorded for 58 minutes making two animations on heat transfer.

This was a much longer animation creation session as the student teachers were very ambitious with their first attempt animating convection currents and then surprised themselves with the speed with which they managed radiation. Issues with managing the representation for the convection currents meant discussion focused disproportionately on making the animation though again comments concerning the science behind the process and how the task supported them in thinking like a teacher were clearly observable.

There are no major differences in the patterns of the discussions that can be linked to whether the student teachers were primary or secondary school trainees and their data were aggregated. The numbers of total instances for each of the organising themes identified in their discussions are given in Table 1 below.

Table 1 The organising themes that appeared in the student teachers' discussions.

Organising theme	Frequency
Making the animation	125
Referring to science behind process	41
Thinking as a teacher	23
Positive comment about how things look	19
Off task talk	18

It is clear that by far the most frequent discussion points were on construction of the animation itself and the next most frequently found theme referred to discussion of the science behind the process. Student teachers would check both their understanding and the accuracy of their representation. Discussion of making the animation was comprised mostly of members of the group debating the representation and its effectiveness, discussing how to use the technology and which images to capture. In this example student teachers are discussing how to represent how the Earth spinning gives us night and day.

Anna: *"I quite like the idea of day and night, doing something on that you know the sun and the moon, you could show half in the light and..."*

Beth: *"We could do that"*

Anna: *"... have the world turning with light coming in."*

Chris: *"We could have a little person stood on it and then they are turning round."*

Anna: *"Mmm."*

Beth: *"Have that half black?"*

Reflections in their discussions that showed the student teachers thinking as a teacher included how making animations could enhance pupil understanding, the preparation needed to teach through animation and its potential use for assessing pupil understanding. Two examples include:

Ella: *"I've done it and I thought the kids got really loads out of it because they really understood the concept, if they play with it themselves they really understand molecules and what atoms are and what molecules are"*
[demonstrating with plasticine by bringing model atoms together to make molecules]

Pete: *Err.. I was thinking about when you, if you, use models, models that are already created to demonstrate something but actually having students creating their own models is a way of testing their understanding. It's much easier, to kind of, see a model already created and go like "that's ok" than to actually create something from scratch. There's a lot, you have to really*

understand kind of what's going on there, so I think it's a really good way of testing the students' understanding

Other comments made in the four groups videoed during animation creation comprised positive remarks about how the resulting models or video were looking (19 comments), off task talk (18 comments) which formed 8% of the total, comments about having fun (3), asking the tutor for help with the science (2) and there was only the one comment about not enjoying the activity.

Many of these observations were reinforced by the points made by the six secondary student teachers who participated in a post-project interview that took place after they had themselves taught science through animation creation. Tables 2-4 show the thematic breakdown following the analysis of the interview audio recordings. There are three tables; Table 2 presents the breakdown of the student teachers' perceptions about the role of the different activities in animation creation, Table 3 the perceived benefits of making animation in school science that they reported and Table 4 the issues or challenges that they found were involved. The frequency shown is the number of times that each theme appeared amongst the student teachers' responses.

Table 2 Themes within comments made on the different animation creation activities by secondary student teachers in post-project interview (n=6)

Activity	Freq
Peer discussion	9
Storyboarding	7
Seeing and discussing the finished animation	6
Making and modelling	5

The student teachers found it hard to separate out the learning outcomes from the different stages in the process of creating an animation however, as shown in Table 2, all agreed as to the importance of the role of peer discussion during the task in enabling and reinforcing learning. For example:

Luke: *“They’d be talking about the science as well and how best to represent it. So I think that would be useful.”*

Clare: *“And then when they came to doing the animation they ..erm.. had one person taking the photos, one person doing the animation and the others in the group were helping out. Like making sure things were in the right place and ..um.. they did it talking to each other, making sure that they had the right thing at the right time. It seemed as though it was a good way of talking about what was going on in the science but also, just kind of communicating, as a skill, that’s quite good for them.”*

However there was a clear split in how the student teachers perceived storyboarding with two of the six being adamant that it wasn’t necessary and the others saying how important it was for effective planning of the sequence to be animated.

Hugh: *“I find storyboarding very dull er.. personally.. when they do it, I must admit, I much prefer just to get on and do it”*

Clare: *“I think planning was quite key to it, you do have to think about it before you start, how you are going to go about it.”*

Fred: *“The storyboarding really helped them with the science”*

The roles of making the models and playing back the finished animations were emphasised as key for learning and enjoyment by most however, two of the student teachers reported they felt that all stages were necessary and had their place. Showing and discussing the finished animation was deemed important for three reasons; it motivates the students, enables whole class involvement and learning through showing up misconceptions that the teacher can then address.

Hugh: *“It is important for kids to be proud of their finished product. They all get a lot more learning from it if they can think ‘yeah, I nailed that’. Yeah, it motivates them, they are happier.”*

Luke: *“...have a class discussion, strengths and weaknesses of what you can see. So the fact that, maybe, one group could produce something that is not quite scientifically that isn’t the end of the world because as long as you discuss it, work through what the problems are, I can see that that would be very useful too”*

Fred: *“And then at the end, when I had people come up to present their different ideas there are different bits where you can see that there are common patterns when they get something wrong, so you can correct it there and then.”*

Table 3 Benefits of making animations reported by more than one secondary student teacher in post-project interview (n=6)

Benefit	Freq
Aids pupils' understanding	9
Enables teachers to 'see' what pupils know	6
Animation is fun, engaging, enjoyable	6
Aids learning to teach by helping us think about how to explain or	4

show concepts to others	
Relevant to all age groups	4
Enables pupil creativity	2
Enables science thinking	2
Enables teachers to challenge & interest pupils in science	2

The most frequently reported benefit was how animation creation could aid pupils' understanding with a number of mechanisms suggested as to how that could occur. These centred on thinking about how to represent and communicate abstract, scientific ideas. For example:

Luke: I can definitely see that this would help pupils think about scientific processes and help them with the abstract.. help them turn what.. you know.. especially those pupils that struggle maybe with um.. words or writing down concepts or that kind of thing. Maybe this would help them [...] start thinking about how to represent ideas and communicate scientific ideas to other people.

The way that animation helped with visualisation was clearly important, not just to understanding the science process being animated but also how having the external representation enabled the teacher to 'see' what pupils know or understand. One student teacher reported:

Ella: "Yeah I think it was good because like... I actually had to build it and put it into a view that everyone could see, explain to someone else and not just what's in your own head."

This was confirmed by four of the six student teachers as a way of supporting the process of learning to teach by stimulating them into thinking about how to present a science process or concept to others via an animation. Also all of them noted how both they and their classes had found it to be a fun, engaging activity. Two of the teachers noted that making animations enabled their pupils to be creative and two pointed out that it enables teachers to challenge and interest pupils in science. One student teacher [Hugh] found that animation creation:

“provoked interesting questions e.g. What are the energy levels made of? How much bigger are the protons than the electrons, which way do the electrons spin?”

However, a number of issues or challenges can also occur when attempting animation creation with a class and the issues with making animations that were reported by the student teachers in post-project interview are reported in Table 4 below.

Table 4 Issues with making animations reported by secondary student teachers in post-project interview (n=6)

Issue	Freq
Lots of preparation	5
Managing pupil over-ambition	2
Need to know the class well	1

The most common concern exercising the student teachers was the need to plan ahead well for a lesson or lessons centring on animation creation which relied on access to both digital cameras and laptops. They needed to find out what resources were available in school and to test their functionality. Two student teachers also pointed out the need to manage

pupils' ambitions, they tended to take too many images for example and one, reported that the teacher needs to know the class well so as to orchestrate the group work involved effectively.

Discussion

Which activities within the process of creating stop-motion animations are perceived by student teachers to promote learning?

When unpicking the student teachers' discussions during animation creation in order to answer the first research question the thematic analysis showed that their predominant topic was physical references to the construction of the stop-motion animations comprising, overall, about three times as many comments as the next most frequently occurring theme. In second place came comments referring to the science behind the process being animated (shown in Table 1). It appeared that having to create the models and plan both the images and their sequence to show their understanding to others led directly to the need to think through the underpinning science concept being animated. This prompted discussion reinforcing or checking learning with peers. Indeed analysis of the post-project interviews presented in Table 2 shows that, when considering the contributions of the different activities involved in animation creation to enabling learning, the student teachers prioritised the associated peer discussion. Pedretti et al (1998) had earlier found that such talk stimulated by using digital technology in a science classroom was reported by 75% of pupils to help them to learn better. Thus, addressing the first research question, discussion around the task appears to be the one activity within the process of creating stop-motion animations that was perceived by student teachers to promote learning.

Other steps in animation creation that were singled out by the student teachers being interviewed as benefiting learning (Table 2) notably included the making and modelling and, to a lesser extent, storyboarding and seeing and discussing the final product. Two trainees did make the point though, that it was not so much any particular step, but the whole task with its sequence of activities, that was important to learning. This reinforces Hoban & Nielsen's (2013) point that each step in creating an animation is important to learning the underpinning science as each activity explores the same concept but in a different mode. This creates a cumulative semiotic progression with meaning building from one representation to the next to promote learning. Kress et al. (2001) reinforce the importance of such processes of transformation and meaning making to learning, making the point that having multiple modes of communication in the science classroom allows what is taken in, in one mode, to interact with what is taken in, in another.

Returning to the student teachers' discussions during animation creation, the majority of the discussion comments coded as 'making the animation' were about debating the representation to use i.e. the best way to show the science concept being modelled. In this particular group of adults it was observed that it was rare to ask the 'teacher' for help, they checked their understanding with each other and the internet. Consequently these discussions progressed in the way suggested by Schank & Kozma (2002) whereby the process of collaboration in the creating and manipulating of the dynamic representations stimulated discursive interchanges. These interchanges lead to convergent understanding within the group about how to represent the topic being animated. They also confirm three of the four affordances of discussion during making 'slowmations' proposed by Hoban & Nielsen (2014) though the fourth, sharing of personal experiences, was not seen here. Kozma (2003) also points out that carefully designed visual representations embedded in authentic inquiry

activities can provide pupils with physical and social affordances that can support scientific talk.

How can learning activities involving stop-motion animations support science teacher education?

Having external representations that can be manipulated also supports Mestre & Cocking's (2002) point that, for prospective science teacher education, tacit knowledge should be made explicit for the novice learners so that they recognise it, learn it and apply it. Indeed animation creation as deployed in this project clearly realises one of Mestre & Cocking's (2002) desirable attributes for courses for prospective science teachers, that they should include construction and sense-making of science knowledge. This should be encouraged through classroom environments in which students are actively engaged in hands- on activities.

Another frequently found theme in the student teachers' discussions, forming about 10% of the total (shown in Table 1), the way the task stimulated thinking as a teacher, also addresses the second research question. Student teachers reported that animation creation enabled opportunities for both enhancing and assessing pupil understanding as well as through preparing them for teaching through animation. This confirms Keast et al.'s (2010) findings that engaging in animation creation with a class can act as a pedagogical scaffold for student teachers through gaining valuable feedback, both about their teaching and their pupils' learning. It appears that making an animation stimulates thinking about how to present a concept to others and this orienting of a presentation of a concept simultaneously to ourselves and to others supports the construction of meaning (Lemke; 1998).

Indeed when asked later in the post-project interviews about potential benefits of making animations the student teachers were very clear that making animations in science lessons could aid pupil understanding (shown in Table 3). Their suggestions as to why and that they also reported making animations aided them in learning to teach by helping them think about how to explain or show concepts to others again resonate with Lemke's (1998) explanation of the process of constructing meaning through organizing connections between related elements of a representation and its viewers. With respect to animation creation though, meaning-making is further enhanced as learners need to translate (cognitively manipulate) ideas and information in different modes to create more than one representation of the concept being animated (Loughran, 2010). Additionally, the student teachers also reported at interview that viewing the models and animations created enabled them to 'see' what their pupils know or understand and take remedial action if necessary. As Hoban & Neilsen (2013; 2014) report from their analyses of their student teachers' discourse when creating 'slowmations', the need to make an animation brings any alternative conceptions held by pupils to the fore thus helping the student teachers learn about their pupils and their understanding. This directly enables the prospective teachers to meet one of the UK National Teaching Standards (DfE, 2011) which specifies that teachers should have a clear understanding of the needs of all pupils and be able to use and evaluate distinctive teaching approaches to engage and support them. Finally, enabling the student teachers to practice with animation tools and apps at university before placement adds to their repertoire of digital skills for teaching in 21st century schools and meets Swain & Pearson's (2002) call that, in order for teachers to meet National Educational Technology Standards for Teachers securely, their training must take place in such a way that they feel confident in their abilities.

Challenges to the use of animation creation for teaching and learning

Lastly, a few issues with using animation creation in class were recounted by the

student teachers; these centred largely on the preparation involved (as shown in Table 4). This included ensuring that the technology and resources for model making were all available and working and, in these first explorations, took more time in the planning than a traditional lesson. There was some concern about available time though, if the tools were available and connected, this was generally misplaced however, the point that pupils could be over ambitious should be noted. Any science teacher preparing animation creation with their class should limit both the number of images to be taken and the allowable time to be spent on editing. One last point, about the need to know your class was well made. As discussed above, the way in which animation creation promotes group discussion was found to be key to its beneficial role in student learning so group composition needs to be well thought out and possibly adding to the necessary preparation time.

Conclusions

In response to the first research question, which activities within the process of creating stop-motion animations are perceived by student teachers to promote learning, within the limitations of this small scale study, it is concluded that the opportunities created for discussion, both with peers and teacher led, are the most likely to promote learning. Other activities such as storyboarding, reviewing the finished animation with the whole class and especially making and modelling are also associated with opportunities for reinforcing learning. These enable students at every level to visualise the science concepts being animated and check their understanding of the processes involved. However, no one particular activity or stage in animation creation stands out as much more important than the other and it is the whole process of representing and re-representing one's scientific knowledge in different modes that makes animation creation appear to have so much

potential to bring about and support science learning.

Addressing the second research question, the learning activities involved in creating stop-motion animations that can support science teacher trainee education are those that trigger reflection on their science understanding in the light of the need to make external representations. This facilitates the student teachers in thinking through the process of communicating the underpinning science concepts. Also, as well as aiding learning to teach by helping student teachers think about how to explain or show concepts to others, animation creation makes it easy for them to 'see' what their pupils know.

In conclusion, it was found that making short animations that enable both reinforcement and sharing of student teachers' understanding can be created in a science classroom within 90 minutes or so. Of particular importance to prospective science teacher education is the way that this activity enables construction and sense-making of science knowledge. It also enables student teachers to discuss the ways of representing and formulating the science subject being animated that make it comprehensible to others directly adding to their pedagogical content knowledge. According to the student teachers' reports, their pupils' science understanding also benefitted from animation creation activities. Though they also noted the need for appropriate preparation i.e. ensuring that the available technology functions as expected, that the pupils know how to use it and, as with any creative endeavour involving digital technology, allowing extra time just in case it becomes necessary. The time taken to create an animation can be reduced very effectively by using a free animation app such as iMotionHD to stitch the images together as tablets and Smartphones have on board cameras. It should be acknowledged though that in this study

with student teachers, they had all studied science to a greater or lesser extent and there was no assessment of the actual science learning that occurred. Recommendations from this study for further research therefore centre on evaluating student learning through animation creation so as to provide evidence as to the actual learning that can take place.

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