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The impact of student created Slowmation on the teaching and learning of primary science.

Jeffrey Brown
Edith Cowan University

USE OF THESIS

THE IMPACT OF STUDENT CREATED SLOWMATION ON THE TEACHING AND LEARNING OF PRIMARY SCIENCE

Jeffrey Brown Dip.T., B.Ed.

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ABSTRACT

Current research indicates that although innovations in science teaching are having a positive impact on science education in many Australian schools, national and international assessments show that student achievement is not improving (Hackling & Prain, 2008; Thomson, Wernet, Underwood, & Nicholas, 2008). Furthermore, there is little or no increase in the number of students choosing science as a post-compulsory study option or as a career path.

There remains a need to further develop innovative teaching methods that promote the development of students' scientific literacy, engenders a joy of science learning through student engagement and encourages a desire to pursue further study of science. It is argued in this thesis that the quality of student discourse in the classroom influences student achievement in science. In addition students need to use a variety of representational modes that develop and share their science understandings. It is proposed that Slowmation, a simplified form of stop motion animation, has the potential to engage students in learning by supporting discourse and multimodal representations of science phenomena.

In response, this study explored and evaluated the implementation of student created Slowmations in a Primary Connections science unit. The study aimed to investigate the ways in which the process of creating a Slowmation engaged students in quality discourse and how the process afforded opportunities for students to use a range of representational modes to develop science understandings and literacies. The research was undertaken as a case study in a multi-aged class in a rural school setting. Transcripts from videos of student interaction, student interviews and analysis of finished Slowmations generated information regarding the extent to which student created Slowmation impacted on science learning.

This study found that small group creation of a Slowmation engaged the students in substantive discourse and generated opportunities for their use of multimodal representations. Furthermore, this rich pedagogy engaged all the students in learning science. The research extends and connects existing separate bodies of research and theory on representation, student discourse, learning technologies and learning in science.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

i. incorporate without acknowledgement any material previously submitted for a degree or diploma in any institute of higher education;
ii. contain material previously published or written by another person except where due reference is made in the text; or
iii. contain any defamatory material.

I also grant permission for the Library at Edith Cowan University to make duplicate copies of my thesis as required.

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TABLE OF CONTENTS

List of Figures

List of Tables

CHAPTER 1 INTRODUCTION

Context

In recognition of the low status and inconsistent practices of science teaching in Australian schools, the Australian review of science education (Goodrum, Hackling, & Rennie, 2001) made several recommendations for the improvement of science education across the nation. Among the responses to recommendations was the development of the Primary Connections primary science professional learning program (Australian Academy of Science, 2009) and the Australian Curriculum for Science (ACARA, 2010a).

Firstly, the Primary Connections science teaching resources link science and literacy in order to "develop the literacies of science that students need to learn and to represent their understanding of science concepts, processes and skills" (Australian Academy of Science, 2007). The units of work utilise an inquiry approach to learning following authentic teaching and learning models and links to the Australian Curriculum are continually under development.

Secondly, the rationale of the Australian Curriculum for Science (ACARA, 2010a) states that:

> In addition to its practical applications, learning science is a valuable pursuit in its own right. Students can experience the joy of scientific discovery and nurture their natural curiosity about the world around them. In doing this, they develop critical and creative thinking skills and challenge themselves to identify questions and draw evidence-based conclusions using scientific methods. The wider benefits of this "scientific literacy" are well established, including giving students the capability to investigate the natural world and changes made to it through human activity. (p. 1)

Problem

Current research indicates that Primary Connections is having a positive impact on science teaching and learning, through improving attitudes to science, better understanding of investigation process and increased conceptual growth (Hackling

& Prain, 2008). Science achievement standards and the uptake of science in higher education and as a career however, are still of concern.

Results for Australian students in the Trends in International Mathematics and Science Study in 2007 indicated that Australian Year 4 students' science achievement was significantly lower than eight other countries and there was no improvement between the 2003 and 2007 assessments (Thomson, Wernet, Underwood, & Nicholas, 2008Thomson et al., 2008). National Assessment of Year 6 science literacy in 2009 indicates that only 51.9% of students achieved or bettered the proficient standard. Surveys of student attitudes and participation in science were also less than promising, with 41% of students indicating they never read books, magazines or newspaper articles about science and 27% never watch TV programs or DVDs about science (ACARA, 2010c). These results indicate that there is a need to further improve levels of students' scientific literacy and interest in science.

In a survey of student experiences in science, "21% of students reported to 'hardly ever' have a science lesson" (ACARA, 2010c, p. 72). Further studies across the globe, including Australia, are recognising that students' experience of less than adequate pedagogy in science classrooms is resulting in a continuing trend away from the choice of science for further study or as a career. These negative experiences, which include authoritarian pedagogies and content which is perceived by students as irrelevant, are doing little to develop positive concepts of science or appropriate science literacy for adult life (Lyons, 2006). Other research suggests that little recognition is given to the teaching of the verbal and written languages of science (Hackling, Smith, & Murcia, 2010; Lemke, 1998; Norris & Phillips, 2003). This includes the nature of science discourse and the languages of science which consist of multimodal representations, including words, diagrams, pictures and graphs. Furthermore there is little acknowledgement given to the way and order that these representations are presented and re-presented. Teachers use the languages of science without teaching those languages and tend not to recognise the links between verbal and visual representations (Lemke, 1998).

Such studies imply a need to improve science pedagogies in order to engage students with science concepts and literacies. Improved pedagogies must take account of students' own cultural contexts, which include a strong visual entertainment and digital media component. They need also to encourage the use and understanding of meaningful discourse and multimodal representations in a science learning context.

Rationale

It is generally accepted that students make meaning through a process of social dialogue that provides opportunities to test and refine their understandings (Mortimer & Scott, 2003) and the quality of this discourse has a considerable influence on student achievement (Mercer, 1995). Vygotsky's theories strongly suggest that social factors have an important influence on students' construction of meaning and for meaningful understanding to take place, students need to interact with teachers, peers and other adults (McInerny, 2002; Reiber & Robinson, 2004). Furthermore, students confronted with a problem will use a combination of speech, action and the use of tools to come to an understanding (Vygotsky, 1978).

To develop and share their understandings in science, students are required to use a variety of representations, including written journals, diagrams, symbols and models (Carolan, Prain, & Waldrip, 2008). One avenue of representation that is beginning to be explored is that of student developed stop motion animations (Gravel & Rogers, 2009; Hoban, 2005). Hoban (2005) has coined the term “Slowmation” which is an adaptation of traditional stop-motion animation techniques and which is more resource and time efficient.

In this study, all students created their group Slowmations during the Evaluation phase of a Primary Connections unit. Student created Slowmations, comprising visual representations complemented with a narration, have the potential to become a powerful multi-representational form, helping to improve the quality of student dialogue to enhance scientific literacy. A completed Slowmation also provides opportunities for reflection, peer review and teacher assessment. Primary Connections is used in many Australian schools and provides an authentic context for exploring the use of student made Slowmations in primary science. In Primary Connections units of study, concepts are developed through “guided investigations related to a sequence of representational and re-representational work” (Carolan et al., 2008).

Teaching students to make animated movies is included among many strategies used in the *Success for Boys* project, that aim to improve students’ educational success through the development of their repertoires of practice, in the areas of sense of self, relationships and culture (Alloway, Dalley-Trim, Gilbert, & Trist, 2006). If we accept that students require increased repertoires of practice to be successful learners, then the use of student animation must have a place in science education.

Slowmation also has the potential to become a new representational tool for students who may not be engaged or able to learn effectively via conventional representations and may further prove to be a useful tool for increased thinking, talking and understandings.

Purpose

The purpose of this study was to investigate the potential of student created Slowmations for developing scientific literacy, in particular its impact on students' understanding of science concepts, engagement in substantive discourse and use of science language and representational modes.

The study aimed to achieve this by investigating the ways in which the process of creating a Slowmation engaged students in quality discourse and by evaluating how the process influenced students' understanding of science concepts as evident in their animated representations and associated narrative.

Research Questions

1. How does the construction of a Slowmation engage students in quality discourse and use of subject specific language?
2. What opportunities are generated for students to use and create representational modes which demonstrate their science literacies?
3. What impact does student created Slowmation have on students' science understandings?

Significance

Much prior research is focussed mainly on the use of teacher generated canonical representations of secondary school science and the ways in which students use or copy such representations. It was expected that this research would generate new information regarding the extent to which student generated Slowmation has an impact on development of scientific literacy, through conceptual understandings, discourse and other modes of representation. The research was expected to contribute towards connecting existing separate bodies of research and theory on representation, student discourse, learning technologies and learning in science. This study adds to the limited educational literature in this field and provides some new knowledge that may help inform further development of Primary Connections, the use of Slowmation and other science resources.

It has been written that science education is very much about the excitement of discovery (Tytler, 2007). There is a strongly held belief among contemporary educators that there is also a place for enjoyment in sharing and describing those discoveries. Film-making, including Slowmation, is a challenging and stimulating process for students, one that engages them within their technological and media culture and provides such sharing opportunities.

CHAPTER 2 LITERATURE REVIEW

Introduction

This chapter reviews the literature related to social constructivism and socio-cultural theory, Primary Connections, Slowmation, student discourse, multimodal representation, science understandings and scientific literacy. The review of literature is used to develop a conceptual framework for the research, which can be found at Figure 3 at the end of this chapter.

Social Constructivism and Socio-cultural Theory

Social constructivism and socio-cultural theory are the foundations under-pinning much of the work undertaken in inquiry based and collaborative learning. Vygotsky's socio-cultural theory has as its central idea "that development and learning involves a passage from social contexts to individual understandings"(Mortimer & Scott, 2003, p. 9). Vygotsky's theories suggest that children learn through interaction and dialogue with others, combining this with their own experiences to construct and internalise their individual understanding. The tools and modes of language used by a social group will play a major role in shaping that group's thinking and understandings, with these ideas and understandings being rehearsed in the social plane before being internalised by individuals (Vygotsky, 1978). Socio-cultural theory tells us that the most effective process of learning is not that a content expert uses their own language to impart knowledge to others, it is that the others bring their own understandings to the forum, the content expert will provide ideas and representations which the individual relates to their own personal understanding and then discusses and re-represents these understandings with others before a collective understanding is agreed upon and then internalised again by each individual. Such transformative or reconstructive learning is further complicated by the fluid nature of language, the ability of words to take on different meaning depending on the context of use or even the prior experience and understanding of each individual. For example, Mortimer and Scott (2003) ask us to consider how the use of the term, "the Sun is rising," has embedded the idea that it is the Sun moving across the sky rather than the Earth spinning out of its own shadow. Things become more complex when we recognise that everyday language differs between students and that school-science language may be different to the language of scientists. These observations of the complex relationships between learning, language, representation and meaning-making help to make clear the importance of recognising that development of understanding is a dialogic process, which involves individuals working in groups to construct, deconstruct and reconstruct understandings (Mortimer & Scott, 2003).

Many science educators now work in the social constructivist paradigm. Science education has at last moved from a time when students were viewed as empty vessels to be filled with knowledge delivered by the content-expert teacher. It is recognised that students come to the science classroom with existing perceptions and understandings about the scientific world built from their own perceptions, experiences, interpretations and social-cultural context. These understandings, which suit the immediate needs of the child, do not always match the contemporary scientific interpretation of phenomenon, often because the nature of science understanding is through symbolic representation (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Osborne & Wittrock, 1983). Students learn in a more meaningful way when they are positioned, by the teacher, to build on their own ideas toward constructing understandings that are seen by themselves to be plausible and useful. They must generate their own models that “organise the information ... in a way that makes sense to them” (Osborne & Wittrock, 1983, p. 493). Osborne and Wittrock go on to say:

> Teaching involves helping pupils to generate appropriate meanings from incoming information, to link these meanings to other ideas in memory, and to evaluate both newly constructed ideas and the way old ideas are related in memory. In addition, the successful learning of scientists’ ideas is as much a restructuring of the way learners think about the world as it is the accretion of new ideas to existing ways of thinking. (p. 505)

While such personal and critical reflection of understandings helps the individual learner to extend conceptual understandings, opportunities for learning are further enhanced when interacting and collaborating with others. Such activity helps to challenge and test individual thinking in a social context, extending each student’s understandings about science phenomena (Goodrum et al., 2001). A social-constructivist perspective acknowledges that students bring prior learning to their experience and recognises that scientific understandings are constructed through social discourse during shared problem solving tasks. Social construction of understanding also helps students align their thinking with scientific views of the world (Driver et al., 1994). Mortimer and Scott (2003) also describe how learners in a science classroom develop their understandings of new concepts in social situations and rehearse these understandings in a variety of social contexts before coming to an individualised understanding.

Primary Connections supports the development of scientific literacy through the use of effective science teaching practices that are underpinned by a social constructivist perspective to teaching and learning, highlighting “the role of learners using prior knowledge and experience to construct their own meaning within the socio-cultural context in which they find themselves, when challenged by teachers to extend and deepen their understandings” (Hackling & Prain, 2005, p. 20). It was anticipated, in this study, that the collaborative nature of developing a Slowmation and the opportunities for multimodal representation using the literacies of science would enhance the development of scientific literacy consistent with the tenets of socio-cultural theory and social constructivism.

Primary Connections

The Primary Connections science programme provides a teaching framework emphasizing the development of scientific literacy and the learning of science concepts, skills and attitudes. The programme was developed in response to the 2001 review of science education and acknowledges “that the major purpose of science education is to develop the scientific literacy of students” (Peers, 2006, p. 1). The programme has been introduced into Australian schools in three phases which have included trials, development, evaluation, research and a strong focus on teacher professional learning (Peers, 2006).

Primary Connections provides opportunities to develop scientific literacy through engagement with the science domain, described as “science as a human endeavour, science as a way to know, and science as a body of knowledge” (MCEETYA, 2006, pp. 4-5). Primary Connections links the learning of science literacies with students’ everyday literacies through explicit teaching (Peers, 2006). “The programme recognises that there a number of science specific and general literacies required by children to effectively engage in science” (Hackling, 2006, p. 75). Tytler (2007) believes that Primary Connections will both assist students to build on generic literacies as well as develop the more specific science literacies.

With a vision of enhancing the teaching and learning of science, Primary Connections uses an inquiry-based, cooperative learning model with clearly articulated and measurable success indicators. The pedagogies underpinning the Primary Connections programme are robust and well researched and can be recognised in models of authentic instruction that advocate higher-order thinking, depth of knowledge, connectedness to the world beyond the classroom, substantive conversation and social support for student achievement (Newmann & Wehlage, 1993). The inquiry-based teaching and learning model adopted by Primary Connections is based on the 5Es instructional model developed by Bybee (1997) and takes students through phases of engagement, exploration, explanation, elaboration and evaluation. During the Engage phase, students are given activities that develop their interest in the topic and elicit prior knowledge. The Explore phase provides hands-on experience of the phenomenon. In the Explain phase, students develop explanations for observations and are given opportunities to represent their developing understandings. Students make connections to additional concepts through a planned investigation in the Elaborate phase and in the Evaluate phase students are required to re-represent their conceptual understanding and reflect on their learning journey. In Primary Connections;

> Students use their prior knowledge and literacies to develop explanations for their hands-on experiences of scientific phenomena. Students have opportunities to represent and re-represent their developing understandings. They are actively engaged in the learning process. Students develop investigation skills and an understanding of the nature of science. (Peers, 2006, p. 10)

Cooperative learning has had many proponents who have argued that that students increasingly need to develop the skills of collaboration for their social and working lives. In Primary Connections inquiry is facilitated through small group cooperative learning (Australian Academy of Science, 2005b) where:

> Working in teams enables students to share their experiences and consider different points of view and solutions to a problem. Teams develop the social skills of sharing, leading, communicating, building trust and managing conflict. These skills are relevant to

> students' lives, not only in school and work, but also in family and personal relationships. (Peers, 2006, p. 10)

While the vision and aims of the Primary Connections science programme and resources are obviously grounded in appropriate research it is the embedded ongoing research component of the project that is also worthy of note. The Stage 2 trial research report found evidence of increased teacher confidence and improved practice. Students developed improved attitudes to science and believed they had learned more in science than through prior learning programmes. This was corroborated with evidence from science achievement data. The report concluded that Primary Connections was having a positive impact on science teaching as well as on student learning and attitude (Hackling & Prain, 2005).

The Stage 3 Interim Research and Evaluation Report 15 had as its purpose the evaluation of "the impact of *Primary Connections* on students' development of literacies of science, science processes and attitudes towards school science" (Hackling & Prain, 2008, p. 8). This evaluation of Primary Connections involving 1467 students and 26 schools concluded that;

> All students whether they be male, female, Indigenous (ATSI), LBOTE or non-ATSI and LBOTE have significantly better literacies of science and science processes in classes where science instruction is based on *Primary Connections* than in comparison classes where science instruction is based on other programs. The impact of *Primary Connections* on students' achievement of literacies of science and science processes is both statistically significant and substantial as evidenced by effect sizes. (Hackling & Prain, 2008, p. 47)

Primary Connections won the 2006 Australian Publishers Award for Excellence in Educational Publishing in the Primary Teaching and Learning category and was short-listed in the 2007 and 2008 awards. The judges recognized Primary Connections as being "a rich and innovative classroom resource" (Australian Academy of Science, 2009). In his foreword to Tytler's, *Re-imagining Science Education*, Australian Chief Scientist, Dr Jim Peacock, endorses Primary Connections as an engaging new way of teaching science through literacy which is having a positive impact on student achievement (Tytler, 2007).

Assessment in Primary Connections is embedded into each unit. Students are supported to create multimodal representations of their understandings which can be monitored by teachers to give students feedback to enhance their learning (Peers, 2006). Assessment is thus ongoing and is used to inform planning for teaching. The 5Es model lends itself to diagnostic, formative and summative assessment, enabling teachers to account for prior knowledge and develop targeted investigation skills and conceptual understandings (Hackling, Peers, & Prain, 2007).

A student created Slowmation can be included in the evaluation phase of a Primary Connections unit, providing a new representation by which students can refine and share their understandings. The graphic representation below (Figure 1), showing elements of the Primary Connections inquiry approach (Australian Academy of Science, 2005) provides a picture of the context in which student created slow animations can be investigated. Student Slowmations are an opportunity to re-represent understandings and can be viewed as one of many multimodal representations that facilitate inquiry and learning.

Figure 1. Inquiry learning model (Australian Academy of Science, 2005)

When creating Slowmations, students have opportunities for developing and refining scientific explanation through discussion of observations and ideas, and monitor their learning through responding to peer feedback during substantive discussion of their science experiences as they plan to represent their understandings as a Slowmation. Hoban (2005) asserts that “Involving children in making Slowmation movies appears to improve their engagement in science lessons” (p. 37). This research will add to the literature in determining if the process further assists students in their understanding of science literacies and concepts in a Primary Connections context.

Slowmation

Instructional film has long been recognised as a useful teaching tool, indeed educational research in the field has been documented from as early as 1918 (Hoban & Ormer, 1970). Having students create animations in the classroom is not new either. The history of this goes back as early as the introduction of 8mm movie cameras into schools, mainly in the fields of media studies, filmmaking, photography and more recently in technology studies. Teaching students to make animated movies has been used in many contexts as a tool for engaging reluctant learners, and is included among many strategies that aim to improve boy’s educational success through the development of their repertoires of practice in the areas of sense of self, relationships and culture (McKeown, 2006), in particular by expanding their confidence as learners, transforming authoritarian modes of relating and acknowledging the cultures that boys prefer (Alloway et al., 2006). The success-for-boys concept is very much based on good teaching practice and has as an underlying theme, ‘success for all’.

For many classroom teachers, the teaching of animation techniques was aimed at encouraging disengaged students in their narrative writing. However, conventional methods of creating stop–motion movies are quite slow and cumbersome and have proven to be difficult to organise in a classroom. A process which films less frames per second and utilises simpler materials, techniques and tools has been developed and given the term “Slowmation” which is a simplified version of stop-motion film-making that uses many of the same learning processes. “The purpose of a Slowmation is to animate a process that is simple to produce and photograph and to show it slowly so that it enhances student understanding” (Hoban, 2005, p. 27). Furthermore, Hoban and Nielsen (2010) remind us that the technologies required are become less expensive and more readily available to the classroom teacher.

Indeed, the film making facilities offered on a standard personal computer are more sophisticated than professional studios of yesteryear.

The classroom process for using Slowmation requires four phases, which can be divided into several steps, depending on the choice of topic and the students' age or abilities; Planning, Storyboarding, Construction and Re-construction. In the Planning phase the teacher implements a science unit to explicitly teach a particular concept that involves a change or movement. The students begin to think about the design of their Slowmation. The second phase involves breaking up the concept into segments, which are drawn as a storyboard. The dialogue that takes place between the students during this phase allows them to further construct their understanding of the topic as well as to make decisions about the narration, what written text might be included and what materials will be used. The storyboard will also include a written draft of the narration. In the Construction phase, the students make the models and diagrams and then photograph them, moving the models slightly between each photo to create the animated effect or illusion of movement or change. Depending on the frame rate required (usually two frames per second in Slowmation) students will need to take "a tenth as many photos as a normal animation" (Hoban & Nielsen, 2010, p. 33). It is to be expected that changes will be made to the Slowmation that differ from that planned in the storyboard as the students refine their understandings and representations through their dialogue. Students may also develop new ideas for improving the narrative content. The Re-construction phase involves downloading the photographs onto a computer before importing them in the correct sequence into an animation program. Students then record and add their narration and any sound effects they see as relevant to complete their Slowmation (Hoban, 2005, 2007).

The finished representation becomes a record of the students' learning and an indication of their level of understanding. In a comparison between using traditional stop-motion processes and Slowmation in the classroom, the same outcomes and pedagogy can be used in both but the Slowmation process can focus more on the concept being demonstrated by the student than on the process of filmmaking. A Slowmation allows the viewer more time to absorb the information and in creating a Slowmation students get to their end product more quickly. Hoban (2005) explains that "Slowmation primarily has an educative purpose so that a … movie is made and played slowly to help students to think about and understand the details of a particular science process" (p. 30). A student created Slowmation can be an effective representational tool for explaining science concepts involving changes or processes. Recent research into using Slowmation with pre-service teachers is indicating that adult learners are increasing their understanding of science concepts through the construction of Slowmation. The pre-service teachers recognised that they were continually refining and developing their own science understandings while creating their Slowmation (Hoban, 2007), confirming the notion that science is learned through refining representations of concepts.

Discourse and Learning Science

The collaborative development of a Slowmation provides opportunities for students to engage in the discourses of and about science, which "are important for students to develop their scientific literacy" (Goodrum et al., 2001, p. 10). It has been argued by many educational researchers that dialogue is central to student learning and there is much documentation on the role of student conversation as an aspect of learning (Cox, Mckendree, Tobin, Lee, & Mayes, 1999; Mercer, 1995; Vygotsky, 1978).

In traditional classrooms student conversation was discouraged as being a distraction from the process of learning content from an expert, usually the teacher. Even more recently, student talk in the classroom has been seen as off-task behaviour. The development of social constructivist and socio-cultural theory (Reiber & Robinson, 2004) and the move towards cooperative learning practices (Bennet, 2001) has recognised the importance of student dialogue for learning. In addition, there has been a focus on the benefits of on-task dialogue or discourse between students.

While dialogue can be seen as talk of any kind between students, discourse is a more reasoned discussion using more subject specific language. It has been observed that much of the talk in group-work or cooperative learning classrooms has not always been aimed at improving understandings (Mercer, 1995). A more recent move has been to encourage teachers to promote meaningful student discourse. It has long been accepted that:

> One good test of whether or not you really understand something is having to explain it to someone else. And an excellent method for evaluating and revising your understanding is arguing in a

> reasonable manner, with someone whom you can treat as a social and intellectual equal. (Mercer, 1995, p. 89)

Research in this field has recognised the functions and benefits of peer to peer discourse. Sharing their ideas with peers and adults can develop and generalise students' understandings (Mercer, 1995; Mortimer & Scott, 2003; Vygotsky, 1978)

Studies of student discourse often analyse the kind of talk that is taking place among students, "The process of evaluation and justification of claims to scientific knowledge is commonly known as argumentation, a process which is involved in both talking and doing science" (Naylor, Keogh, & Downing, 2007, p. 17). Argumentation is in many ways similar to "Exploratory talk, in which partners engage critically but constructively with each others' ideas" (Mercer, 1995, p. 104). Both types of talk are more congenial to cooperative learning than disputational talk (Mercer, 2008).

Proponents of authentic teaching use the term "substantive dialogue" which is evident when there is considerable interaction about the ideas of a topic, where students share ideas in interactions in which they explain or ask questions and when "the dialogue builds coherently on participants' ideas to promote improved collective understanding of a theme or topic" (Newmann & Wehlage, 1993, p. 7).

The work of Kurth, Kidd, Gardner and Smith (2002) "has focused on language through the integration of science and literacy with particular attention to oral discourse" (p. 793). Their studies were undertaken with students who were prepared in the use of particular oral language strategies in science contexts such as agreement, making a claim, disagreeing, reasoning and respect and looked at student use of narrative and paradigmatic discourse. "Bruner distinguished two modes of thought, narrative (story) and paradigmatic (argument)" (Kurth et al., 2002, p. 796) and while it is to be expected that students of science would use the latter, the study found that the students were able to blend the two modes in complementary, meaningful ways. Kurth et al.(2002) go on to say: "More attention to the blending process of narrative and paradigmatic modes in science may be important in maintaining students' engagement" (p. 815).

While it may be a commonly held belief that primary age children do not have the linguistic sophistication, nor depth of understanding of science processes and concepts to engage in constructive discourse, Naylor et al. (2007) found otherwise. Their research, using concept cartoons in junior primary science classes:

> set out to determine whether primary school pupils would engage in purposeful argument in science, given a suitable stimulus, and to characterize any argumentation which occurred. Transcripts of the pupils' conversations show unequivocally that they can and do engage in argumentation and that this is a purposeful process for them. (Naylor et al., 2007, pp. 35-36)

Not only did young students find the process purposeful but the research also provided evidence that “worthwhile argumentation can be generated in relatively young pupils by a combination of an engaging stimulus, clear curriculum relevance and learning goals which are framed in terms of science conceptual development” (Naylor et al., 2007, p. 37). Of further interest is the finding that primary aged students are able to “co-construct an argument rather than viewing argumentation as confrontational” and that in the absence of a teacher, student discourse was less inhibited and more productive, “When pupils work in small groups in the absence of the teacher they are working more as equals and can create their own rules to govern the conversation” (Naylor et al., 2007, pp. 36-37). This has positive implications for the implementation of Slowmation into science teaching, where students work in groups.

Many schools explicitly teach students appropriate methods for conducting effective and meaningful discourse. While this takes place very much in literacy classes as ground rules for exposition or debate, recent initiatives into the teaching of philosophy have also provided such scaffolding (Trickey & Topping, 2004), as have integrated units of work following cooperative learning pedagogies (Bennet, 2001).

A number of theories have been developed that describe the type of conversation that is most effective in the classroom and there have been several studies regarding the context in which effective student discussion takes place. It is accepted that, given appropriate ground rules for the conduct of collaborative learning and discussion, student discourse “has been shown to be valuable for the construction of knowledge” (Mercer, 1995, p. 98). Mercer describes the conditions under which meaningful talk can take place: group members must have to talk to undertake the task; the activity should be designed to encourage cooperation; there should be a shared understanding of the point and purpose of the activity; and, rules should encourage a free exchange of ideas. It is in this context of student dialogue that student developed animation may well have an important place in the primary science classroom. The process of creating an animation is one in which students are required to work collaboratively to create a finished film with accurate content, thus providing opportunity for sustained conversation and deeper knowledge of science concepts and improved use of science literacies and representation.

Mortimer and Scott (2003) draw on the work of Bakhtin to describe learning as "a dialogic process, which always entails bringing together and working on ideas" (p. 11), describing how learning takes place through talk, whether as a participant or an observer. Mortimer and Scott (2003) further argue that for students to learn science, the teacher must stage a performance which places the ideas of science in the social dimension of the classroom while assisting students to internalise skills and understandings. This performance must also support students to generalise and use the skills and ideas of science. In this process students use the varied literacies of science as they engage in discourse about science ideas and processes.

Multimodal Representation

One aspect of literacies of science emphasised in the Primary Connections programme is the knowledge of and ability to use the representations of science. These representations, some of which are shared with mathematics, others with the social sciences and some are everyday literacies, can be in the form of tables, diagrams, graphs, models (both 2D and 3D), journals, posters, charts, role-plays and narratives. There is more to representation than simply sharing information. In learning the representations of any discipline in social contexts and applying them in individual contexts, students develop their own representations and construct their own understandings.

It is useful to draw from the literacies of visual art representation and compare them with the literacies of science representation. A young child without the representational understandings inherent in interpreting the illusions of perspective in a drawing, sees one object as smaller and higher up the page, whereas a person with the appropriate representational understandings knows to interpret the smaller objects higher up the page as being further away (Carolan et al., 2008). Many art teachers accept that while they might teach this concept, children have developmental limitations that inhibit their ability to use this knowledge. Children construct their understanding of their world through drawings that show a conceptual idea rather than a visual representation of what they see. It is as they work with their representations, over many years, that they come to an increased understanding of the world and of the literacies of the visual arts. Likewise, working with the representations of science assists children to build on their understandings of the world of science (Jayashree, 2009).

Carolan, Prain and Waldrip (2008) argue that relevant representational competence is "crucial to learning in science" (p. 19) and draw on Peirce's triadic model from 1934, to show the relationship between representation in a sign, diagram or image, with the interpretation of this sign and with the actual phenomena the sign refers to. They add, "for learners to understand or explain concepts in science, they must use their current cognitive and representational resources to learn new concepts at the same time that they are learning how to represent them" (Carolan et al., 2008, p. 19). Effective student discourse is itself a representational mode that mediates the generation of other representational forms. Students use representational conventions as tools for thinking and developing understandings and are further assisted if they are given the opportunity to develop their own representations (Carolan et al., 2008). It is as they work with science representations that students further develop their science literacies in order to communicate their understandings using other representations. It is very much a circular and dynamic process. Hoban and Nielsen (2010) further develop this idea by describing how creating a Slowmation involves repeated re-representations in a series of Peirce's triadic models.

Tytler (2007) argues that "students must understand different representations of science concepts and processes, be able to transfer across these and understand their coordinated use in representing scientific knowledge and constructing explanations" (p. 36). Such an argument supports student creation of multimodal representations. Tytler also recognises that students live in a multimodal world and are likely to be quite sophisticated in their experience of varied representations. This level of representational sophistication "must be part of the learning agenda of school science" (Tytler, 2007, p. 37).

This understanding is embedded in the units of work of the Primary Connections science teaching resources, with students guided towards creation of various representational modes of particular science concepts.

As the concepts and processes of science cannot be learnt separately from

> their representation (Gee, 2004; Lemke, 1998; Norris & Phillips, 2003), literacy practices are needed to engage with science phenomena and ideas. The Primary Connections programme therefore incorporates a range of literacy practices and forms of representation to engage students in learning both science and literacy, and to provide ways for students to show what they know. (Peers, 2006, p. 9)

Science has as its foundation the development of representations of the ideas that explain our world. Students make sense of science concepts through interactions with multiple forms of representation, both the conventional systems of representation that expert scientists use, which children must come to understand, as well as students' own representations. Students' scientific understandings develop at the same time as their knowledge of and practise with modes of representation (Gravel & Rogers, 2009). Jayashree (2009) argues that:

> Expertise in using visual and spatial modes needs to be developed, for these to become effective tools for thinking [and] we need to find and test ways of developing such expertise in the science classroom. … Recognising the seminal role of visual learning will open up new ways of looking at all aspects of science education including practical work, classroom discourse, concept understanding and assessment. (p. 297)

This research focussed on a newly emerging form of representation in science; that of student created slow animation, with accompanying narrative and its role in helping students formulate their science understandings. Slowmation is a visual mode of representation and "visual thinking is an integral part of doing and learning science. The models or idealisations of science are simplifications of complex, real-world phenomena, often expressed in concrete, visual or symbolic modes" (Jayashree, 2009, p. 301).

Carolan, Prain and Waldrip also recognise that, "students are more motivated and learn more when they have opportunities to refine understandings through revising representations" (Carolan et al., 2008, p. 18). The collaborative process of developing an animation, under appropriate ground rules should provide great opportunities for such refinement through revision in a Primary Connections context where concepts are developed through "guided investigations related to a sequence of representational and re-representational work" (Carolan et al., 2008, p. 20).

Tytler asserts that, “Research is needed into ways in which student representational resources can be effectively harnessed to support learning of key science ideas and ways in which representational negotiation can support students” (Tytler, 2007, p. 37). Student created Slowmation provides an alternative and multimodal form of representation and harnessed appropriately can afford opportunities for engagement, discourse and development of science understandings.

Science Understandings and Scientific Literacy

The concept of scientific literacy first appeared in the late 1950s but did not become a focus of curriculum development until the late 1980s and the 1990s, where in both the United Kingdom and the United States of America reviews of science education were recognising the shortcomings of contemporary science curriculum. Studies were showing that science curriculum was aimed very much at developing science practitioners and academics, was overly content based, too broad and not providing students with science skills and understandings that would benefit them in later life and society as a whole (Goodrum et al., 2001).

More recently it has been reiterated that “Scientific literacy is essential to an individual’s full participation in society. The understandings and abilities associated with scientific literacy empower citizens to make personal decisions and appropriately participate in the formulation of public policies that impact their lives” (Bybee, 2008, p. 567). Murcia (2009) further elaborates the notion of science for active citizenship and argues that scientific literacy includes not only competence but disposition, stating that “scientifically literate citizens would have general, broad and useful understandings of science that contributes to their competence and disposition to use science to meet the personal and social demands of their life at home, at work and in the community” (p. 16).

While there is a generally accepted rationale for the importance of scientific literacy, the debate over an appropriate definition and position within science education has been robust. A common theme is that students need to gain a clear understanding of science process, are able to communicate science learning to others, have the ability to make reasoned judgements about science related social, health, ethical and environmental issues and to be lifelong learners of science.

For example, scientific literacy is defined in the U.S. National Science Education Standards, as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (NRC, 1996, p. 22). These standards also include notions of what scientific literacy means to individuals and to society. It recognises that individuals have different needs and interests and that their literacy will develop over the years beyond schooling. The standards also explain what we might expect a scientifically literate person to be able to do, which includes also, "a capacity to engage in the discourses of science and the ability to evaluate scientific evidence and arguments" (Goodrum et al., 2001, p. 11).

For the purposes of the review of Australian science education, Goodrum, et.al (2001) defined the characteristics of a scientifically literate person as;

> the capacity for persons to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well being. (p. 15)

The program for international student assessment (PISA) is a triennial survey of the knowledge and skills of 15-year-olds across 57 participating countries. The rationale behind the PISA assessments is the monitoring of the functional literacy of students at the end of junior high school. For the purpose of the PISA science assessments, scientific literacy is defined as the extent to which an individual:

- Possesses scientific knowledge and uses that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues.
- Understands the characteristic features of science as a form of human knowledge and enquiry.
- Shows awareness of how science and technology shape our material, intellectual and cultural environments.
- Engages in science-related issues and with the ideas of science, as a reflective citizen. (OECD, 2007, p. 12)

Tytler (2007) points out that a science literacy perspective is in essence a humanistic perspective which has a focus on the nature of science and its processes as well as science concepts. Furthermore, Murcia (2009) asserts that "scientific literacy could be viewed as multidimensional and a composite, in some way, of science concepts and ideas, the nature of science and the interaction of science and society" (p. 218). These authors recognise the changing nature of science and its challenges as well as the differing needs of future scientists and future citizens.

Norris and Phillips (2003) argue that to achieve competence in scientific literacy, a person needs to be able to interpret science texts in a science paradigm, it is not about simply decoding and comprehending a science text, which they argue is simple literacy, it is about interpreting a text through an understanding of science theory. Norris and Phillips believe that literacy and science understanding are inextricably interwoven, western science has come to an agreement of understandings of theory and concepts through its association with written literacies and a focus on scientific literacy is a way to "capture what is truly exciting about science, namely, how it all fits together into a remarkable whole" (p. 237).

Hackling and Prain (2008) assert that:

> Scientific literacy is a multidimensional construct (Bybee, 1997, OECD PISA, 2006; Roberts, 2007) and requires citizens to be interested and engaged with scientific matters and have the knowledge and skills that can be applied in real-world contexts to investigate, represent and communicate findings and solve everyday problems (Figure 2). The literacies of science and processes of science components are closely inter-related, for example, science investigation requires the application of processes such as observation and measurement to gather data, literacies of science to represent data as diagrams, tables and graphs in ways that enable relationships and patterns in data to be identified and interpreted using processes of science and then claims are made on data and communicated using literacies of science. (p. 7)

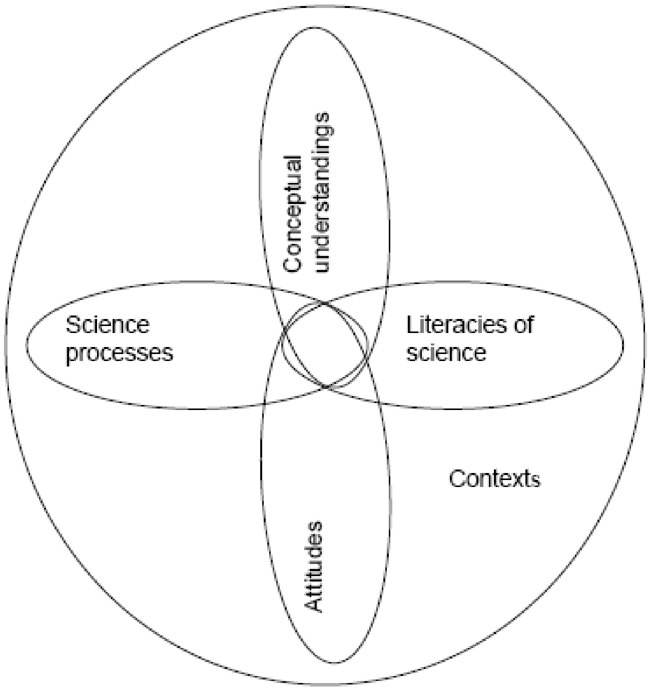


Figure 2. Scientific literacy- a multidimensional construct (Hackling & Prain, 2008)

Specific dimensions of scientific literacy that might be seen to operationalise the definitions provided include; interest in science, understanding of science concepts, engagement in science discourse, ability to recognise and engage in the science process, representational practices of science and use of these literacies to make informed decisions (Tytler, 2007).

Conceptual Framework

The study is framed within a broad theoretical perspective based on social constructivism and socio-cultural theory and was set in the context of a unit of work which employs an inquiry-based and collaborative learning approach to science education.

Students utilise substantive discourse and various modes of representation while working in a small group to create a Slowmation during the Evaluate phase of the Primary Connections unit, *Spinning in Space*. Substantive discourse is defined as sustained talk around the content of the topic, with successive turn-around in the conversation and use of language specific to the topic in question. Representational modes include those that are part of science literacy, such as conventional science diagrams and the features used within them and also cross-curricular modes of representation such as speech, writing and gesture. The student-created Slowmation is a multimodal representational form in itself, which includes graphical and narrative forms of representation, specifically; animation, diagram, text and spoken word.

The study analysed the opportunities that were afforded for students to develop enhanced representations and accurate explanations of the science concepts included in the Primary Connections unit, *Spinning in Space*, which include the relationships between the Sun, Earth and Moon and day and night. It is argued that engagement in science, through creation of the Slowmation supported by substantive discourse and multimodal representation will lead to enhanced scientific literacy.

Conceptual Framework

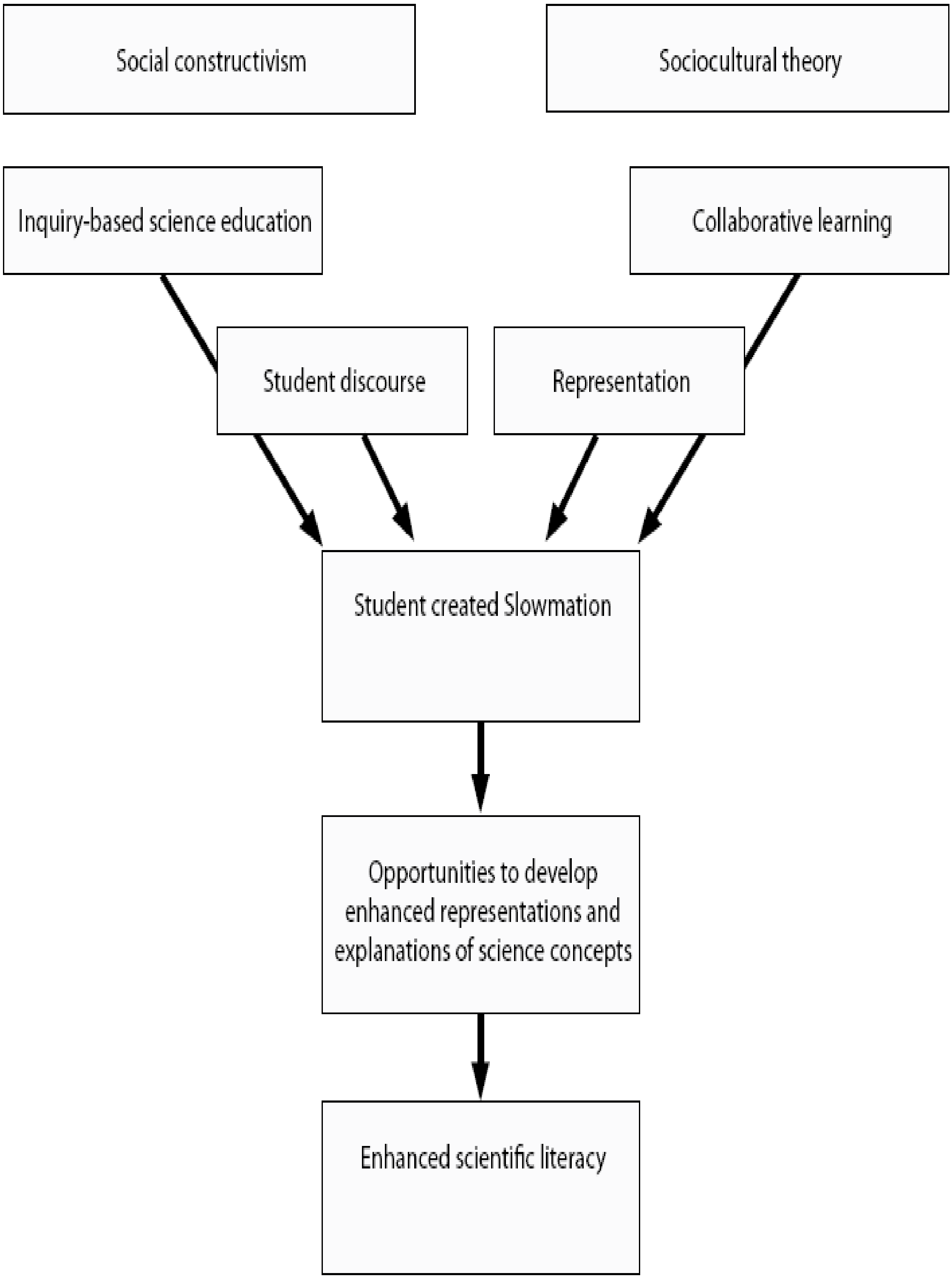


Figure 3. Conceptual framework

CHAPTER 3 METHODOLOGY

Approach

In developing the methodology used in this study it was useful to recognise that the Researcher was a part of the world being researched, being the classroom teacher and also the school principal. This in itself had the potential to introduce particular and additional complexities to the normal multifaceted educational workplace. To this end an eclectic approach utilising aspects of ethnographic and naturalistic research was undertaken as a case study (Cohen, Manion, & Morrison, 2007). The study explored the introduction of student created Slowmations into the evaluation phase of a Primary Connections science unit delivered to two groups in a single multi-aged class. Audio and video recordings were made during key stages of the Primary Connection unit, these were transcribed and analysed alongside the research journal, student artefacts, such as diagrams, tables, charts, learning journals and ultimately their collaborative Slowmations. Long extracts of conversation were recorded to avoid losing the complexities offered for analysing the student's developing thinking, particularly their use of gesture, drawing and discussion of ideas brought from other learning dimensions, such as home, books and television (Robbins, 2007).

It needs to be recognised that in such a video-ethnographic case study, the very act of video-taping a group can influence the nature of the data collected (Pink, 2007) and as such it was important to have the students become familiar with the technology to a point they were no longer noticeably influenced by its presence. This was achieved by using the audio and video equipment in lessons preceding the study. This does not assume that their discourse was not influenced by the data collection method but it proved useful for ensuring that gestural representations were not lost, as would have been the case in straightforward audio recordings.

The case study approach generated thick descriptions of teaching and learning processes, events and artefacts (Yin, 2009) and allowed student discourse to be studied in some depth affording an analysis of any evidence of student growth in scientific literacy and understanding evident in the finished Slowmation. Education involves complex processes and interactions and achievement is very much influenced by the ability and motivations of teachers and students, and as such it will always be context bound. A strength of a case study approach is the potential to look at the phenomenon in a real-life context and blend a description of what happens with an analysis of why it happened (Cohen et al., 2007; Yin, 2009).

Yin, (2009) suggests that “how” questions are most suited to case study research and the predominant question being asked in this research: “How does the implementation of student-created Slowmation influence the development of students’ scientific literacies?” fits this category. Case study research can also describe “an intervention and the real life context in which it occurred” (Yin, 2009, p. 20) which again supports the choice of this method for the research. Yin adds that the case study strategy may be used to explore “those situations in which the intervention being evaluated has no clear, single set of outcomes” (Yin, 2009, p. 20) and in the case of this research proposal there was no proposition as to what would be discovered. The research had clearly defined beginning and end points, a clearly distinguished unit of analysis (a small group of students) and clearly articulated criteria for interpreting the findings (based on increased science understandings, substantive dialogue and use of multimodal representations) all of which suggested the suitability of a case study approach (Yin, 2009).

Context

The study took place in a small, somewhat isolated, rural school of approximately 40 students. The class is a multi-aged, mixed gender group of 16 students in Years 4 to 7 (ages 9-12 years) who take science with the school principal. There are limited opportunities for integration of science topics into daily literacy timetables but some class time is allocated for the completion of science tasks. The students generally have positive perceptions of science as a learning area and have been exposed to Primary Connections science units and approaches in the past two years. The nature of such multi-age groups is that units of work have to be open-ended and flexible enough to allow for students to engage with them at their level of development. It is the experience at the school that Primary Connections science units allow this. The Primary Connection unit covered during the research was *Spinning in Space* (Australian Academy of Science, 2006). Further in-depth description of the context is provided in Chapter 4.

Procedure

Bell (2008) advises that a case study approach should be defined in terms of its beginning and end points and should contain specific propositions, adding that;

“Evidence has to be collected systematically, the relationships between variables studied and the investigation methodically planned” (p. 10) and as such, the study was planned within a clear structure.

The students were first given an opportunity to revise the processes for making a Slowmation, using content of a previous science unit, with the whole class making one Slowmation led by the teacher using a strategy recognised as the jig-saw approach (Hoban, 2005). This allowed the teacher to model a collaborative production and introduce the ground rules for reasoning and problem solving discussion. The ground rules for discussion followed the work of Mercer and Dawes (Dawes, 2009) who suggest that rules for talk should include: Sharing ideas and listening to one and other; talking one at a time; respecting each others’ opinions; giving reasons to explain ideas; asking “why?” questions if we disagree; and, aiming for consensus.

The Primary Connections unit *Spinning in Space* was commenced and lessons videoed from the outset to give students confidence and familiarity while being filmed. It took about two lessons before the majority of students relaxed in front of the camera and were able to work without constantly acknowledging its presence. Work samples were collected as normal practice in the first (Engage) stage of the unit to provide baseline information regarding students’ level of understanding. The Explore phase provided hands-on shared activities to develop understandings of the shapes, sizes and positions of the Sun, Earth and Moon and also concepts about light and shadows. During the Explain phase of the unit, students participated in a role-play representation to explain and support their developing understanding of day and night. Small group discussion was recorded to generate useful baseline data regarding student discourse and examples of students’ work were collected. Interviews with students helped determine developing understandings. At the Evaluate phase of the unit, the lesson was structured to allow students to follow the steps outlined by Hoban (2005) in the construction of a Slowmation; Planning, Storyboarding, Construction and Reconstruction. The student discourse was videoed as it took place during the planning and during the construction of the Slowmation. The group of 16 students was too large to be involved in the construction of a single Slowmation, therefore students were organised into three groups. Two of these groups were videotaped, the other was a non-research group. Changes to this structure were made during the course of the study due to students leaving the school, which is documented further in Chapter 4. The video taken during planning and construction of the Slowmation was transcribed and then analysed to provide a description of the nature of student discourse and the development of students' understandings. After the Slowmations were constructed they were analysed to determine the representation of the concept and the levels students displayed against the Primary Connections intended learning outcomes for the unit and the draft National Statements for Science (MCEETYA, 2006). Students were also asked to evaluate their own Slowmations and to make a judgement about the usefulness of creating a Slowmation in a science unit. Student interviews provided further information about student perceptions and developing understandings.

Data Analysis

Given the small group sizes and the limitations of context it was determined that descriptive statistics about frequencies of types of talk and non-parametric statistics to compare frequencies of codes between explain and evaluate lessons would have little statistical value and as such, any consideration of using some quantitative methods was dismissed so that the case studies would be compiled from student artefacts, research journal, excerpts from the video, dialogue and from the interviews (Bell, 2008).

Audio and video recordings were taken of the two student groups as they developed their Slowmation. The recordings were transcribed such that both verbal and gestural communication was recognised, giving a rich picture of the quality of the discourse taking place. This was achieved by directly transcribing verbal communication and writing clear description throughout when gesture was used alone or in accompaniment to verbal discourse. The discussion was analysed for substantive conversations that contributed to the development of science understandings and more broadly to scientific literacy.

A range of literature was drawn on to assist in defining the nature of substantive discourse for the purpose of analysis. In reaching a definition of what substantive discourse looks like, researchers advocate various descriptions. Firstly, Naylor et al (2007) suggest; making a claim to knowledge, offering grounds to support knowledge, offering further evidence to support a claim, responding to others' ideas and sustaining an argument or conversation. Secondly, Mercer (1995) offered; cumulative talk, characterised by minimal disagreement with positive repetitions and elaborations and exploratory talk, characterised by challenges, requests for clarification and responses which provide explanations and justifications. Asserting of a point of view, challenging ideas, explaining ideas and requesting clarification were later additions (Mercer, 2008). Furthermore, Simon, Naylor, Keogh, Maloney and Downing (2008) see substantive discourse as including; asking reasoned questions, justifying a view, encouragement, recall of knowledge and descriptions of observations and concepts. Many such descriptors can be identified and it is useful to recognise that "substantive discourse builds coherently on participants' ideas to promote improved collective understanding of a theme or topic" (Newmann & Wehlage, 1993, p. 7). It was within such a framework that student discourse was analysed with transcribed vignettes used to illustrate the nature of the discourse and how it contributed to students' development of science understandings. Gestural communication events were also recorded as it became apparent that discourse was integrated with other multimodal representations. The storyboards were analysed to determine developing understandings against the students' conversations and the finished Slowmations were analysed for accuracy of science concepts.

Ethical Considerations

Issues regarding informed consent arise when research participants are young children, especially if the Researcher is the school principal who is regarded as having some authority over the subjects. The nature of the relationship between teacher and students is recognised as possibly allowing undue influence regarding the level of voluntariness of participants. Cohen et al. (2007) advise that researchers first gain permission from those people responsible for the subjects, that is, the parents and teachers. The WA Department of Education and Training has particular protocols for research to be undertaken in its schools and school principals are encouraged to seek the support of the school council before allowing any research to be undertaken in a school. The WA Department of Education and Training requests adequate safeguards to ensure that all people involved are completely informed about the research and that the voluntary nature of participation is made explicit in all research-related correspondence. These safeguards also consider confidentiality, which can be ensured by removing any information that may identify the participants, other students or staff. Participants can withdraw from the research and have their data destroyed at any stage of the study on request. Useful templates for drafting letters to all stakeholders are available (DOE, 2009b). In the case of this study, the District Director of schools was the point of liaison with the education department. The purpose of the research was explained, and questions invited. The research did not proceed until permission was granted from all responsible parties, including the children. The school council, parents, students and other teachers were all approached and all gave their support to the project. It was explained to all parties that objections would be duly respected and those wishing not to participate recognised and respected. Arrangements were made for those students who did not wish to participate in the research to participate in the lessons by being part of a group not being studied. Anonymity and confidentiality were guaranteed.

Given the nature of the research it was difficult to have a researcher other then the principal/teacher collect interview responses and analyse video, therefore it was important that parent/caregivers, students and other teachers had a full understanding of the nature and purpose of the study. Parents/caregivers and students were provided with information that clarifies the principle of voluntariness, the notional and practical separation of school initiated activities and the research activities and the role of the teacher/principal. The research proceeded once information letters and consent forms were received and ethics clearances granted from the University Human Research Ethics Committee and from the WA Department of Education.

CHAPTER 4 CONTEXT

Contextual factors greatly influence the approach and findings within any given study. This Chapter outlines a description of the school, community, socio-economic factors, history, values, resourcing, classrooms, student achievement standards and a timeline of teaching events around the curriculum topic, *Spinning in Space*. This presentation of context is provided so that the reader might gain a deeper appreciation of the key findings.

Community

Green Pastures Primary School (GPPS. Pseudonym) is a small rural school located in a town site of approximately half a dozen houses in regional Western Australia. There are 37 students, a teaching principal, two full-time teachers and two part-time teachers. While in some years there have been families with school aged children living in the town site, all the students at the school in 2010 reside in the outlying agricultural areas and are either the children of farming landowners or farm workers. All but one family travel by bus to school. There are two school buses provided: Bus One picks up its first students at 7:30 am from approximately 30kms west of the School; Bus Two at 7:40 from approximately 25 km east of the School. The roads are predominantly constructed from gravel and there are frequent disruptions to the service during winter due to road conditions.

The community is very supportive of the school and it is seen as a major part of the physical and social community infrastructure. The School Library shares facilities with the Community Library which is used by a wide range of community members and seasonal workers. The students are involved in cultural events and interactive days with neighbouring schools which are between 30km and 100km distant. There is a strong supportive relationship with the District Education Office in the nearest large town.

The highly supportive Parents and Citizens Association (P&C) has, over the years, provided an undercover area, and extensive play and learning equipment. Regular P&C meetings are held monthly and are usually well attended, with a range of issues open for discussion. In 2009 the P&C made significant contributions toward teaching resources. They also supported the school financially through the purchase of trophies for the sports carnival, donations to the school library, providing book awards and funded the provision of hot water to the toilets and to the staff room. The P&C also supports the school through busy bees and helping out at school and community events such as the local fete and sports carnivals. They also provide financial support to for the bi-annual cluster Canberra Camp, when Upper Primary Students join students from throughout the district in a week-long educational excursion to the nation's capital. Classroom assemblies each fortnight are attended by a cohort of interested parents and community members and parents regularly make formal and informal contact with the teachers and principal to discuss a range of interests. Once a term School Council meetings address wider issues.

Socio Economic Factors

"The Index of Community Socio-Educational Advantage (ICSEA) is a special measure that enables meaningful and fair comparisons to be made across schools" (ACARA, 2010b). The variables that make up ICSEA include socio-economic characteristics of the areas where students live (in this case an ABS census collection district), as well as whether a school is in a regional or remote area, and the proportion of Indigenous students enrolled at the school. It has been developed specifically for the *My School* website for the purpose of identifying schools serving similar student populations. The average ICSEA value is 1000. Most schools have an ICSEA score between 900 and 1100" (ACARA, 2010b).

GPPS has a School ICSEA value of 1086 placing it slightly above the average band of schools. The WA Department of Education's Socio Economic Index for the School is 109.35 which also places it among the slightly above average group. GPPS's disadvantages are those of distance from regional centres and services, rather than those of socio-economics.

School History, Ethos and Values

Green Pastures was first settled by Europeans in the 1880s, but the town-site was not gazetted until 1922. A School was established in 1927 and closed in 1934. Since 1966 when the current school was established, the school community has developed a strong ethos over the years with a public view that the school is here to maximise each student's potential. The School is committed to maintaining a positive work environment that is safe, healthy, well resourced and educationally sound.

The school motto is “Undaunted” and the school community strives to ensure that all students are equipped to meet the challenges of life. The school fosters the development of the whole child through the provision of a learning environment that is supportive, safe, stimulating and inclusive, encouraging all students to be actively engaged and motivated learners by immersing them in a positive learning environment (DOE, 2010). Green Pastures Primary School promotes a responsible and professional workforce dedicated to developing current and life-long skills relevant to the changing world, preparing students to participate successfully within the wider community. The school provides strong organisational support through whole school collaborative planning of a challenging curriculum. Quality learning activities are provided for all students in all learning areas. Students are encouraged to take responsibility for their own learning and behaviour. Teachers are actively involved in, and committed to, the delivery of an outcomes based education with reference to achievement targets in Years 3, 5 and 7. Teachers regularly meet with others in the schools’ network to ensure common understanding of student standards (DOE, 2009a).

Resources

The School is well resourced in terms of staffing, accommodation and teaching materials. The School has 3.6 full-time equivalent (FTE) teaching staff as well as resourcing additional staff time using Commonwealth and School Grant funding. There are two full-time teachers, two part-time teachers and a Teaching Principal. 1.1 FTE Classroom Education Assistants and a 0.9 FTE Special Needs Education Assistant.

There are three classrooms and an additional Art/Science/Music Room. The grounds are an attractive and useful asset to the School which are incorporated into the delivery of the curriculum. The recent National Building Program has funded a new library building, seen classrooms re-painted and relocation of the sports equipment shed. A National Solar Schools project was finalised in 2010 with 86 photo-voltaic panels added to the nine installed under a previous grant. Students have access to the data available to evaluate the value of solar energy use.

Literacy and Numeracy texts are reviewed and updated annually and the School subscribes to both Literacy and Numeracy online services as well as CSIRO’s Double–Helix Science by E-mail. Due to a carefully managed computer replacement plan, the school has a ratio of one computer (less than four years old) per four children, each networked with internet access. All classrooms each have an interactive electronic whiteboard with teachers undertaking relevant online and peer mentored professional learning.

Based on socio-economic indices both nationally and state wide, GPPS is within an average range, with its main disadvantage being distance from regional centres and services. It can be inferred from the information provided above, that the school in which the study took place is typical of most found in rural Western Australia.

Key Finding 4.1

The study takes place in a typical Western Australian small rural school.

Students

Ranging from Kindergarten to Year 7, the children are taught in three classes, following the Western Australian Department of Education's developmental curriculum. There is one student identified as being of Aboriginal descent. The student population of 37 for 2010 was down on the 42 of 2009. Census figures predict stable enrolments generally, although in 2010 there was a substantial drop in numbers due to a variety of personal factors, from work dissatisfaction, family break ups and farming difficulties.

Academic, social and emotional needs of students are catered for by the high staff to student ratio. The teachers, who range in experience from 30 years to two years, are committed to the welfare and well-being of each student and offer them every incentive to achieve their ultimate potential. Students learn respect, leadership skills, responsibility and citizenship. There is a strong collaborative element to whole school planning and decision making, with teachers encouraged to cater for the individual needs of their students facilitated very much by the small class sizes. The early-childhood class, started 2010 with 14 kindergarten, pre-primary and year one students, the Year 3/4, 11 students and the study group of Year 5/6/7 12 students. By the end of the study both the Year 3/4 class and the Year 5/6/7 were down to eight students.

Attendance

Attendance rates provide a good indication of the value placed on education by families and in analysing data from the Semester 1 Attendance Census in 2009, the

Principal wrote; “While 82% of our students maintain above 90% attendance there are continuing issues with students being taken from school early for after-school activities (mainly sporting) conducted 80km away in the nearest large town. While this could be deemed as parental choice there is a need to raise parent awareness of the implications of student non-attendance” (DOE, 2009a, p. 3).

Attendance rates at the end of 2009, at 94.5% were above the state average of 92.9%. In-depth analysis of data within small populations has the potential to breach individual’s confidentiality and low student numbers can make statistics somewhat invalid. When individual cases are studied there are clearly justified reasons for all the indicated, moderate and severe absence risk categories. Attendance rates for the majority of students in Semester 2 2009 and Semester 1 2010 were much closer to 100%.

Student Achievement

Student achievement is measured in literacy and numeracy using the National Assessment Program in Literacy and Numeracy (NAPLAN) and for science using Western Australian Monitoring Standards in Education (WAMSE) science. Contextual information influencing student achievement is also reported.

National Minimum Standards In Literacy and Numeracy

The National Assessment Program in Literacy and Numeracy (NAPLAN) is a curriculum-based assessment that is criterion-referenced and tests students' knowledge and skills in numeracy, reading, spelling and writing. The National Minimum Standard (NMS) is the agreed standard of performance that professional educators across the country deem to be the minimum level required for Year 3, 5 and 7 students to make adequate progress. The NAPLAN assessment materials are designed to measure the range of performance expected of Year 3, Year 5 and Year 7 students, including achievement of the NMS. The tests give an indication of how students are performing in relation to the NMS and national averages. In 2009 the School was able to report that 100% of students achieved at or above the National Minimum Standard in Numeracy, Reading and Grammar/Punctuation. In addition, the percentage of students achieving above the National Average increased from 25% in 2008 to 51% in 2009 averaged across all learning areas. In 2010 there were no students below the NMS in literacy or numeracy. This data is available for teachers as a comparison between like schools and all other state schools. Data is provided in percentages for each year level. Analysis of the data indicates that this school compares acceptably with like school and other state schools in literacy, with improvements on 2008. Average Numeracy results for one particular year level was below that of other “like” schools and plans were put in place to address this during 2010. Comparisons have shown that throughout their time at Green Pastures Primary School, students maintain acceptable growth against “like-school” averages in national (NAPLAN) and state testing (WALNA) in Reading and in Numeracy.

WA Monitoring Standards in Education (WAMSE) Science

These tests of Science Understanding and Science Investigation skills were conducted with Years 5 and 7 students during 2009 and 83% of students at this school achieved at or above the WAMSE minimum standard in both Science Understanding and Investigation, which compared favourably to the State Average of 66%.

The School attributes much of this success to the resourcing for a Science Specialist during 2008, involvement in the WA Education Department’s *Primary Science Project* (DOE, 2005) and the subsequent use of Primary Connections science resources. These should be considered important factors in terms of this research, in the choice of school, the overall context and the findings.

Contextual Information Influencing Student Achievement

As reported in the Director of Schools 2009 Standards Review; the standards of student achievement at Green Pastures Primary School are acceptable in the school context. At the time of writing, the School has a cohort of 30 students, with a dwindling population due to economic and environmental factors. Attendance levels and academic achievement are comparable to like-schools, with small student numbers allowing for high levels of individual attention.

This data indicates that the students of GPPS are typical of students in similar small rural schools.

Key Finding 4.2
Students are typical and achievement is slightly above average.

The Case Study Groups

The Year 5/6/7 class was chosen because the research is based around current practice at the school. Currently the School integrates the teaching of stop-motion animation into Art, English, Science, Technology and Enterprise (T&E) and Information and Communication Technology (ICT).

There were two groups of four students from within a Year 5/6/7 class of originally 13 students. An additional group of five students who did not wish to participate in the research undertook the same unit of work. This proved fortunate as two were able to join the other groups seamlessly when student numbers dropped. One student in the class chose not to participate in the research, and as there was still a requirement to undertake the activities, video footage of this student was deliberately pixellated and no audio recordings or other data were collected from this student.

Group 1

The Year 5/6 group, comprised four male students, aged from nine to 11 years. Three of the students (Students 1, 2 and 3) have been at this school since Kindergarten and have been family friends since they could walk. The other student (Student 4) joined the school two years ago from interstate and has integrated successfully both socially and academically. There is a high level of familiarity and social competiveness between all four of these boys. All four students have a positive attitude to science activities and have achieved sound results in science over the past years.

Student 1 (Year 6) is of average ability but with an inclination to minimal output, especially in writing. He achieved a very high score in the 2009 Year 5 WAMSE Science Assessment. Student 2 (Year 6) is overcoming literacy difficulties, having been on an individual educational plan for literacy, both in reading and writing. Much of his difficulties stemmed from behavioural problems in K/P when he would hide under the table and refuse to undertake any activities. Students 1 and 2 are highly competitive between each other but great friends. Student 3 (Year 5) achieved sound results in all areas up until Year 4 but is finding abstract conceptual development difficult without the support of the Junior Primary Education Assistant. He has a positive attitude to all subjects and likes to do well. Student 3 has a fear of failure and rarely takes risks in learning, preferring to acquiesce to others' viewpoints. Student 4 (Year 5) displays above average ability across all learning areas, with a particular interest in numeracy and science. Student 4 enjoys challenges and has been known to behave inappropriately when he finds learning activities unengaging.

Key Finding 4.3

Students in Group 1 are a diverse range of male students, both in ability, engagement and attitude and have a positive perception of science at school.

Group 2

The Year 6/7 group comprised two male and two female students aged from 11 to 12 years. Student 1 (Year 7 male) is a dominant member of this group, academically engaged, successful and capable across all learning areas, he has a keen interest in both science and art. Student 1 can become distracted and obsessed by factors outside the task at hand but rarely to the detriment of his or others' learning. Student 2 (Year 7 male) is considered an average student who sometimes has to work hard to maintain achievement targets in both literacy and numeracy. Student 2 displays a very positive attitude to science and is fully engaged in all activities. Both Students 1 and 2 have been at the School since Kindergarten and are very familiar but cooperative with each other. Student 3 (Year 6 female) has been at the School for the past two years, having moved from the metropolitan area and integrating well into the school community. She is a high achieving student engaging fully in all learning areas but easily distracted socially. Student 3 displays a positive attitude to all science activities and scored extremely highly in the 2009 Year 5 WAMSE Science Assessment. Student 4 (Year 7 female) has also been at the school for the past two years, having moved from Interstate and integrating well into the School community. Student 4 is a social person who likes to help others as well as being an engaged student who likes to do well. She enjoys science but declares no overzealous passion for it, preferring to engage in the activities and complete the work required. Student 4's results in science are good and she is achieving the targets expected of a Year 7.

Key Finding 4.4

Group 2 comprises a diverse range of students, both in gender, ability, engagement and attitude, with all enjoying learning science at school.

Principal/Teacher/Researcher

One of the unique or complicating facets of this study is the role of the Researcher as the participating children's science teacher and the school Principal. The concept of voluntary participation was made very clear to students and parents prior to the commencement of the project, with parents/caregivers and students provided with information to clarify the principle of voluntariness, the notional and practical separation of school initiated activities and the research activities and the role of the teacher/principal. It is the nature of such small schools in which the Principal has also to build relationships with students as a teacher that enabled the School Council, parents, students and other teachers to accept and embrace the research taking place at their school.

The Teacher/Principal has 31 years teaching experience in a number of regional, metropolitan and rural schools in Western Australia, both Public and Private. Several of these years were spent as a Primary Art Specialist. He gained Level 3 Teacher status which is earned in recognition of exemplary teaching practice in the classroom before becoming a teaching Principal in two remote rural schools, a role he has enjoyed for the past six years. Teaching experience includes three years as a curriculum writer for The Schools of Isolated and Distance Education, in two roles which included team writing the Mathematics Curriculum for Upper Primary and Integrated Curriculum (including Science) for Middle Primary. He has been at Green Pastures Primary School for four years, supporting Literacy and Numeracy from K-7 and having responsibility for the ICT and the Whole School Art Curriculum for four years and Science for the past two. In his previous school he was involved in the Primary Science Project which was an Education Department initiative to improve the teaching and learning of science in primary schools (DOE, 2005). The Primary Science Project in the district released a key teacher from their classroom for one day a week to work with colleagues, supporting small school cluster collaboration and modelling science teaching strategies and action plans for science learning programmes. In the first two years at GPPS he led the budgeting and staffing provision of a science specialist and supported Science as a priority at the School. The project also initiated the use of Primary Connections science resources in the school.

The teacher/principal first became interested in stop-motion animation when he used it as a tool to engage reluctant learners in narrative writing during the 1990s.

This proved to be successful in improving the literacy skills of a selected group of students and thus he continued to use the strategy with all students, facilitating both remediation and extension. During 2005 in a similar small school, the teaching Principal initiated a cluster involvement in the *Success for Boys Project* which encouraged and modelled good teaching practice with the aim of improving boys' educational success through the development of their repertoires of practice in the areas of sense of self, relationships and culture (McKeown, 2006), in particular by expanding their confidence as learners, transforming authoritarian modes of relating and acknowledging the cultures that boys prefer (Alloway et al., 2006). Stop-motion animation was promoted as an effective tool for engaging learners validating this teacher's use of the process across all learning areas, integrating understanding, concepts and knowledge across ICT, media studies and critical literacy. It was during this time that he was exposed to a modified process called "Slowmation" (G. Hoban, 2005) and began integrating this into science lessons. Further reading led to interest in evaluating the effectiveness of the process which in turn led to this research study. The teacher holds strong views about teaching which are reflected in the GPPS School Plan and include the following beliefs about teaching and learning.

Learning experiences should:

- enable students to observe and practise the actual processes, products, skills and values which are expected of them:
- connect with students existing knowledge, skills and values, while extending and challenging their current ways of thinking and acting;
- be meaningful and encourage both action and reflection on the part of the learner;
- be motivating and their purpose clear to the learner;
- respect and accommodate differences between learners;
- encourage students to learn both independently and from and with others; and
- take place in school and classroom settings that are safe and conducive to effective learning.

Children learn at different rates and learn best when they:

- have a good rapport with their teacher;

- experience success and are able to build sound self-esteem;
- are confident to take risks; and
- view learning as enjoyable and value the experience as worthwhile or purposeful.

Children learn through exposure to:

- a variety of teaching methods (direct instruction, cooperative and independent learning);
- a variety of classroom organisation;
- explicit instruction (modelling, demonstration, a variety of questioning techniques, teaching of strategies);
- opportunities to talk, interact and reflect; and
- opportunities to be involved in hands-on, multi sensory and concrete learning experiences.

Key Finding 4.5

The teacher/principal/Researcher has over 30 years of teaching experience across the primary curriculum, with some in-depth understanding of curriculum development and some six years experience as a school principal. Interest in stop motion animation and participation in the *Primary Science Project* has led to a special interest in the use of Slowmation, a modified stop-motion process in the primary science classroom. Beliefs about teaching include the notions of engagement, challenge, variety, explicit teaching and social constructivism.

Curriculum Content

Primary Connections is a commercially available programme that links the teaching of science with the teaching of literacy in the primary years. It was developed by the Australian Academy of Science and supported by most state education authorities in Australia. GPPS uses the Primary Connections units across the school to facilitate a whole school approach to the teaching of science. Primary Connections is based on the 5Es inquiry model (Bybee, 1997) and provides opportunities for students to develop literacies of science through constructing representations.

The Primary Connections, *Spinning in Space* unit of lessons are designed to develop a range of scientific literacies and provide opportunity for multimodal representation. The focus of the unit was to develop understandings about the sizes, shapes, movements and relationships of the Sun, Earth and Moon, which included understanding the cause of day and night, the illusion of the Sun moving from East to West across the sky, and investigation of the changing lengths and positions of shadows. Students were also exposed to activities to help demonstrate relative distances between the Sun, Earth and Moon.

Key Finding 4.6

The topic, *Spinning in Space*, with its focus on the movements and positions of the Sun, Earth and Moon and the relationship of these phenomenon to night and day provide an appropriate context for animated representation.

Timeline of Events

This chapter has provided an outline of the procedure taken but it is useful to provide a timeline of events to further establish a picture of the process of this study. There were some unforseen occurrences which may or may not have had a bearing on the findings. The unit was conducted over Term 1 of 2010. Students and parents returned their consent forms in order to comply with ethics requirements. Approvals for the research to take place were given by ECU and the WA Department of Education.

10th February

The students undertook an activity to review what they remembered and understood about the construction of a stop-motion animation. They practised their skills by making a whole class Slowmation depicting a spinning planet.

15th February

Engage phase, Lesson 1, *Our place in space*, was conducted with the whole class in three groups, Group 1, Group 2 and the non-research Group 3. The students discussed their understandings, misunderstandings and observations about day and night.

After group discussion, group leaders added current knowledge to a TWLH chart at the front of the classroom. Such a chart displays a written representation of what the students think they know (T), what they want to know (W), what they have learned (L) and how they know (H). Such a chart is an ongoing process of reflection and other questions were added to the chart during a whole class discussion led by the teacher. An audio recording was made of the group discussions and selected sections of the transcripts are analysed in this report.

17th February

Engage phase, Lesson 1, *Our place in space*, was continued with the whole class in three groups, Group 1, Group 2 and the non-research Group 3. The students documented their understandings of a scientific diagram and created their own diagrams showing what they currently understood about the positions, movement, shapes and relative sizes of the Sun, Earth and Moon. They then completed the *Day and Night – What do you think?* resource sheet individually before discussing their responses with their partner.

24th February

Explore phase, Lesson 2, *Shapes and sizes*, was conducted with the whole class in the three groups. This involved the children creating models to scale of the Sun, Earth and Moon to gain an appreciation of their relative sizes. The students then took these models to the School oval to see how the tiny Moon can look the same size as the giant Sun, developing their awareness of relative distance. Students made a journal entry after this activity.

3rd March

Explore phase, Lesson 3, *Shadows at play*, was conducted with the whole class in the three groups. This involved development of the understanding that light travels in a straight line and exploring shadows. Students made a journal entry after this activity.

10th March

Explain phase, Lesson 4, *In a spin*, was conducted as a whole class activity. This involved the students modelling the spinning of the Earth on its axis as it orbits the Sun, using basketballs in the light of a projector. This was followed up by a role-play in which students linked together to form a representation of the spinning Earth and spinning into the light and into the dark. Groups 1 and 2 role-plays were recorded onto video however the sound was lost. The students made individual journal entries to record their understanding of the positions and movements of the Sun Earth and Moon and their concept of day and night. They also undertook a short on-line quiz, providing a useful insight into developing understandings.

During the following weeks, individual and group interviews were conducted to elicit information about each student's developing scientific literacy.

17th and 24th March

Elaborate phase, Lesson 5, *Investigating Shadows*, was conducted in the three groups. This lesson involved planning and conducting an investigation of the shadows formed by a stick at intervals through the day, and recording, presenting and analysing results.

31st March

Individuals refined their original posters drawn in Lesson 1 making changes to demonstrate what they now understand about the shapes, positions and movements of the Sun, Earth and Moon. Groups began planning and storyboarding.

The school holidays interrupted the programme and at this stage three students from the class left the school. A female student left group one and a male and female left group two. The groups were re-arranged and made up from volunteers from the non-research group. Group one then became an all male group and Group two became two males and two females, as described at the beginning of this chapter. This changed the dynamics of the groups and resulted in some changes to Slowmation planning.

21st April

Students completed their storyboards, made models and filmed their Slowmation. The two groups were videoed and transcripts of the audio are used for analysis.

28th April

Students transferred their still frames onto the computer. Group one used *SAManimation* software and Group two used *Stopmotion-Pro*. The variation due to different computer specifications. The students manipulated timing of frames and added text and captions. There was some difficulty with the technology, with frames freezing and or dropping out. In both groups it was observed that some students were resilient in solving such problems, some gave up and left the problem solving to other members of their group.

5th May

Groups planned and recorded their narration onto their Slowmation and converted the files to movie format. In some instances the quality of video capture was compromised dues to technical difficulties. Preparing video for the web was discussed but was not followed through.

12th May

The whole class viewed the Slowmations and assessed them using a Positives, Minuses and Interesting (or “Improvements”) points approach to discussion (Often known as a “PMI”). Final individual and group interviews were recorded with transcripts taken and used for analysis in Chapter 6.

Key Finding 4.7

The lessons were conducted in a logical sequence with some interruption due to school holidays and changes to group membership required due to departing students. There was some deviation from the proposal procedure and some technical difficulties with the software.

Summary

This Chapter identifies the contextual factors that impact on this study. There is evidence of a supportive community, good attendance and sound academic achievement comparable to like schools (KF 4.1 - 4.3). The study groups were shown to be average students with a good attitude towards science in school (KF 4.4). The teacher is represented as having a diverse experience in teaching and a high level of interest in curriculum development, student created animation and science education (KF 4.5). The unit of work focussing on the relationships between the Sun, Earth and Moon and the phenomenon of Day and Night is based on a well researched approach to inquiry with an emphasis on science literacy and multimodal representation to develop conceptual and investigative understandings (KF 4.6). A timeline is provided that provides a context of the time and place as well as the changes and difficulties that may have an influence on the findings (KF 4.7).

The key findings drawn from the contextual data suggest that the school, students and unit of study provide a sound context in which to explore the research questions.

CHAPTER 5 THE PRE-SLOWMATION PHASES

The preceding chapter described the context in which the study took place and a timeline of the events for the study. This Chapter describes the students' journey prior to their construction of the Slowmation. The purpose being to look at developing conceptual understandings and literacies of science as evidenced through student discourse and other modes of representation during the first four phases of the *Spinning in Space* unit. To best facilitate the development of a narrative, the story will be presented chronologically through the Engage, Explore, Explain and Elaborate phases, looking at each group of students separately, using various work samples, artefacts, observations and transcripts of audio and video recordings. Key findings are based upon literal observations leading to the development of interpretations and assertions in the discussion chapter (Chapter 7) that focus on the key research questions.

Engage Phase

The Engage phase is useful for diagnostic assessment, being designed to engage students with the topic and elicit any prior knowledge (Australian Academy of Science, 2006). In this study it also involved the students undertaking an activity to review what they remembered and understood about the construction of a stop-motion animation.

Activity 1: Review of Ground Rules for Discussion and Slowmation Process

The teacher began the unit of work by reviewing the ground rules for discussion and the process of making a Slowmation. The students engaged in the creation of a Slowmation based on previous science lessons. The students displayed ability to create a short Slowmation with teacher guidance but in the early stages of this process they had some difficulty following the ground rules for discussion, with a few students dominating the talk, others withdrawing from the discussion and some distracting the others (Research Journal 10/02/2010). This was addressed by the teacher who reviewed the ground rules, (Mercer, 2008) which had been discussed previously and gained an undertaking from the students as to their understanding of and commitment to the agreed ground rules.

Key Finding 5.1

Students had difficulty following ground rules for discussion and required encouragement to engage appropriately in order to facilitate constructive discourse.

Activity 2: Resource Sheet One. Whole Class and Group Activity.

The next activity involved the whole class discussing their understandings and observations about day and night. A teacher initiated discussion, asking; “How do we know it is day?”, “What might we see in the day?”, “How do we know it is night?” and “What might we see in the night?” was followed by the handing out, to each of the groups, the worksheet “Day and Night” (Australian Academy of Science, 2006) which presented three propositions:

a. The Sun goes around the Earth once a day
b. The Earth goes around the Sun once a day
c. The Earth spins around once a day

And asked three questions;

a. Do any help explain day and night?
b. What do you think causes day and night?
c. Why can’t we see the Sun at night?

The quality of discourse and use of gestural representation is outlined in the transcripts below, taken from analysis of video footage:

Group 1

Female 1 (*Reads aloud*), “the Sun goes around the Earth once a day.” no, because the Sun doesn't move, it stays where it is. “B, the Earth goes around the Sun once a day”. No the Earth doesn't go around the Sun once a day, doesn't it take a year to go around the Sun? It takes a year to do a whole circuit around and as it does that it spins.

Male 1 Yeah and the Earth as it does that. (*Voice is drowned out*).

Female 1 (*Interrupting*), it spins and it moves like a centimetre every day.

Male 2 Nooo! The Earth wouldn't move a centimetre a day otherwise the Sun would move a centimetre a day.

Female 1 The Sun doesn't move at all.

Male 2 I know, that’s.

Male 1 The Sun moves.

Female 1 That much a day (*holds hands apart to indicate a distance*).

Male 2 No, then when we looked up the Sun would move.

Male 1 The Earth spins.

Male 2 Say it’s there and (*uses one hand to indicate the position of the Sun and the other hand to indicate the position of the Earth*).

Female 1 We can tell the time from where the Sun is so that means we move and not the Sun.

Male 2 Yes I know, but you’re saying the Earth moves like that (*holds hands apart to indicate a distance, repeating Female 2’s previous gesture*).

Female 1 Yes.

Male 2 That much a day. So that means, that means. I know the Sun doesn't move but, it moves, I know it doesn't, but you know what I mean? (*Giggles*).

Female 1 No I don't, anyway *(reads*) “The Earth spins around once a day.” Yes it does, not around the Sun but it does spin around every day!

Male 2 Well, the Sun doesn't move, we know that, I'm saying that the Sun doesn't move but it looks like the Sun's moving.

Female 1 If the Sun doesn't move.

Male 2 It would be like. (*lost in noise*)

Female 1 Not necessarily, because it could move like that much (*indicating a small distance with thumb and forefinger held up*).

Male 2 It would go swoooosh.

Female 1	It would go that much on the clock, we could tell the time from the Sun, have I made my point yet?
Male 2	Nah.
Teacher	Do you remember the Sun telescope we looked at last year?
All three	Yeah!
Teacher	Remember how fast it moved across the sky?
Male 1	Oh yeah, that was fast!
Male 2	So it doesn't move that far a day (*gesturing with hands to demonstrate a small distance*).
Male 1	It moved much farer than that.
Male 2	Yeah.
Male 1	It moved like that far (*gesturing with hands to demonstrate a larger distance*).

Group 2

Female 1	We can't see the Sun at night because we turn.
Male 2	Because the Earth rotates.
Female 1	And it's rotating around from the start and the other side of the Earth is in daylight.
Male 2	And the Sun's here (*using hands to indicate position).*
Female 1	And the other half's in night.
Male 2	And the Sun sets and we turn and we can't see it anymore, that's how it is. (*These two are talking independently, not in conversation but interrupting each other at each turn.*)
Female 1	If we looked at the Earth from up above it would be like cut in half.

Lighted up.

Males 2 and 3 (*muttering)*, definitely

Female 1 And yes, the Sun goes around the Earth once a day.

Male 3 No, it spins around and goes around.

Female 1 Rotates around the Sun once a day.

Male 3 Yes and it also spins at the same time.

All Yes, and.

Female 1 Goes around the Sun once. No! No! No! The Earth goes around the Sun once a year, we turn around once a day.

Male 3 Yeah.

Female 1 We orbit around the Sun once a year.

Teacher Ahh, you're doing a diagram to help.

Female 1 We go, we turn, we orbit around the Sun once a year.

Male 3 Yeah I know.

Female 1 I'll write it down.

Male 3 It's OK.

Female 1 I like explaining things. (*students are writing*)

Male 3 The Earth spins around once a day, that's the next one I reckon, C, maybe.

Female 1 Yes it does.

Male 2 It’s dark on this side, the Moon dark (*mumbles*).

Female 1 The Earth goes around the Sun once a year and we spin around.

Male 3 Yeah so its “C”.

Female 1 Rotate around once a day.

Male 3 So, “C” is right!

The students were engaged in a process of evaluation and justification of claims to scientific knowledge and are engaging critically and usually constructively with each others’ ideas. Students in both groups are using gesture and conversation in discourse that builds upon each others’ thoughts and statements. There is sustained conversation around a topic with many turn rounds in the conversation. Such conversation lies within the definitions of substantive discourse.

Key finding 5.2

Students engage in substantive conversation during pre-slowmation activities.

The students are also using a range of representations to explore, share and clarify their own and others’ current understandings. Some are writing, all are speaking and others are using gestures with their hands and fingers to indicate the shapes, positions and movement of the Sun, Earth and Moon.

Key Finding 5.3

Students use a range of representational tools (writing, speaking and gesturing) in pre-slowmation activities.

Activity 3: Resource Sheet One; Individual responses

The activity that followed required the students to individually complete the worksheet after the discussion and there we find further evidence of developing conceptual understandings, and, as expected, there is a mixture of sound understanding and misconception, at an individual level.

Group 1

Table 1 (below) shows individual responses from Group 1, taken directly from their worksheets.

Table 1

Group One Student Responses to Questions on Resource Sheet One.

Group 1	**Student 1**	**Student 2**	**Student 3**	**Student 4**
1. Do any help explain day and night?	*No because it just tells us about the Earth and Sun turning around.*	*Yes because the Earth does spin around once a day and the Earth does go around the Sun once a day.*	*Yes because you can see at daytime but you can't at night.*	*No because the Earth spins half way around the Sun.*
2. What do you think causes day and night?	*The Earth rotates around the Sun while spinning itself.*	*Well, when the Earth points towards the Sun it is day time but when the other side of Earth is pointing towards the Sun it is day time for us.*	*Maybe something about space or an electronic might be up in the space making day and night on Earth.*	*Because the Moon covers the Sun and it comes night time.*
3. Why can't we see the Sun at night?	*Because the other side of the Earth is getting the Sun.*	*Because the Sun is at the other side of the Earth.*	*Because the Sun goes down at night.*	*Because the Sun is on the other side of the Earth.*

Student 1 sees no connection between the possible explanations for day and night on the resource sheet and what he understands about day and night, which may be indicative of a possible literacy difficulty with the structure of the statements. He displays some understanding that the movement of the Earth is relevant but may have a misunderstanding that the Earth's rotation around the Sun has an influence on day and night. This student's answer to the third statement seems to indicate some understanding that a person's position on the Earth in relation to the Sun is what results in night. Student 2 displays some understanding that the side of the Earth pointing towards the Sun has daylight but a misconception that the Earth goes around the Sun once a day. He displays some understanding that a person's position on the Earth in relation to the Sun is what results in night. Student 3 makes literal observations and has a fairly obtuse misconception about the cause of day and night. He is possibly the student who has most to gain from involvement in this unit of work. Student 4 has a misconception about the Earth's movement and a misconception about the Moon's influence on day and night but does indicate an understanding that a person's position on the Earth in relation to the Sun is what results in night. An inference may be taken that, at this stage, students' literacies of science and language may not be well developed enough for their articulation of conceptual understandings about day and night or that students are conflicted by what they observe and what they think they know to be the science facts.

Key Finding 5.4

Responses on the resource sheet indicate that three of the students in Group 1 display some understanding that day and night are the result of the movement of the Earth and/or Sun but do not describe such movements in accurate detail, with one student displaying little understanding.

Group 2

Table 2 (below) shows individual responses from Group 2 students, taken directly from their worksheets.

Table 2

Group Two Student Responses to the Questions on Resource Sheet One

Group 2	Student 1	Student 2	Student 3	Student 4
1. Do any help explain day and night?	*Only C helps because the Earth does spin around once a day (24hours). (A) doesn't help because the Sun doesn't move. (B) doesn't help either because the Earth circles the Sun once a year (365 or 366 days)*	*Yes because the Earth spins around and then the Sun light is on one side and not on the other.*	*Yes and no because it depends which way we are facing which is how fast we are spinning.*	*Yes because the Sun stays where it is and the Earth spins around the Sun.*
2. What do you think causes day and night?	*Day is when your side of the Earth is facing the Sun but while that is happening the other side of the Earth is dark or night.*	*The Earth spinning around.*	*The Earth moving, one side is facing the Sun and the other is facing the Moon that is day and night so what causes it is the Earth spinning around.*	*The Sun stays in the same place so the place that is facing the Sun is day and the side that isn't facing the Sun is dark and the whole Earth rotates.*
3. Why can't we see the Sun at night?	*Because if it is night on your side of the Earth our planet is blocking the Sun so we can't see it unless you can see through planets.*	*Because the Sunlight is on the other side of the Earth.*	*Because we are not facing the Sun when it is night we are facing the Moon.*	*Because the Sun is on one side and the dark side doesn't have the Sun shining on it.*

Students 1 and 2 understand that the Earth spinning into and out of the sunlight results in day and night. Student 3 displays some understanding that the Earth spins and daylight is determined by which way we are facing but may have a misunderstanding that the Earth faces the Moon to be in night. Student 4 displays some understanding that day and night is a result of the Earth spinning but may have a misunderstanding that the Earth's movement around the Sun also has an influence on day and night.

Key finding 5.5 All students in group 2 display understanding that the spinning of the Earth results in day and night but none are unable to articulate a comprehensive explanation.

Activity 4: Individual Diagrams

Students were asked to draw a diagram to represent what they know about the Sun, Earth and Moon. The teacher began by initiating discussion about the main features of a scientific diagram (mode of representation). Most students recognised the need for a drawing with labels and a title but needed prompting to include captions, lines, arrows and a scale. Not all students used all the features that were discussed with the whole class.

Group 1

Student 1's diagram displays a relatively accurate understanding of the size differences. He captioned "Earth moves" and added an elliptical orbit of the Earth around the Sun with the Moon orbiting Earth after discussion with other group members, using dashed-lines rather than directional arrows. The Sun is annotated; "does not move" and another annotation displays understanding that distance was too large to show at this scale. The diagram does not indicate cause for day and night. Student 2's diagram displays relatively accurate understanding of size differences and he has attempted to indicate a scale. Arrows indicate that both the Earth and the Moon travel in the same direction around the Sun but no indication of a complete orbit, no indication that the Moon orbits the Earth nor any indication of causes for day and night. Student 3 has drawn the Sun, Earth and Moon as rough spheres each the same size. No movement, scale, positional relationship or distance is indicated. Student 4's diagram displays some understanding of relative sizes but the diagram shows no indication of the scale of distance. Arrows indicate the Earth spinning and the Moon orbiting the Earth. There is no indication that the Earth is orbiting the Sun, nor any indication of causes for day and night.

Across the group there is a range in the use of diagrammatic conventions which leads to Key Finding 5.6

Key finding 5.6

Responses on the resource sheet indicate that all of the students in Group 1 are still developing the literacies for science diagram representation which include the use of annotations for clarification and arrows to indicate movement.

The diagrams were also used by the teacher to assess students' conceptual understandings in this phase of the unit of work.

Against the National Scientific Literacy Progress Map (for *Spinning in Space* only) (MCEETYA 2006) two of Group 1's students are displaying emerging concepts at beginning Level 3, recognising that day and night are related to the spinning of the Earth. One student is achieving Level 2 by describing the shapes of the Earth Sun and Moon and by making comparisons between sizes. The other student is at beginning Level 2, being able to identify features of the Sun, Earth and Moon. The students in this group are displaying a range of conceptual understandings in the Engage phase of the unit of work, which is to be expected for students of this age group. Some show some understanding that the movement of the Earth results in day and night and that the Earth orbits the Sun in a given time frame of one year. However, no students made a reference to changing shadows.

It is at this point in the unit that the Researcher noted the complexity of the conceptual understanding, particularly for this younger group of students (Research journal). Students are required to come to terms with what they actually observe; which is the Sun moving across the sky and that which they are coming to understand; the Sun appears to move across the sky because of the spinning of the Earth.

Key finding 5.7

Group 1 students' diagrams reveal developing understandings of the relationships between the Sun, Earth and Moon.

Group 2

Student 1's diagram has a title but no scale. It shows the entire solar system, including all planets, with dashed lines indicating their orbits around the Sun, these lines have been annotated "The planet's rotation". An arrow is used to show Earth's "rotation" but the Moon is not represented. Other annotations indicate the Sun's temperature, "approximately 5000000 degrees at centre" and statements of fact "Every planet has a different time span to rotate around the Sun" and "It takes eight minutes for light to travel to Earth from the Sun." There is no indication of the causes for day and night. Student 2's diagram displays "Earth's rotation path" orbiting the Sun in an ellipse and the use of arrows to indicate that the Moon orbits the Earth. The Sun has solar flares and there is no representation of day and night. Student 3 has drawn an inaccurate scale, indicated the Moon's orbit around the Earth but not indicated Earth's orbit around the Sun. There is no indication of day and night. Student 4's diagram has annotations to indicate that the Earth "rotates around the Sun" and that the Moon, "rotates around Earth." All students have drawn the Sun, Earth and Moon as circles, which is a 2D representation of a sphere.

The individual diagrams reveal a developing understanding of the parts of a scientific diagram and recognition of a diagram as a form of representation for sharing knowledge or information.

Key Finding 5.8 All the students in Group 2 are developing the literacies to represent their understandings as a science diagram. These literacies include the use of annotations for clarification and arrows to indicate movement.

Again, the teacher used the students' diagrams to assess their conceptual understandings in this phase of the unit of work.

Against the National Scientific Literacy Progress Map (for Spinning in Space only) (MCEETYA, 2006) all of this group have achieved part of Level 2, being able to describe the shapes and sizes of the Sun, Earth and Moon but make no reference to changing shadows to describe the apparent movement of the Sun across the sky. These students are developing Level 3 outcomes, knowing that day and night are related to the spinning of the Earth and that people on one side of the planet experience day while those on the other side are experiencing night.

Key finding 5.9

Group 2 students' diagrams reveal developing understandings of the relationships between the Sun, Earth and Moon.

Activity 5: TWLH Chart

A TWLH chart is a tool used in Primary Connections to elicit students' prior knowledge, to determine what questions they would like answered and to record what they learn and how they have come to an understanding (Australian Academy of Science, 2006). In the Engage phase of the Spinning in space unit, students discussed and completed the first two parts of the chart, "What we think we know" (T) and "What we want to know" (W).

The current knowledge added to the TWLH chart at the front of the classroom displayed a range of understandings and misunderstandings about day and night, the Sun, Earth and Moon and included comments regarding the planets. Students recognised temperature, visibility and differences in human and animal activity between day and night. They recognised that the Sun is a star which is close to us and provides light and warmth. They noted that some stars are planets and others are suns and that some require telescopes to view them clearly. They commented on human exploration of the Moon. On the concept of how we get day and night there was some confusion about the spinning of the Earth and its orbit around the Sun. One student began to explain seasons as something to do with position and movement of the Sun and Earth but stopped when they realised they were not quite sure how it worked.

Key finding 5.10

Both groups of students have a range of knowledge on the subject of Earth and Beyond, including recognition that the Sun is a star, that it influences life on Earth and that the differences in day and night have an effect on animal and plant activity. There was obvious confusion between what they know to be true and what they observe regarding the relationship between day, night and the apparent movement of the Sun. The students are well positioned for further development of conceptual understanding and science literacies.

Explore Phase

The Explore phase is useful for formative assessment and provided hands-on, shared experiences of the shape sizes and positions of the Sun, Earth and Moon and of shadows and light. The activities at this stage of the Primary Connections unit are designed to provide opportunities for learning new concepts. The first activity involved comparing sizes of the Sun, Earth and Moon using a basketball, marble and peppercorn size bead. There was discussion regarding the students' original drawings and the phenomenon of perspective that makes the Sun look the same size as the Moon, even though we know the Sun to be much larger. Groups went outside onto the oval to see how far away the basketball needed to be in order for the bead to look the same size, giving an indication of how far away the Sun is compared to the Moon. The class had to move to the larger community oval because the school oval wasn't long enough to conduct this investigation. This excited the students somewhat and entries in their journals indicate the learning that took place.

The students' journal entries following this activity indicate that they were all exposed to new concepts, these being the relative sizes of the Earth, Sun and Moon and the relative distances between the three. Students' journal entries are presented in Table 3 below.

Table 3

Students' Journal Entries: Explore Phase, Activity One

Group 1	**Journal entry**
Student 1	*The small Moon looks the same size as the huge Sun because the Sun is so far from the Earth.*
Student 2	*The small Moon looks the same size as the huge Sun because when things are far away they look the same size.*
Student 3	*The interesting bit was the Sun is a lot bigger than the Moon and the Earth.*
Student 4	*I learnt today that the Moon is tiny compared to the Sun. I can't believe how far the Sun is away from the Earth.*

Group 2	**Journal entry**
Student 1	*I learnt the equivalent length of the Sun, Earth and Moon they are apart. I also found interesting that how far you had to walk back for our second test.*
Student 2	*I learnt how small the Moon and the Earth are compared to the Sun. Also how far you have to go to make the Moon look the same size as the Sun. I found it interesting that is was 106 metres to make the Sun the same size as the Moon.*
Student 3	*The small moon looks the same size as the huge Sun because the Sun is further away from the Earth and the Moon is closer but if the Moon was the same distance as the Sun we wouldn't be able to see it. I thought the most interesting part was when we got to walk really far away from the other students and see how far we had to go before the Sun looked the same size as the Moon.*
Student 4	*I learned that the Moon is roughly 26 cm away from the Earth and the Earth roughly 106 metres away from the Sun. The Moon is roughly about 2.5mm, the Earth is 1 cm and the Sun is 1 metre.*

The students were also able to use different representational modes to help develop their understandings. They used models (different size balls) to show relative sizes and positions and all were impressed by the distance from the Earth to the Sun and especially by the size of the Sun. Student 4 in Group 2 was particular about sizes during journal writing without indicating that these are scaled measurements. Subsequent discussion between this student and the teacher revealed that this student does understand the concept of scaled representation.

The second activity involved students exploring and observing shadows. The lesson began with students chasing each other's shadows and then looking at how the shadows of trees changed over the course of 15 minutes. Another part of the lesson required students to infer that light travels in straight lines when viewing objects at a distance through a straight and a bent drinking straw and by lining-up punched holes in two pieces of card to allow sunlight to pass through onto a surface. Students made comments and diagrams in their science journal, as shown in Tables 4 and 5 below:

Table 4

Group One Student's Journal Entries: Explore Phase, Activity Two

Group 1	**Journal**	**Description**
Student 1	*A shadow is the sun shining down light but your body is blocking it*	Diagram shows straight lines of light with a square casting a shadow. As copied straight from whiteboard.
Student 2	*We have proved that light travels in a straight line by getting a straw and looking through it and then bending the straw then you can't see the object you were looking at.*	Diagram shows straight lines of light with a square casting a shadow. As copied straight from whiteboard.
Student 3	*A shadow is something you block the light from. It is also a reflection from the Sun. A shadow is a dark spot on the land at day or night. I know how the light travels in a straight line because if you stand under a light you wouldn't have a shadow but when you stand under a light you have a shadow and the light is travelling straight.*	Diagram shows light travelling in a straight line through punched holes in two pieces of card (as per activity).
Student 4	*We looked through a straw and we could see objects. Then we got two pieces of paper and did the same thing. Then we went outside and lined three pieces of paper over each other and see if the light would go through it and it did.*	Diagram shows light travelling in a straight line and a square object casting a shadow (similar to white-board diagram).

Table 5

Group Two Student's Journal Entries: Explore Phase, Activity Two

Group 2	Journal	Description
Student 1	*A shadow is a place where the light is blocked.* *Light always travels in a straight line unless there is something reflective involved.* This student favours diagrammatic representation to explain phenomenon and has drawn an effective diagram to illustrate how shadows are formed.	The diagram shows; *The rock blocking light making shadow* and an area with *No shadow because nothing is blocking the Sun or light.* Second diagram shows light travelling in a straight line and a cube casting a shadow.
Student 2	*A shadow is where the Sun is stopped by something that is not see through. Which means there is no Sun in that spot.* *Light travels in a straight line. We know this because we lined two pieces of paper with a hole in it and made the holes line up.*	Diagram shows a person casting a shadow. Diagram shows straight lines of light with a square casting a shadow.
Student 3	*A shadow is something the light goes around and that makes a dark spot = the shadow.* *Today in science we proved that light travels in a straight line. We went outside and looked through three pieces of paper.*	Diagram shows a line casting a shadow. Diagram shows straight lines of light with a square casting a shadow
Student 4	*What is a shadow? It is where something and someone is in the way of the sunlight so the sunlight reflects off you and where that something or someone is it makes a shadow. We proved that light travelled in a straight line. We used a straw to see if light travelled in a straight line because if we looked at something we could see it but if we bent the straw we could not see the object we we're looking at.*	Diagram shows a flower casting a shadow Diagram shows straight lines of light with a square casting a shadow

Students were introduced to three more new concepts during this activity: light travels in a straight line and cannot bend around or pass through solid objects; where an object blocks light it casts a shadow; and, shadows change shape position and direction during the course of the day. The student's were able to use diagrams, with their own annotations or captions, to demonstrate their understanding that light travels in a straight line, that it cannot travel around a solid object and as such there will be a shadow on the unlit side of a solid object. Another component of this activity asked students to observe how moving an object in a fixed light source resulted in changing shadows. When students began looking at shadows on spherical objects they began making the link between sunlight and how the Earth's shadow results in night. When a matchstick was stuck to a ball and the ball spun in the light, students observed the changing size, shape and position of the shadow. Some students recognised that this was a representation of changing shadows during the course of the day.

Explain Phase

The Explain phase is useful for formative assessment and introduces current scientific views by providing an activity to support students to represent their understanding about what causes day and night. Students took part in a kinaesthetic/embodied representation under teacher guidance which involved the students role-playing the spinning of the Earth into the light and out of the light into the shadow. Student discussion during the activity was fluent with many "call-outs" and responses of observations and ideas as individuals recognised and explained what was happening in their human model with what happens in reality.

Students were still developing explanations for day and night but were displaying an increasing understanding that day and night is related to the Earth spinning. Group 1 Student 3, provided a kinaesthetic representation, using a ball as a model to show the Earth orbiting around the Sun causing day and night, having the Earth spin on its axis just once during the orbit, this is a misconception he carried right to the end of the unit. Other students used this opportunity to begin making conjectures about why we experience seasons without making any accurate explanations. The teacher made a note to cover seasons in a future science activity.

Students were exposed to new concepts during this activity; day and night are the result of the Earth spinning, a person on one part of the Earth experiences day when they are on the side facing the Sun and experience night when they are in the shadow of the Earth or on the side facing away from the Sun, shadows change length, size and direction as the Earth spins into and away from the Sun's light.

> Key Finding 5.11
>
> Students were taught several new concepts during the Explore and Explain Phases: the shapes, sizes and positions of the Sun, Earth and Moon; light travels in a straight line; shadows are the result of a solid object blocking the light; and, changes in shadows and from day to night a caused by the Earth spinning on its axis.

Individual Interviews

Individual interviews were conducted as a diagnostic tool, to provide some gauge of student's individual understandings prior to undertaking their own investigation. The questions were designed in particular, to elicit each student's current awareness of forms of representation and concepts relating to the shapes, size, positions and movements of the Sun, Earth and Moon.

To ascertain students' awareness of forms of representation, students were asked how a scientist might share their information. Responses included such ideas as written reports, e-mails, telephone and face-to-face discussion. One student suggested role-playing and only one offered graphs and diagrams as a means for sharing findings, with three citing written forms of communication and five recognising speech as a tool. There was no recognition of animation or film as a form of representation or method of sharing information.

> Key finding 5.12
>
> Students have a limited understanding of modes of representation available for communicating science information.

When asked about what causes day and night there were a range of responses as indicated below:

"I was thinking about this yesterday. I used to think that when it was day the Sun was out and when it was night the Sun was on the other half of the planet. Now I know it's kind of true, we get day and night because the Earth is spinning on an axis and we're getting daytime while people on the other side of the planet are getting night time and when they are getting daytime we are getting night time" (Group 1, Student 1).

“Day is when a country, like Australia, is facing towards the Sun its daytime and when Australia’s directly facing the Sun its lunchtime and when we can just see the Sun its morning and when it’s about to be dark the Sun looks like its fading, a bit orange. For night time it’s when Australia is not facing the Sun. It’s spinning and also orbiting the Sun at the same time” (Group 1, Student 2).

“It’s the Sun isn’t covered by the Moon, at night time the Sun becomes a shadow. The Moon’s blocked the Sun side of sunlight for day time at this part of Green Pastures and night time” (Group 1, Student 3).

“Night is the shadow, like it’s when half of the world is in daytime it means the other half is in the shadow, day and night is caused by the Earth spinning around on its axis and the Sun only, in certain periods of time only shines on one side and afterwards shines on the other side, it lasts 24 hours which is a day” (Group 2, Student 1).

“Well it’s just the light from the Sun going onto the Earth, while the Earth is spinning its always got one light side and one dark side. When we're in the shadow side we call it night and when we’re are in the light we call it daytime” (Group 2, Student 2).

“Shadows. When one side of the Earth is facing the sun is day and the side facing the other way is night” (Group 2, Student 3).

It can be seen that after the explore and explain phases of Spinning in Space, all but one of these students now recognises that day and night are a result of the Earth spinning.

Key Finding 5.13

After the explore and explain phases of the unit of work the majority of students understand that day and night are caused by the spinning of the Earth on its axis.

When asked to explain what they know about the shapes of the Sun, Earth and Moon, the students provided evidence that they all know that the Sun, Earth and Moon are spheres (even though a couple could not at this stage, pronounce the word accurately).

When asked about the sizes of the Sun, Earth and Moon the students' explanations varied but all students were able to place the Sun, Earth and Moon in size order, although there was some inaccuracy and variation in describing relative sizes. This is interesting because in the "explore" phase they were introduced to the basketball, marble and peppercorn sized bead as representations of the Sun, Earth and Moon respectively.

Key finding 5.14 The majority of students understand that the Sun, Earth and Moon are spherical and that the Sun is the largest of the three bodies, much larger than the Earth and that the Moon is the smallest.

Another question asked students to describe what they know about the positions and movements of the Sun, Earth and Moon. Responses indicate that the students had a range of concepts about the Earth's place in space and had some difficulty explaining the positions of the Sun, Earth and Moon using the spoken word. One student used a diagram to help explain the movements. The Researcher notes that this perhaps shows the limitations of spoken and diagrammatic representation for sharing this complex concept and proposes that animation may provide a better tool for displaying this understanding (Research Journal March 2010).

After the interviews most students agreed that they knew only a little about the sizes, positions and movements of the Sun, Earth and Moon prior to the Engage, Explore and Explain lessons and that the activities so far had helped them clarify their understandings. These individual interviews provide evidence of many developing science understandings. There is evidence of increased and developing understanding of concepts relating to the shapes, size, positions and movements of the Sun, Earth and Moon.

Key finding 5.15 The majority of students displayed increasing but not comprehensive understandings of the positions and movements of the Sun, Earth and Moon at the end of the Explain phase.

Elaborate Phase

The Elaborate phase is useful for summative assessment of investigation skills. It is also designed to extend understandings and makes conceptual connections through a student planned investigation to find out what happens to the length and direction of shadows during the day. The investigation provided opportunities for students to further develop their inquiry skills. They determined variables to be changed, measured and kept the same. They conducted a “Shadow stick” experiment over the course of a day before completing a table and graph to share and compare findings. After discussing the findings, the students completed a question sheet to ascertain individual understandings.

In Group 1, Student 1 recognised that the Earth spins and moves but was still developing the understandings and language to explain why shadows change. Student 2 recognised that the Earth spins but believed that the Sun moves also and was also still developing understandings and language to explain why shadows change. Student 3 believed that the Sun moves as well as the Earth and displayed no recognition that the Earth is spinning. Student 4 made well considered and accurate predictions and good observations. Student 4 expressed the idea that the shadows changed because the Sun moves. There was some group discussion on whether the Sun was moving or whether it appeared to be moving because the Earth was spinning (Research Journal 26/03/2010). It is uncertain at this stage whether individual students believed that the Sun is moving or if they recognise that it appears to move. There appears to be a lack of resolution for the students between the science concept and the perceptual experience of seeing the Sun move across the sky. Students may well be experiencing a conflict between everyday science, that which they observe and what may be termed, school science, as they undertake a conceptual change. Another view is that these students may understand the actual phenomenon and are still developing the representational skills to explain what is happening. This is discussed further in Chapter 7.

Key finding 5.16 The shadow-stick investigation indicated that Group 1 students were still developing an understanding of the links between day and night, changing shadows and the spinning of the Earth.

In Group 2, all students recognised that the Earth spins resulting in changing lengths and directions of shadows and two of them utilised both diagrammatic and written representational skills to share their understandings. Only one student accurately described what happened to the direction of the shadow.

Key finding 5.17 During the shadow-stick investigation, all Group 2 students recognised that the Earth spins, resulting in changing lengths of shadows during the day.

All of the students from Groups 1 and 2 successfully used the supplied framework to record shadow lengths and directions in a table to re-represent and share their results as a graph.

Key finding 5.18 All students were able to use a range of representational modes of science, tables and bar graphs when provided with a framework.

Summary

This Chapter followed the students' journey through the Engage, Explore, Explain and Elaborate phases of the Spinning in Space unit.

After beginning with some difficulty following the ground rules for discussion (KF 5.1), the students showed that they were able to engage in meaningful and substantive discourse (KF 5.2). Students displayed minimal representational literacies but were able to construct tables and graphs with supplied frameworks (KF 5.3 and KF 5.18) by the end of the Elaborate phase.

Students revealed in the Engage phase that they had minimal understanding of the relative size, positions and movement of the Sun, Earth and Moon (KF 5.4 and 5.5). During the Explore, Explain and Elaborate phases, the students developed their understandings through engagement with the inquiry learning processes. Later in the unit they displayed an understanding that the spinning of the Earth results in day and night and that shadows shorten from morning to noon and lengthen from noon until evening, facing south and moving from west to east as the Sun appears to move from east to west. The varied abilities in representing this understanding, in writing and in diagrams is commensurate with the varied ages of the students, although few of them were precise in their description of the changing position of the shadow (KF 5.6 to KF 5.17).

The pre-Slowmation phases of the unit of study provided a foundation for discourse, representation and conceptual understanding. It was anticipated that during the group construction of a Slowmation in the Evaluate phase, students would be able to use the animated nature of the representation to show their collective understanding of the size, shapes, position and movement of the Sun, Earth and Moon and that the social nature of the activity would enable them to build on their individual understandings through substantive discourse, while providing opportunities for multimodal representation.

CHAPTER 6 EVALUATE PHASE

This Chapter provides an outline of the students' Slowmation creation process, looking at the development from storyboarding, through making the Slowmation to adding the narration. It analyses discourse, actions and artefacts that reveal developing conceptual understandings and developing representational literacy. The first part of this Chapter narrates the students' journey through storyboarding, making the Slowmation and adding the narration. The second part compares conceptual understandings evident in individual pre and post diagrams and in the group Slowmation. The third part shares student perceptions of their own learning and of the Slowmation process. The Chapter closes with a summary of the key findings.

The Process

The students have made stop-motion animations and Slowmations in the past and reviewed the process at the beginning of the unit of work. The students were provided with a scaffolding worksheet to clarify the content requirements of their Slowmation, which was; what they understand about the shapes and sizes of the Sun, Earth and Moon, the apparent movement of the Sun from east to west, the changing lengths and directions of shadows during the day and the phenomenon of day and night.

They began by drafting a storyboard, which is a series of drawn diagrams that outline the key frames within a film. The process was videoed and a transcript was made of the discussion. After completing the storyboard and making the required props, the students began taking still photographs for the Slowmation. The still photos were then transferred to a stop-motion software program, "Sam-animation" or "Stop-motion-pro", where the students edited, organised and manipulated the pictures and frame durations to create a short Slowmation. They then used the software facility to create a movie file which was transferred to "Windows Movie Maker" for the addition of their narration.

The essence of their group knowledge is represented through the Slowmation, via a process that provides opportunities for discourse and for multimodal representation.

Storyboarding

Group 1 Storyboarding

During the first session of storyboarding this group talked about the concepts they wanted to show. The transcript below, edited to include only relevant discussion, provides an example of the nature of the initial discourse, showing how the students were coming to terms with the science ideas and with the associated representational requirements.

Student 2 So, who's got an idea of what we should do?

Student 1 Me, well, we could have an Earth spinning on its axis, around the Sun and the Sun there (*points to the diagram the other student has drawn*) then a Moon spinning around the Earth.

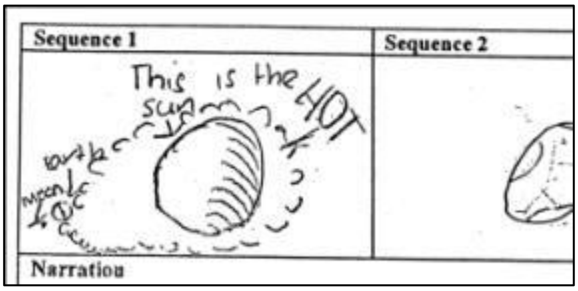


Figure 4. Part of Storyboard of Student 1.1

Student 2 Faster than the Earth going around the Sun.

Student 2 Because the Moon spins there (*points to the same diagram).*

Student 1 Yeah, I get what you mean and then we could say even like stuff happened like "hey look it's a full Moon, or look its crescent Moon."

Student 3 My idea for this is, this is the Sun and that's the Earth and the Moon and the Earth and the Moons.

Student 1 Yeah and.

Student 3 And the Moon's hanging around the Earth while the Earth is spinning and spinning around the Sun.

Student 1 And then with mine, with the things that pop up we could go, "and now on Earth it is the day." No, or on one half of the Earth the half where Australia is, is the day.

Student 2 (*Interrupts loudly but speech is not clear.*)

Student 1 The southern hemisphere is now getting Sun, is getting daytime which is light.

In the first part of the discussion the students were building on each others' ideas. They were animated and excited about what they wanted to show although it appeared that they were very much absorbed by only their own ideas and not necessarily listening to each other. They then began to talk about what materials they would use:

Student 2 We could make an Earth, get cardboard, cut it out, colour it in make it interesting and all that um and then we could like.

Student 1 The thing is.

Student 2 Yes I know, cut out half a black bit sort of thing, make it the same size as the Earth and put that half of the Earth (*demonstrating using a piece of card laid on top of his drawing*).

Student 3 I see what you mean now, cut out a black piece and stick reddish orangey little bits.

Student 1 It's explaining day and night. I like my idea.

Student 2 You could do this, this is what I'm saying, say that's the Earth (*demonstrating by tracing finger over the drawing*).

Student 1 Weird.

Student 3 Tricky.

Student 2 I know.

Student 2 Cut out half and you've got half of black paper over there (*scribbles*) and you see that's daylight and that's dark.

Student 1 And that's the other thing we do, my idea! We're on the right idea, D's (*name*) and T's (*name*). OK we know what we're doing now.

The students then engaged in more informal discussion as they began to draw onto their individual storyboard planning sheets. After approximately 10 minutes, the students decided between them that they knew what they were going to do and wanted to get on with making the movie. So they approached the teacher;

Student 1 I just want to start getting on with the thing. The movie.

Student 2 We've basically already got it in our heads, so can we?

Teacher You need to plan carefully.

Student 2 So we've got to write it all down on paper?

Teacher Because the last time you did a Slowmation and it wasn't planned, it didn't get finished properly.

Student 2 Didn't it?

Teacher No. What is your narration going to be? What captions are going on what screens? What are you going to show? How will you film moving shadows?

Student 2 Are we going to be able to choose how many frames per second?

The three students talked with the teacher about animation being repeated scenes with minimal movement between each frame, the teacher explained that they should deal with frames per second when they are putting it together, and that variable frame rates will apply depending on captions and scenes. They then talked about the number of frames they would need and the teacher explained that it would depend on what they wanted to show and how they wanted to show it. After a short while they shared their individual ideas. At this stage each student had drawn one or two frames on their storyboard. In the example below, in which Student 3 was the weaker student of the group, it can be observed that Student 2 was required to elaborate his explanation using multiple modes of representation to help Student 3 understand the concept of day and night:

Student 2 So this is one scene, here is the Sun, do that on one scene and say, this is the Earth and one half is day and one half night. Sun and Moon.

Student 3 D (*name*) now I'm confused what you've done.

Student 2 This is the Earth with one side.

Student 3 Isn't the Moon supposed to be on there?

(No response)

Student 3 D (*name*) isn't the Moon supposed to be on there?

Student 2 Let me do my second scene and then you'd know what I'm doing.

Student 2 then worked on his next drawing as Student 3 observed, adding arrows and shadow, to show the concept of day and night. They continued to draw and to discuss what a narration is. They also talked about the captions and titles they may need. Students 1 and 2 began to argue, the teacher managed to get Student 1 to explain his ideas, the others claimed that he hadn't explained it. The three continued to argue, with Student 1 indignant that they had not listened to him. They maintained he had not explained anything. There is no evidence in the recording that Student 1 made any such explanation and it became clear that the ground rules for discussion had broken down, as has the cooperative learning process. At this point the group had minimal storyboard and no shared idea of how they would present their understandings in a Slowmation. A conclusion was drawn to the lesson after 30 minutes by the teacher.

The following lesson, a week later, saw the group continue planning. Another student had joined them and there seemed some positive change in the dynamics of the group as well as in the quality of the discourse. As they talked, they represented the movement of the Moon around the Earth using hand gestures. The group also discussed a phenomenon not expected of their Slowmation, that of eclipses. As they talked, each member of the group was looking at each other's diagrams and writing or drawing onto it.

Student 4 The Moon blocks the sunlight off the Earth.

Student 3	Off here?
Student 1	Yes, when the Moon blocks the sunlight off the Earth.
Student 3	It's an eclipse.
Student 1	And it's a full Moon.
Student 2	There's the Sun and there the Moon comes (*students are using their hands and their pencils to show this phenomenon to each other).*
Student 3	And this is the Sun.
Student 1	And when it's a full Moon they're both facing each other because the Moon lights up from the Sun's reflection, there.
Student 2	Yeah.
Student 3	Because the Sun, Earth and the Moon.
Student 1	(*speaks over student 3 but we cannot hear what they say*).
Student 3	Turning around the Earth and the Earth and Moon are rotating around the Sun.
Student 3	Eclipse.. (*mumbles*) like the Earth and the Sun.
Student 1	Mmmm? Well that's saying, that's the Sun, that's going around like that, it doesn't go underneath it, it just goes around (*student using an eraser to represent the Sun and indicating the Earth's pathway by moving a pencil around the eraser).*
Student 3	(*Repeats student 1's representation with own pencil as the others look on)* oh that doesn't work.
Student 2	It's still spinning round but, it doesn't matter which way it is going.
Student 1	It's still going around like that, around that.
Student 3	Yeah, the Moon's spinning.

Student 1 (*Talks over student 3*) hold it up, hold the rubber up (*uses student 3s name*), it can go like that but not like that, it can go anywhere really (*students are holding an eraser and showing Earth's pathway by moving their hands and pencils- three are engaged physically in this while the fourth looks on).*

Student 3 Yeah, but not on top.

Student 2 It doesn't move.

Student 1 It spins on its axis, it spins on its axis.

Student 1 is repeating his explanation to help the others understand how the Moon travels around the Earth as they both travel around the Sun.

Student 2 Not the Moon.

Student 4 No, the Earth.

Student 2 I thought you were talking about the Moon, not the Earth.

Student 3 Say this is the Sun (*holds up eraser*) and this is the Earth (*uses finger to show movement*) rotating around that while the Moon's going around the Sun.

Student 4 The Moon goes around.

Student 1 (*Interjects*) the Moon goes around the Earth while the Earth goes around the Sun (*demonstrating by using one hand as the Moon and the other as the Earth, moving the Moon hand around the Earth hand and then using one hand to represent the Earth and Moon and showing them moving around the other hand, representing the Sun*).

Student 2 It's like the Moon is the Earth's best friend and they just follow around.

Student 3 Basically, basically.

Student 1 (*Repeats the demonstration with hands*) the Earth goes around like that and it goes round once in a year.

Student 4 Yeah, it doubles.

Student 3 Basically what he said is.

Student 1 (*Demonstrates the orbit of the Earth with one hand going around the other hand representing the Sun*) and it goes round once in a year.

Student 3 Basically what he said is like they are friends going around each other but only the Moon's going around the Earth.

Student 2 Spinning like this (*uses finger to demonstrate the Moon's orbit*).

Student 1 And when it goes round the Sun once, that's one year.

Student 2 Yes (*uses pencil to demonstrate the Earth moving around the eraser representing the Sun, directed to student 4*) that's the Earth spinning.

Student 3 And when it gets back there it's a whole year.

Student 1 (*Uses the eraser and pencil to represent again*) it basically goes round like this (*as he demonstrates he calls "eclipse", eclipse" as Student 3 calls one year, one and a half years, two years*).

Student 4 Not every year is an eclipse.

Student 2 No.

Student 4 Because every year if, there would be an eclipse if the Earth stayed still.

Student 2 So every four years an eclipse happens.

Student 4 And the Moon's turning (*demonstrating with hands to show the Moon turning as it goes around the Earth*) and that's why there's not an eclipse every year.

As observed in the transcript, students used various representational tools such as gesture, speech, found objects and diagrams in their discussion of the Moon's movement around the Earth.

Key finding 6.1

The process of storyboarding afforded opportunity for substantive discourse supported with various representational modes, including speech, gesture, found objects and diagrams.

The teacher shared with the whole class, Student 2’s delightfully anthropomorphic idea that, “it’s like the Moon is the Earth’s best friend and they just follow around” and made a note to provide a later opportunity for inquiry into the nature of an eclipse. The students continued to share their individual storyboards and had a discussion about whether or not they could put it all together and what they would start with. As they shared their diagrams they also shared ideas for the narration and continued discussion about the movement of the Sun, Earth and Moon.

Student 3	Mine’s showing how the Sun, the Earth and the Moon rotate, basically movement, this showing where the Sun’s going round. I mean where the Earth goes around the Moon, nah! (*covers face with hands*).

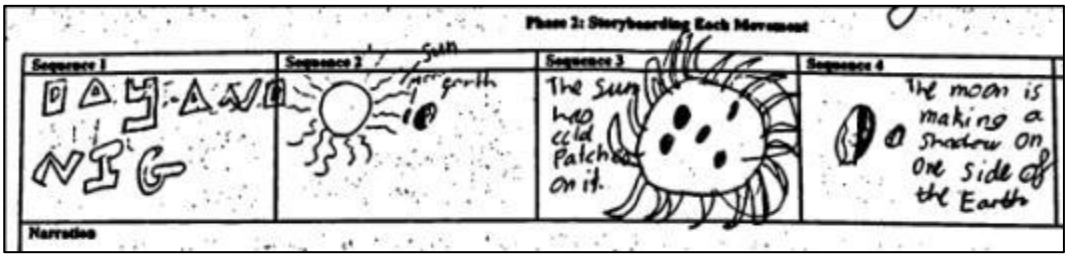


Figure 5. Part of Storyboard of Student 1.3

As can be seen in the fourth panel of Figure 2, student 3 still has some misunderstandings about the role of the Moon in the concept of day and night, writing: “The Moon is making a shadow on one side of the Earth.”

Key Finding 6.2

Students are still developing conceptual understandings about the cause of day and night while creating the storyboard.

Student 1	Where the Moon goes around the Earth.

Student 2	The Earth’s got to be there and the Moon’s got to be there.

Student 4 No, the Earth's got to be there.

Student 1 So the Moon's got to be on the inside?

Student 4 Yeah.

Student 3 Yeah.

Student 1 It doesn't really matter because the Moon spins around the Earth so it could be anywhere.

Student 4 (D*raws Figure 6*). That's the Earth and the Moon's got to be in there.

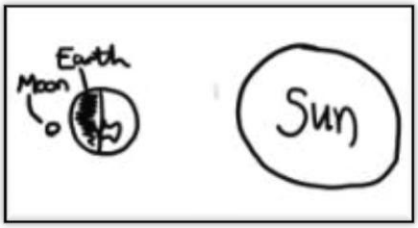


Figure 6. Diagram by Student 1.4

Student 1 No it doesn't, otherwise you wouldn't be able to see the Moon. It can be anywhere around there (*points to Student 4's diagram*).

Student 4 No, it's got to be in line.

Student 1 That's only to be an, um.

Student 3 That's an eclipse.

The class were distracted by another student coming into the room and they lost their train of thought before continuing on another aspect of their representation.

Student 1 Which are two different sizes and when you move the basketball back the basketball looks the same size as the baseball. So they look the same size because of the distance of the Sun and the Moon.

Student 3 Yep.

Student 4,	I did, this is the size of the Sun, Earth and Moon and when the Moon is in front of the Earth it is an eclipse.
Student 2	It is.
Student 4	And I did the shadows. The shadows change because the Earth is spinning round the Sun.

(No comments were made about this inaccuracy).

Student 2	I did the sizes of the Sun the Earth and Moon and its rotations. (*Points to own diagram*.) There's the Sun, the Earth and the Moon. Shows how it rotates around the Sun and how it spins as well, the Moon goes around the Earth, and I've done day and night.
Student 1	I was wondering how we were going to do that.
Student 2	There's a picture of the Sun putting light on the Earth and I've got it spinning, I was going to put it on its axis but I forgot, and there's the shadow, night and daylight (*points to own diagram*.) and it's telling it looks like the Sun is moving but we are, and it has times of the day.

Already there was evidence that the storyboarding process engaged students in conversation around the relevant science concepts, furthermore the students used subject-specific language in their descriptions of the Sun, Earth, Moon, shadows, orbits and eclipses.

Key Finding 6.3
Opportunities were afforded for substantive discourse and the use of subject-specific language. Gesturing supported the discourse and students were using this discourse to share and develop their own and other's conceptual understandings.

The storyboarding process for Group 1 finished here and they moved on to make props and take photos for their Slowmation. The storyboard generated during these two lessons is reproduced at Figure 4 on the following page which indicates the student's level of scientific literacy and conceptual development. The storyboards were used as a guide in the construction of the Slowmations and were viewed very much as "working documents" which invited changes. The storyboards themselves indicate use of diagram as a form of representation, depicting changes in events and the use of captions.

Key Finding 6.4
Storyboarding provided opportunity for students in Group 1 to use conventions of diagrammatic representation.

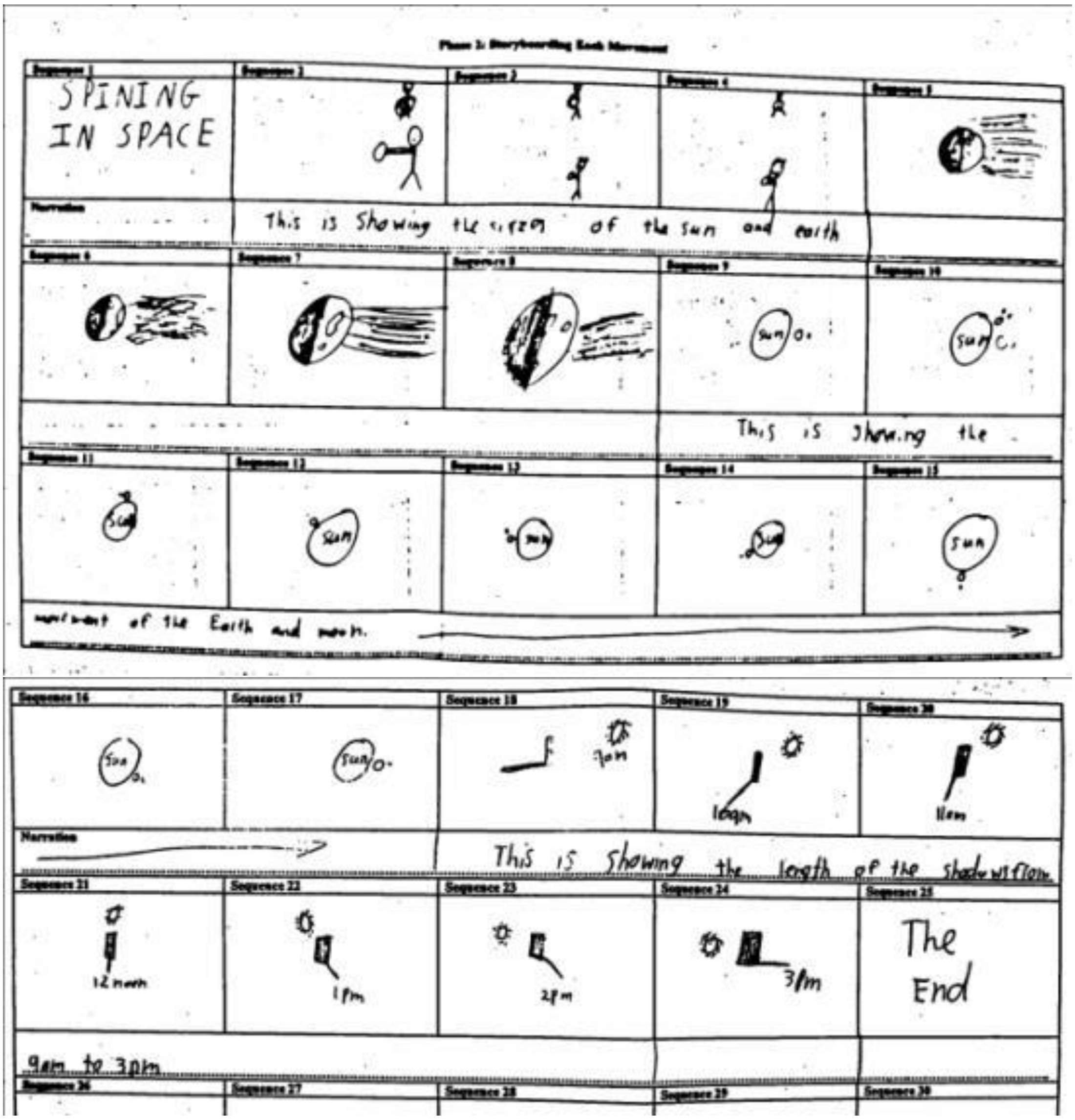


Figure 7. Group 1's Storyboard

Group 2 Storyboarding

Two students took charge of the group, beginning by reading aloud the guidelines provided. The role of "scribe and artist" was given to the most competent illustrator in the group who began by drawing a diagram (Figure 5 below) to show how the group might begin filming their Slowmation and the conversation proceeded from there. This group spent a lot of time discussing how they would represent the Sun, Earth and Moon giving a perception that they all had a good understanding of the concept they needed to represent. The transcript below, edited to include only relevant discussion, provides an illustration of the nature of the discussion, demonstrating how the students are coming to terms with the cooperative nature of the task as well as with the concepts and the associated representational requirements.

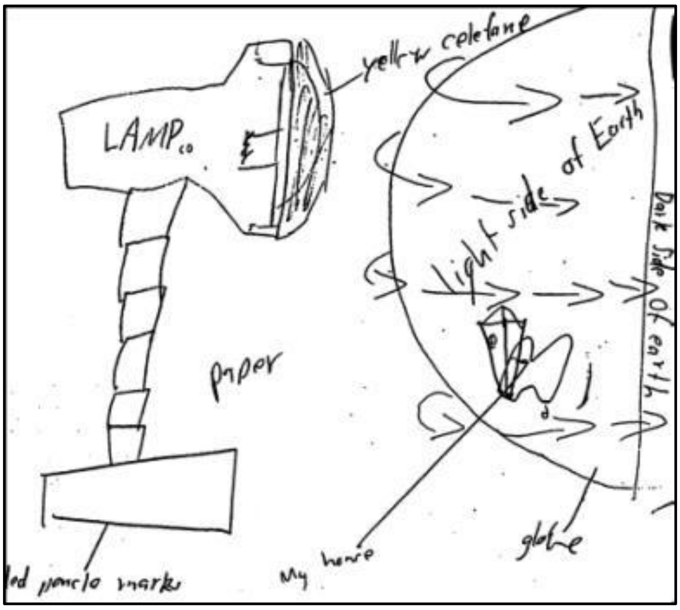


Figure 8. Drawing by Student 2.2

Student 3 (*Looking at Student 2 drawing*) Oh yeah we can get that big, ball, Earth thing.

Student 2 (Mumbles something).

Student 3 (*Incomprehensible*) compared to that it's only that big.

Student 1 That is the Sun.

Student 3 (*Drawing*) light side, that's the dark side. Dark side of the Earth (*watching student 2 draw*) Student 2's name- the Earth aren't going to be that big.

Student 2 There's the arrows.

Student 1 Oh, where it's spinning around.

Student 2 Do it, take a picture, move it take a picture, take a picture.

Student 1 You don't move there you move somewhere down there (*pointing to diagram*).

Student 2 That's our house that's going (*mumble*).

Student 3 So that's going (*mumble*).

There followed some extended discussion about frame rates, filming and general construction of a Slowmation and the discussion was interwoven with intervals of group members drawing their own storyboards and watching Student 2 drawing.

Student 3 And then it says, "the Moon has changed" and then, Sun.

Student 1 The Moon? The Moon has changed?

Student 3 No, the Earth.

Student 2 We can make (*mumble mumble*).

Student 3 Make it tilted.... and you could have a satellite with a camera on it.

Student 3 Put a satellite there and then you could have like, scientists watching.

Student 1 Arrows.

Student 3 We could do it every turn to night, not every one.

Student 3 We're still going to do those scientist people, do you want a satellite there?

Student 2 No.

While students drew their storyboard they had a discussion or argument about how they would show the scientist watching, adding aliens, keeping it realistic, adding voices, wanting to add a spaceship. They then started to talk about the captions they would need.

Student 1 The Earth is spinning around the Sun.

Student 3 It is? Isn't it orbiting? Not spinning. You need to write.

Student 1 Why is it only Australia that is moving and other countries aren't?

Student 3 The Sun (*writing*).

Student 1 And America.

The teacher noticed a break in the discussion and provided a prompt;

Teacher Explain to me what is happening.

Student 2 That's the lamp but we won't be showing it and that's the dark side and the light side of the globe, we're going to spin it, take pictures and spin it and spin it and its going to blur out and then black out and there's an alien spaceship and its going to go off and then it will say "the Earth is spinning" and the Sun.

Student 3 (interrupts) And then we'll do the light side is always facing the source of the light.

There was more discussion about an alien invasion.

Student 1 But if it's the shapes and sizes of the Earth, Moon and Sun we need the Moon in there, there's no Moon in there.

Student 3 There's going to be.

Student 1 There needs to be a Moon.

Student 3 OK put the Moon in there.

Student 2 (*Begins drawing the Moon into the storyboard*.)

Student 3 Make the Moon a little slither.

Student 2 What do you mean, make a little slither?

Student 1 But we've got to do the Moon going around the Earth and the Moon going around the Earth while the Earth is going around the Sun. You're only doing day and night.

Student 2 What are you talking about?

Student 1 You're only doing day and night and showing the Earth and the Sun.

Student 2 We have to show the shapes and sizes of the Earth, Moon and Sun, the first bits day and night.

Student 3 Look, that's the Moon, no, that's not right.

Student 1 No it's not.

Student 3 You put it there and it's the full Moon.

Student 2 (*Draws onto the storyboard and sighs)*

Student 3 Put it right (*points)* there. Think it's a slither?

Student 2 (*Draws onto the storyboard*)

Student 3 How's it meant to be a slither?

Student 1 (*Points to group's diagram*) because if that's the Moon shouldn't it be like that?

Student 3 (*Talks over Student 1*) it's a slither when it is really (*looking at diagram*), when it's there just on top?

Student 1 What's that meant to be? Is that meant to be the Earth and that's the Moon?

Student 3 Yeah and that's the Sun thing, but that's not the right size, so we've got a problem.

Student 1 Let's do it really, really, really small and do the Moon, I mean the Earth, bigger.

Observing individual's diagrams and the group's storyboard at this point in time (Figures 8 and 9) it was evident that students were using additional conventions of science diagrams, such as arrows to indicate position and movement. This initial storyboard also afforded opportunities for students to share their ideas and understandings, providing clarity for conceptual understandings.

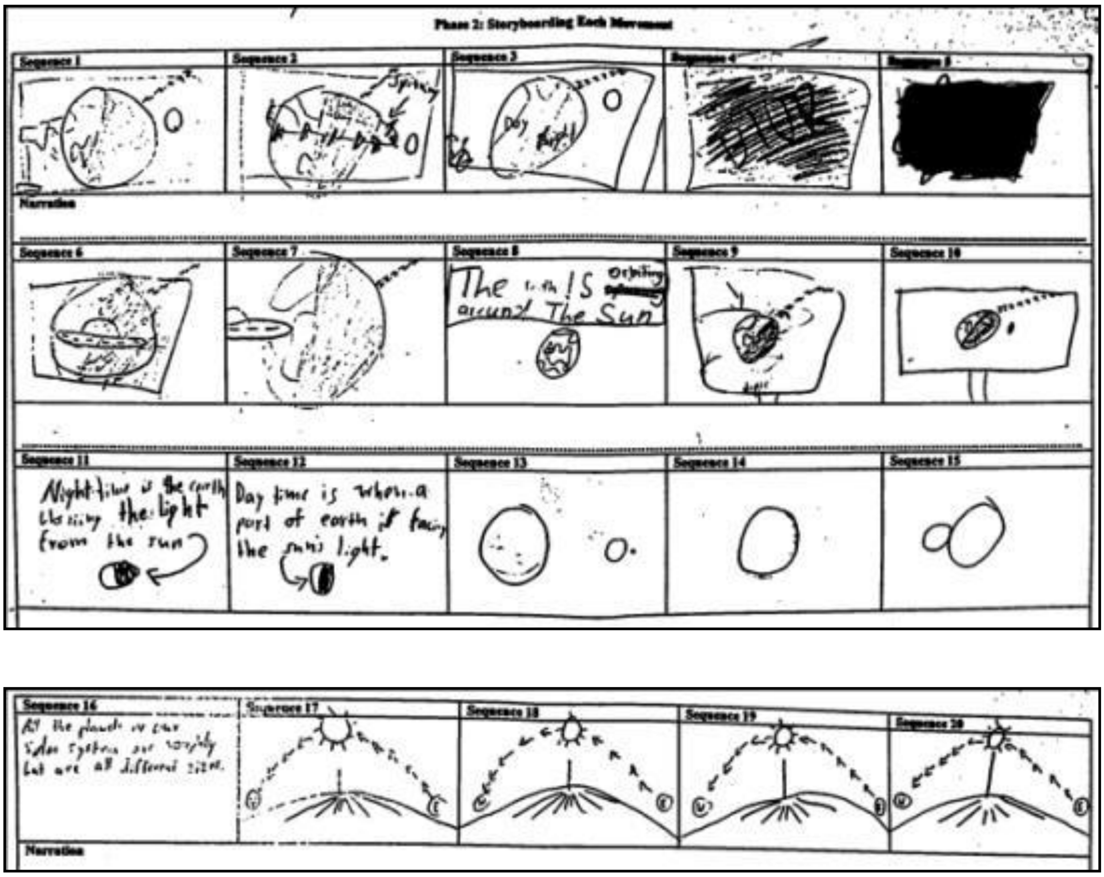


Figure 9. Group Two's Storyboard draft

Key Finding 6.5 Storyboarding provided opportunities for students in Group 2 to use a range of diagrammatic conventions in representation to elucidate their own and others' thinking.

The bell rang and the students ended their discussion. When they returned the following week the group continued with a discussion on the resources they would need. The conversation was about what materials to use, whether to have scientists or aliens watching and how it will change one year later. Two of the students made additions to their diagrams to indicate humans sleeping at night. Another student disagreed with the use of Z'ds to show night (see sequence nine and 10 in Figure 9 above). The conversation lead to a discussion about what night and day are the result of.

Student 3	We've still got to do, another thing that's like night and shadow, night is like a shadow, yeah write that.
Student 2	Night is shadow, daytime is.
Student 3	Put a little box in, and then night is a shadow.
Student 2	Night is a shadow (*reading aloud while writing this text*) and daytime is light.
Student 3	Daytime is facing the source of the.
Student 2	Is facing the source of... no, night time is the Earth blocking the light from the Sun and daytime is.
Student 3	Night is like the Earth blocking the light from the Sun.
Student 2	Blocking the light from the Sun.
Student 1	Night time is.
Student 3	And the light...err daytime is facing the light.
Student 1	You're confusing me! Daytime.
Student 1	Is (*pause*) when the Earth, no.
Student 2	Is when part the Earth is facing the Sun.
Student 1	No, is when one side of the Earth is facing the Sun.
Student 2	It doesn't have sides.
Student 3	One bit of the Earth, no one half, one half.

Student 2 A spot.

Student 3 One half.

Student 1 No, not a spot.

Student 3 One half because one half the earth would be.

Student 1 Yes.

Student 2 Part of Earth?

Student 3 Half!

Student 2 (*Says student 3s name and demonstrates with the globe*) half and then it turns and we'd have to cut it again, then again, then again.

Student 3 Oh, (*pause for thought*) it's still half the Earth is lit up. If it turns again, it's still half the Earth lit up (*demonstrates using globe*).

Student 1 It's like this (*demonstrates using globe*).

The discussion above provided clear evidence of substantive discourse; it is quite sustained around a single topic with students re-phrasing and reflecting to clarify their understandings.

Key Finding 6.6
The storyboarding process provided further opportunities for substantive discourse.

Group 2's second storyboard (Figure 10 below) was modified and more refined displaying evidence of improved conceptual understandings.

Key Finding 6.7
The storyboarding process afforded opportunity to use re-representation to refine understandings.

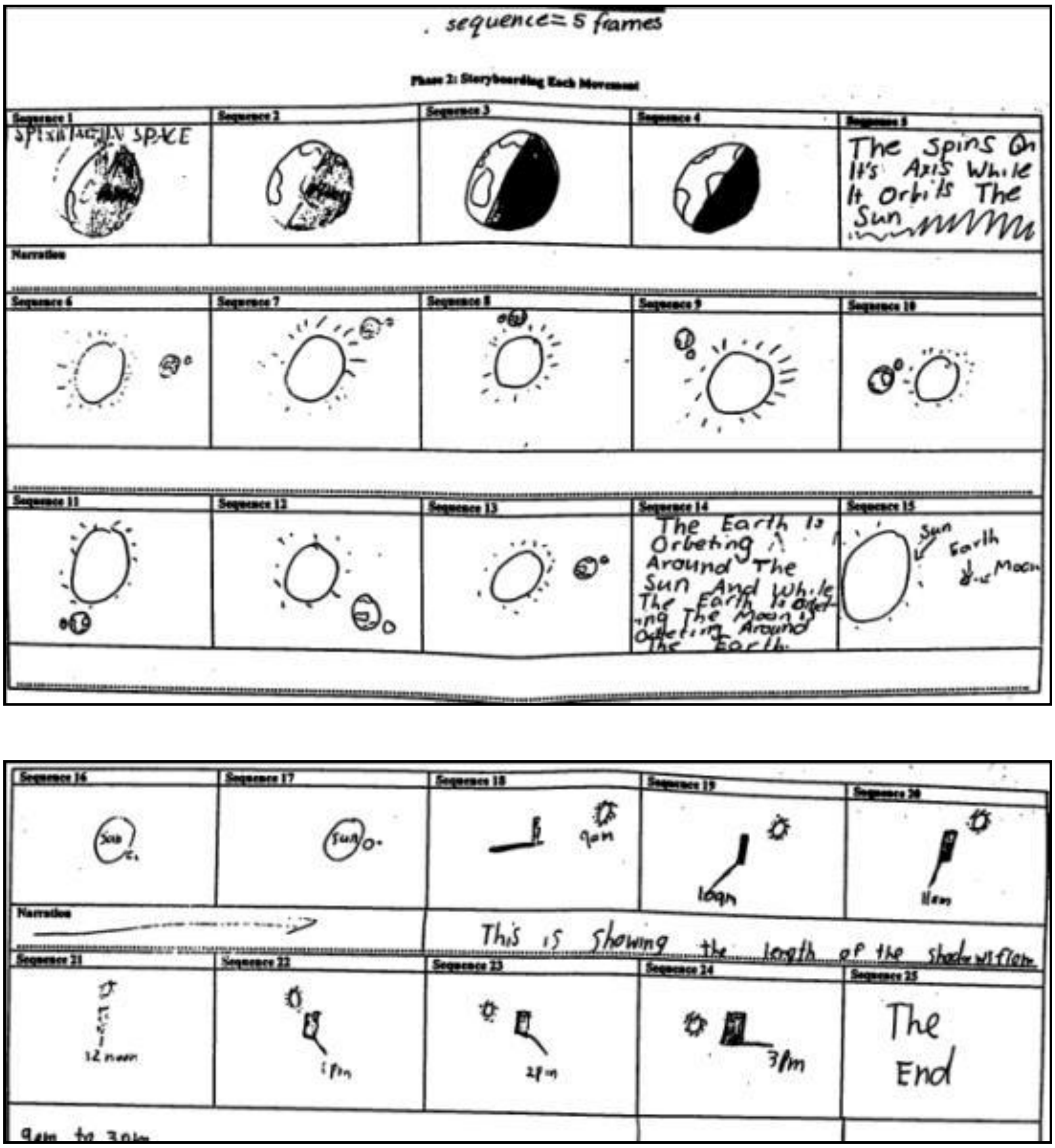


Figure 10. Group 2's Storyboard

The final storyboard provided evidence of improved understanding of the science concepts related to day and night, the size, position and movement of the Sun, Earth and Moon and the phenomenon of shadows changing size and direction during the course of the day.

Key Finding 6.8

Storyboards provide evidence of improved science understandings.

The students then went on to talk about how many photos they needed for the Slowmation and with teacher prompting, students shared what their Slowmation would be showing and how they might represent that. The teacher also prompted for them to think about some of the activities they had been doing in the Spinning in Space unit and how each might be used in a Slowmation. They had ideas of putting a model tree on the globe and showing the changing shadow as it was spinning in front of the projected light. They discussed the use of time-lapse photography or a torch to project shadow and how they might show the relative sizes. They discussed the length of time it takes for light to get from the Sun to the Earth and how the speed of light is measured or calculated. They concluded by all agreeing that they are ready to organise their props and begin filming.

Making the Slowmation

The narrative now continues through the students' creation of the Slowmation.

Group 1 Making the Slowmation

The students made cardboard cut-outs of the Earth, Moon and Sun, they had the camera set up on the tripod and were moving the models and taking their still pictures. Figure 11 provides an image of how two of the students managed the camera while the other two were moving the models.

Figure 11. Group 1 students filming

Students predominantly discussed the technical aspects of making the Slowmation, such things as whether an object should be in the centre of the screen, how big it should be, the need for captions, whether the paint will dry on the background and so forth. There was some discourse around conceptual content as evident in the following transcript of selected conversation during the Slowmation making process.

The transcript has been edited to exclude non-constructive arguments and technical discussion about filming.

Student 4 You can't see the Moon any more.

Student 2 Yes you can only see half of it.

Student 3 I was going to say.

Student 4 But the Moon hasn't been.

Student 1 Remember the Moon spins rotates faster than the Earth.

Student 2 It's the other way round, that's a month and that's a day (*demonstrating with the cardboard cut-outs they are filming*).

Students continued photographing.

Student 4 Eclipse!

Student 2 Mr (Teachers name) that's an eclipse.

Student 4 No, don't take it, pull the Moon out a bit.

Student 2 Move the Sun slightly.

Student 4 How come the Moon's falling behind?

Student 3 Looks like the Moon's spread away from.

Student 2 Yeah.

Some of the conversation became inaudible as they continue to photograph and move items and then continued again with the students discussing technical aspects of filming. After about an hour and a half they then shared what they had filmed so far with the teacher who confirmed that what they had filmed would go together to make an appropriate Slowmation. On the evidence available, the filming process appeared to be predominantly a Technology and Enterprise Media Studies exercise, with minimal evidence of substantive discourse being used to clarify or develop conceptual understanding.

Key Finding 6.9

There was limited evidence of substantive discourse related to the key science concepts from Group 1 during the filming process.

The students then went on to compose their Slowmation on the computer using SAM animation software. Figure 12 provides an illustrative image of the cooperative and interactive nature of the task.

Figure12. Students editing

They transferred their still photographs into a folder on their computer. After beginning and naming a new project in Sam-animation, they opened their photos and previewed them, deleting some and re-arranging the order of others. In over an hour of footage there was little discourse about the science content but much about choice of shots, order of shots and where they might need to retake or replace shots. During this editing process the students were repeatedly viewing their Slowmation and at one stage, one student made a comment about the Moon not orbiting the Earth often enough, as the Earth orbits the Sun. Students were engaged in constructing a group understanding through viewing and re-arrangement of their filmed representation.

Key finding 6.10

Transferring the images to animation software provided opportunities for construction of Group 1's conceptual understandings through re-representation.

There followed some discussion about size and sequence before the teacher suggested they plan their narration. The group watched the Slowmation as they wrote their ideas for the narration. Again the transcript has been edited to exclude non-constructive arguments and technical discussion.

Student 2 We'll just watch it through and then work it out.

Student ? What's that?

Student 2 Aw, it's not in order!

Student 1 Because remember we didn't save it.

Student 3 Let's save it right now.

Student 1 Should we say we did an experiment in class to show the sizes of the (*stops talking and begins to write*).

Student 2 These are the sizes of the Earth and Sun, why don't you describe what we are doing?

Student 1 That would be like of kind of a recount would it?

Student 3 No it would say we are doing the shapes, sizes and the shadow.

Student 2 No, this is (*stops to think*), these are, the sizes of the Earth and the Sun.

Student 2 This is showing how far.

Student 1 The Sun looks small because of the distance.

Student 2 They look the same size just because of the distance.

Student 1 What looks the same size?

Student 2 The Earth (*pause*), the Sun and the Moon look the same size because of the distance.

Student 1 But we're not doing them, look (*points to image on screen of students showing the Moon and the sun the same size because the small Moon is closer and the large Sun is the other end of the school oval. (Shown below in Figure 13).*


Figure 13. Exploring size relationships

Student 2 The Sun and the Moon look the same size because of the distance.

Student 1 It's between them (*points to screen again*).

Student 2 Fine then, The Earth and the Sun look the same size.

Student 2 could see what was being shown by the image on the screen and was getting frustrated with Student 1 who was incorrect in his interpretation/memory of the activity. Student 2 didn't seem to be able to explain the image clearly so ended up agreeing with Student 1. They then moved onto their next segment.

Student 2 This is explaining day and night on Earth.

Student 1 Can you put it really slow please?

Student 2 Yes.

Student 1 I was thinking if we could put Australia, like, Australia is now in the Sun.

Student 2 Yeah.

Student 1 That's good.

Student 3 Day and night on planet Earth.

Student 4 Is it on planet Earth or just Earth?

Student 3 Yeah, on planet Earth.

Student 2 No just Earth.

They finally agreed to the caption “this is day and night on planet Earth” and then moved to the next section of their Slowmation.

Student 1 This is showing the Earth and the Moon.

Student 3 Orbiting.

Student 1 Orbiting the Sun.

Students then talked about adding “this is interesting” to the narration before moving onto the next section of their Slowmation.

Student 1 This is showing shadows (*pause*). No this is showing times of day!

Student 4 And shadows.

Student 1 Shadows of the day doesn’t really make sense (*pause*), shadows of the times of the day, that’s good actually.

They then started to try to record their narration and had some technical issues, so continued their narration planning.

Student 1 Shadows each 24 hours. You guys we’re adding 24 hours at the end.

Student 3 I wrote each 24 hours.

Student 1 That actually sounds really good.

Student 4 Not 24 hours though.

Student 1 24 hours.

Student 3 Yes it is.

Student 4 It’s not shining 24 hours.

Student 1 Yes it is.

Student 4 No it’s not (*goes to show the others on their Slowmation*).

Student 1 Yes it is, coz it's going like this (*demonstrates by bringing palm of hand in an arc, towards himself*).

Student 2 *(Points to screen*) let's see it there. (*Student 2 reverses their Slowmation to their animated representation of the shadow stick experiment.*)

Student 4 (*Pointing to the shadow stick representation on the screen*) 3pm!

Student 1 Aargh!

Student 2 From 9 to 3, from 9 o'clock to 3 o'clock.

Student 4 9am to 3pm.

The students moved between modes of representation, those of speech, animation and gesture, to clarify their own and each other's understandings at the same time as they were reviewing the animated representation which they were constructing in a complex process or re-representation and social construction of knowledge.

Key Finding 6.11

The construction of the Slowmation provided an opportunity for social construction of knowledge through a complex process of multimodal re-representation.

The students then continued to write their individual narrations with no further discussion and soon they were ready to make their audio recording.

Group 2 Making the Slowmation

This group chose to use a globe of the Earth as their main prop and acquisitioned the class overhead projector to use as their light source, as illustrated by the photograph at Figure 14 (below).

Figure14. Group 2 students filming

The students shared video effects with teacher, commenting on how realistic the image of the globe looks with the light shining from one direction. While some students were filming, others were painting backgrounds and writing notes on their storyboard. In the initial phase of Storyboard creation this group predominantly discussed technical aspects of making the Slowmation but reached a need to talk about the captions they would use;

Student 2 What do I write?

Student 3 The Earth is spinning but the shadow stays the same, in the same spot.

Student 2 did not respond to this and continued writing. There followed some discussion with the teacher about who in the group is responsible for which part of the Slowmation and a discussion ensued regarding cooperation and group work. All students seemed happy that what they were filming was an accurate representation of the concepts they needed to represent with little or no discourse on the concepts being filmed.

When the students were transferring images to the computer and arranging the slides and timeframes there was again very little discourse on the conceptual content. The students appeared confident in their understanding of the concept with acknowledgement that their representation reflected their current understanding.

Key Finding 6.12

There was little evidence of substantive discourse from Group 2 during the filming and animation process.

The students then composed and wrote the narration as a group. Students were writing individual parts of the narration despite being advised by teacher to discuss the whole narration. As they looked over their animation, they seemed happy with the individual roles they assigned each other.

It is during this process of review that two members of the group realise their part of the film was not accurate. They discovered they had created an animation in which shadows were following the Sun rather than pointing in the opposite direction. They were watching their animation and one remarked, “are you sure that’s right?” and the other replied, “No, the shadow should be that way,” showing with her hands how it should look. They did not speak to each other as they re-filmed and the other members of the group continued planning their narration. Such an event provided evidence that the process or re-representation presented opportunity for reflection and clarification of understanding for these students.

Key Finding 6.13

The Slowmation process provided opportunity for Group 2’s student development of conceptual understanding through re-representation.

As they were writing, an older student asked if the North Pole and Antarctica were different places and a younger student explained they are different, one is in the north and one is in the south. The older student stated, “the Earth spins around 365 times as it goes once around the Sun” and other students nodded in agreement. No other substantive discourse took place during these incidents. Soon however the group began to share their narrations and a conversation ensued.

Student 2	Isn’t there something about the Earth only sees one side of the Moon?
Student 1	No, oh yeah
Student 2	(*Demonstrates by holding one hand as a fist and facing the palm of the other hand as it moves around*) because it’s always like that.

Student 3	Yours doesn't make sense.

Student 1	(*Reads own written narration*) the Earth spins on its axis while it orbits the Sun, that's why we have Antarctica and the North Pole.

The teacher interrupted, asking if this was covered in Spinning in Space or if it was a new question and with a response to the affirmative, the students continued writing.

Student 1	(*Points to partner's writing*) orbiting around the Sun, not spinning.

Student 2	We say spinning.

Student 1	We don't.

Student 2	(T*eacher's name*) said we say spinning.

Student 1	(*Turns to teacher*) does the Earth spin around the Sun or orbit?

The teacher re-explained that the Earth is orbiting the Sun as it is spinning daily. One student created a representation of the movement with his hands and added the word "orbiting" at a correct point. Students 1 and 2 had a conversation about the spelling of the word "orbiting" before they continued writing.

Student 1	(*Points to Student 2's writing*) the Earth is orbiting around the Sun and while the Earth is orbiting, no, spinning (*pause*), no, orbiting.

Student 2	Aaagh! Orbiting.

Here it is evident that the cooperative learning nature of the task led to student discourse affording opportunity for the use of subject specific language and development of conceptual understandings.

> Key Finding 6.14
>
> The Slowmation process afforded opportunities for student development of conceptual understanding and use of subject specific language through substantive discourse.

Analysis of Storyboarding and Slowmation Creation

In both groups there was much sharing of individual ideas of how to represent the phenomenon of day and night, what resources and materials to use and what dialogue would take place in the narration. There was a lot of time spent discussing the technical process of creating an animation, including the resources and materials required for each scene. It was apparent that these students did not relish the drawing and writing aspect of planning and they were keen to get on with filming. It took some time for their shared ideas to gel into a cooperative enterprise, with much repeating of individual thoughts in the hope that they would be taken up. The students' dialogue reveals a range of understandings and some diversion into other aspects of *Earth and Beyond* knowledge. The younger, Group 1 students, more often used gestural representations than the older students in Group 2. In Group 1, it is evident from their statements that Students 1 and 4 appeared to have a more developed understanding of the concepts, with Student 2 not far behind. Student 3 relied heavily on the knowledge shared by the others and reinforced his position in the group by repeating what others had said. It is evident from their discussion that all students in Group 2 had a reasonable grasp of the concepts and more robust discourse allowed for clarification and building on ideas. The last part of their conversation provided a good indication of how the students were constructing their own and each others' understandings. The Researcher noted that the students were continuing to move back and forth in their use of the terms rotating, orbiting and spinning, although when prompted they were able to explain the differences. Students in both groups were able to describe the phenomenon of day and night, position and movement of the Sun, Earth and Moon and describe changing shadows. Some used specific science language but not always accurately. All students were able to share their understanding of the size differences of the Sun, Earth and Moon and they talked about associated phenomenon such as the appearance of the Moon from the Earth and the tilt of the Earth.

Research question three asks, "What impact does student created Slowmation have on students' science understandings?" and to reflect on this there is a need to turn to the finished Slowmations. It is difficult to reproduce a filmed animation in a written document, therefore to provide adequate context, the narration transcript is presented in association with the relevant images, with the narration italicised.

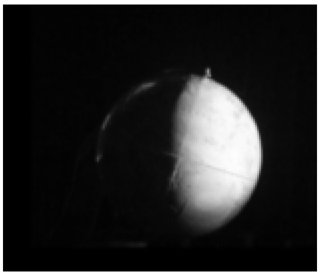
Group 1 Slowmation

Spinning in space

These are the sizes of Moon and the Sun.

The Sun looks small because of the distance.

The image shows a student with a one metre model of the Sun at the far end of the school oval, with the closer student holding a ping-pong ball.



This is explaining day and night on planet Earth.

In the animation, the globe is seen spinning.

This is showing the Earth and the Moon orbiting the Sun.
Did you know that the Earth spins on its axis?

Well this is interesting.

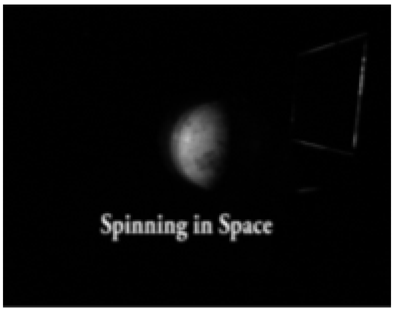
The animation shows the Moon orbiting the Earth as they both orbit the Sun.

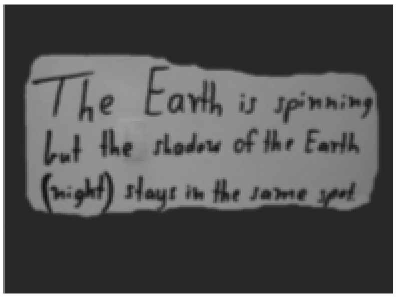
This is showing shadows at different times of the day, from 9 to 3pm.

The animation shows the shadow changing size and position as the Sun moves across from East to West.

Group 2 Slowmation

The Earth spins on its axis while it orbits the Sun



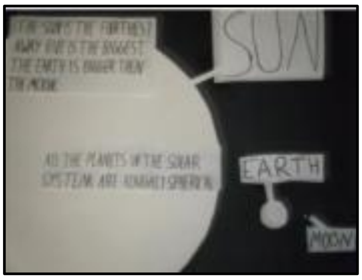


The Earth is orbiting around the Sun and while it is orbiting the Moon is orbiting around the Earth.

The animation shows the Moon orbiting the Earth as they both orbit the Sun.

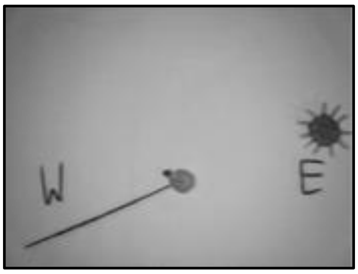
The Sun is the biggest but it is the furthest away.
The Earth is bigger than the Moon.
All the planets in our solar system are roughly spherical.

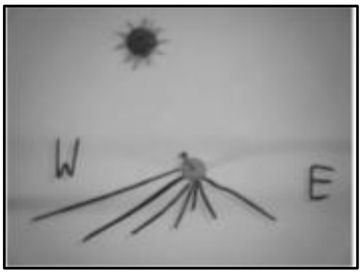
No movement is depicted in this still diagram.



Sunrise and sunset shadows are basically the same besides the direction. Midday shadows are the shortest because the Sun is directly above it.

The animation shows the shadow changing size and position as the Sun moves across from East to West





Analysis of Slowmations

Both groups' Slowmation provides evidence that the students collectively have understood that day and night are a result of the Earth spinning, with the side of the Earth facing the Sun in daylight and the side facing away, in the shadow of the Earth, experiencing night. Both groups have understood the size relationship between the three bodies, Group 1 using the *Spinning in Space* activity involving models and observation across the school oval to demonstrate their knowledge, which also displayed some understanding of relative distance. Students in Group 2 used a science diagram to represent their understanding but were not able to accurately demonstrate the relative distances between the three bodies. Subsequent discussion provided an agreement that this was difficult to do given the vast scale required. Both groups have demonstrated the movement of the Moon around the Earth and the Moon and Earth around the Sun. The groups also agreed that it was difficult to get the Moon to orbit the Earth every 28 spins of the Earth and to also combine this with 365 spins of the Earth during one orbit of the Sun. While they were able to explain these phenomenon using gestures and in diagrams, the technical requirements of such accuracy in an animation were beyond the skills and experience of students at this level and probably require students to consider a fully framed sequence of animations rather than the minimal frames required of a Slowmation.

The function of the narration was slightly different for each group. The groups' narrations display their understanding of the concepts covered in the science unit. Group 1's narration provides little additional information for the viewer, stating, "this is showing" or "this is explaining." Group 2 provided more useful and descriptive captions, with their narration extending the information available to the viewer, for example the statement, "the Earth spins on its axis while it orbits the Sun" is viewed in conjunction with an image of the Earth spinning and a caption stating, "the shadow of the Earth stays in the same spot."

The groups' Slowmations and narrations provide evidence that the students were able to collectively demonstrate the science outcomes of the unit, *Spinning in Space*, which are;

- describe the shapes and sizes of the Sun, Earth and Moon;
- describe the apparent movement of the Sun from East to West, and;
- describe the changes in length and direction of shadows during the day.

In addition, students demonstrated that they also understood the movements of the Earth and Moon around the Sun, how and why the spinning of the Earth results in day and night and why the Moon looks the same size as the Sun.

Key finding 6.15

The groups' Slowmations and narrations provide evidence that the students were able to collectively demonstrate the science outcomes of the unit, *Spinning in Space.*

Research question one asks, "To what extent does engagement in the construction of a Slowmation generate quality student discourse and use of subject-specific language?" The transcripts of student discussion from both groups show many turns in the conversation with sustained discussion around relevant subject content.

Key finding 6.16

Creation of a group Slowmation generates quality student discourse.

Research question two asks, "What opportunities are generated for students to use and create representational modes which demonstrate their science literacies?" Apart from the opportunities for gesture and discourse during the construction process, the finished multimodal Slowmation includes diagrams, gesture, models, written and spoken language. Slowmation allows students to demonstrate their understanding in a way that is not available via a single mode of representation. Furthermore affordance is given by Slowmation for students to represent their understandings of movement and change through an animated representation.

Key finding 6.17

Slowmation affords opportunity for students to engage with multimodal representation and share understandings in an animated form using science literacies.

Comparison of Pre and Post Diagrams

In the Engage phase of *Spinning in Space*, students were required to draw a diagram to record their ideas about the size, shapes, position and movement of the Sun, Earth and Moon. In the Evaluate phase they were required to draw a second diagram to communicate their ideas and what they have learned to an audience. The posters themselves are multimodal, including written and visual information (Australian Academy of Science 2006). Comparison of these pre and post-activity diagrams provide evidence of individual conceptual growth and in some cases, increasing science literacies.

Group 1

All of Group 1 students' Evaluation phase diagrams appear rather rushed, demonstrating little improvement in their ability to use the conventions of science diagrams. Student 1 added new information to show the spinning of the Earth with one side in the light and the other in shadow, which was not evident in the Engage phase diagram. Student 2 indicated that the Earth orbits the Sun every 365 days as the Moon orbits the Earth every 28 days. There is also a small drawing demonstrating the Earth spinning and showing a dark and a light half to indicate day and night. None of these features were evident in Student 2's first Engage phase diagram. Student 3's second diagram shows the movements of the Earth and Moon around the Sun and their relative sizes, none of which were evident in the first diagram. Student 4's second diagram has captions to inform the reader that the picture shows the relative sizes of the sun, Earth and Moon and the statement, "The shadows change because the Earth is spinning around the Sun." As a reference to seasons this may be accurate but as a reference to day and night this is wrong.

Group 2

All of these students used four diagrams to separate the different phenomena they want to illustrate and have added explanatory captions. Each student's first diagram indicates the Earth spinning, with information about the spinning of the Earth resulting in day and night. The second diagram demonstrated the relative sizes of the Sun, Earth and Moon. The third shows the apparent movement of the Sun and the resulting changes of shadows on the Earth. The fourth diagram shows the positions and movements of the Earth and Moon around the Sun. It is evident that this group has used their shared understandings to create their final diagrams which all display improved understandings. These students' individual diagrams also display improved use of science diagram conventions, such as lines, borders, arrows, numbers and captions.

Key finding 6.18

Group 2 students have improved their science diagram literacies.

Students individually displayed evidence of knowledge regarding the following concepts, all of which were not evident in the Engage phase of the unit;

- the Earth spinning causes day and night which is a result of being in the lit side or the shadow side of the planet;
- the apparent movement of the Sun is a result of the Earth spinning and manifests in changing length and position of shadows;
- the Sun is very large, the Earth much smaller and the Moon tiny in comparison, and;
- the Moon orbits the Earth as they both orbit the Sun.

Key finding 6.19

All students' Evaluation-phase diagrams display conceptual understandings not evident in their Engage-phase diagrams.

Post-production Discussion and Journal Entry

After the unit was completed the teacher gave the students an opportunity to reflect on the unit of work and the Slowmation process by asking; "How did making the Slowmation help you to understand the science?" and, "How much more do you now know about the Sun, Earth and Moon?" The students made written responses to these questions.

Group 1

Students 1 and 2 were absent for this session and no opportunity for follow up was available.

Student 3 wrote; "We had to figure out how to solve our science problems. I now know a lot more now such as the Earth orbits around the Sun 365 days a year."

Student 4 wrote; "If you got it wrong you could get help from your group. I have learned more now than when I started such as the Earth spins around the Sun 365 times."

Both these students suggest they know more than they did at the beginning of the unit but are having difficulty articulating their knowledge in writing, as evident from their own journals.

Group 2

Student 1 wrote; "We had visual aids to help us, so if someone didn't understand, the Slowmation would be able to help them. I have learnt lots such as how many times the moon spins in a year and the Earth is on a tilt."

Student 2 wrote; "If you said something wrong people would tell you and then you would know. Lots, such as the seasons is not because of how close the Earth is to the Sun."

Student 3 wrote; "It helped me understand it by making me realise my mistakes. I learnt lots such as, the Sun rises in the east and sets in the west (before I always got mixed up on that) and in night time we are just in the Earth's shadow."

Student 4 wrote; "When you started you knew what you were doing but when you did your Slowmation you made a mistake so you had to go back and do it again. I have learned much more, such as the Earth spins around 365 times, in a leap year there is 366. The Moon orbits around the Earth while the Earth is spinning around the Sun."

Whole Class Discussion

The discussion that followed provides a further insight into how the students perceive the value of the Slowmation creation process. A transcript of the whole class discussion is provided below, edited to include only relevant data.

Teacher	How did making the Slowmation help you understand the science concepts?
Student 2.2	If you said something wrong in the animation they (other members of the group) would tell you.

Student 1.4	Well, if someone got it wrong you could help each other and then they'd understand it, like how it works, like that.
Student 1.3	Sometimes you could help each other with ideas and sometimes you could do it on your own if you think it'd work.
Student 2.4	Sometimes when you did the storyboard and you'd made a mistake and you kept on going and you knew what you were doing but you did it the wrong way you could see from the animation when it started and it made a big difference.
Teacher	And what happened when that happened to you?
Student 2.4	We had to do it again
Student 1.2	You'd learn from other people in your group because they'd know maybe a bit more about it and when they tell you it'd be a bit more in your head, solid like and if you got something wrong they'd tell you and you'd know never to do it again.
Student 2.1	Slowmation, it sort of helped us because when you're explaining something they might not have understood, the Slowmation might have helped them because they saw it instead of just hearing it.
Student 1.1	It was better than writing it down on a piece of paper, putting it on the computer, like some of the others have said, you can kind of help your friends.
Student 2.3	When we made our mistake, when we downloaded it onto the computer we could see it and someone pointed it out so that meant we had to go back and do it again and then we got it right.
Student 1.1	One of the annoying parts of the Slowmation was the computer deleted it sometimes and froze, it was annoying.
Student 2.2	It was frustrating when the sound system didn't work when we recorded onto the computer.

The students all appear to have a positive perception as to the nature of peer support and discourse, agreeing that it helped to talk with other members of the group. The student comment regarding seeing something rather than “just” hearing it, struck a resonance with the other students who nodded in agreement. There was general consensus that the software glitches and transfer of data provided some frustrating difficulties and although they were overcome, the teacher noted a need to ensure the compatibility of software and clarification of technical requirements. It is evident from the conversation that there is general consensus among the students that the process of making a Slowmation was beneficial to their learning. Specifically they noted the benefits of peer support, discourse, problem solving, visual aid and opportunity for review and reflection.

Key finding 6.20

Student perceptions of the benefits of creating a Slowmation were positive and included references to peer support, discourse, problem solving, visual aid and opportunity for review and reflection.

Post-production Reflection

The whole class viewed Group 2’s Slowmation and the teacher asked if and how it could be improved and whether or not the science was accurate. The teacher prompted the use of a PMI chart on the whiteboard (looking for positives, minuses and improvements). There was little response and one student said “Yes, (the science is accurate)” with the majority of the students again nodding in agreement. All students appeared to agree that the science on display was accurate and there was little needed to improve the presentations. The teacher kept prompting but no student could see any errors or areas for improvement. Another student made an attempt to further the discussion, “changing shadows could be really smooth if you did it like an hour long.” There was no response from the other students, so the class viewed Group 1’s Slowmation. Again there was minimal discussion.

Student 2.1 The Earth touched the Sun

Teacher So there’s no scale?

Student 2.1 Sort of. Ours scale isn’t too good, it goes like that.

Teacher Is there a difficulty showing an accurate scale?

All students Yes.

Student 2.2 If you did you'd have to make the Earth like that small (*indicating a tiny distance by holding thumb and forefinger apart*).

The teacher talked about what might be needed to show an accurate scale and in the absence of any further discussion the teacher ended the lesson. The reluctance of the students to participate in analysis of each others' Slowmations raised a number of questions: Were they afraid of offending each other? Have they still a great deal to learn about providing honest and fair peer appraisal? And, have they still not yet come to terms with the ground rules for generating substantive and robust discourse?

Key Finding 6.21 There is a need to scaffold protocols for engaging in critical assessment of own and others' work.

Final Interviews

A repeat of the first interview was conducted to provide a comparison with the pre-study interviews. When asked how a scientist might share their information, there was evidence of some increased awareness of forms of representation, with all students repeating suggestions of telephone, talking, texting, email and other written forms. One student in Group 1 suggested graphs, posters, drawings and diagrams which they did not suggest in the first interview and a student in Group 2 suggested computers and photographs, again an addition to earlier responses. It is of note that no student suggested animation as a form of representation.

Key Finding 6.22 Students do not interpret Slowmation/animation as a mode of communication for science.

When asked about what causes day and night, students were more descriptive in their responses than during the pre-Slowmation phase. When asked to explain what they know about the shapes and sizes of the Sun, Earth and Moon, statements of comparison were similar to responses in the first interview but on the positions and movements of the Sun, Earth and Moon explanations were more accurately descriptive as illustrated by these typical responses which provide evidence of increased understandings:

“Night is when part of the Earth isn’t facing the Sun, it’s like in the shadow. And the part of Earth facing the Sun is daytime because the Sun doesn’t move and the Earth goes around the Sun and spins at the same time” (Student 1.2).

“The Earth spins on its axis and if we’re spinning one side can’t see the Sun because the Earth is blocking it and the light can’t go through the Earth and the other side’s light” (Student 1.4).

“The Sun stays still and as the Earth spins around one side is facing the Sun and the other side isn’t. The side facing the Sun is in daylight” (Student 2.4)

“The Moon goes around the Earth but it’s always facing the same side. The Sun stays in the same spot and the Earth orbits the Sun while it is spinning” (Student 1.1).

“The Sun is in the middle of all the planets and the Earth goes around the Sun and while it’s doing that the Moon’s going around the Earth” (Student 1.2).

“The Sun just stays in one spot while the Earth orbits and the Moon orbits around the Earth. The Earth is spinning” (Student 1.3).

Key Finding 6.23 The Slowmation process has resulted in increased conceptual knowledge for all students.

Additional questions were asked to solicit student perception of the Slowmation process in terms of opportunities for discourse and development of understandings.

Students were first asked if they found the ground rules for discussion useful. Their responses indicate that they valued the process for a number of reasons as evident from the selected transcripts below;

“It was easier to talk and to share your idea” (Student 1.1).

“It gives everyone a chance to share their ideas and it helps the group so they can understand a little bit more” (Student 1.2).

"Yes, you could share what you wanted to say and no one was being too loud or talking over you" (Student 1.4).

"It was actually useful, we would have talked over each other. When we used the rules we could support their idea and not interrupt" (Student 2.1).

"Everyone always had their turn, we all shared who was talking, we didn't talk over each other, we could add to it" (Student 2.4).

The students all appear to have a positive perception as to the value of having ground rules for discussion, agreeing that it helped to moderate talk with other members of the group.

Key Finding 6.24 Students appreciated and understood the value of having ground rules for discussion.

The students were then asked if making the Slowmation helped them to understand the science concepts involved. Responses varied but a general consensus was quite positive as illustrated by the selected transcripts below:

"If you didn't have an idea someone else might have an idea you could share on that and build and come up with a really big idea" (Student 1.1).

"You're learning as you are going along, you have to design it and think about what you are going to do and then you do experiments to see how you're going to make the animation" (Student 1.2).

"Yes because you could see. If you did something wrong you could see what was wrong and then understand it" (Student 1.4).

"Yes. When you were doing it you could see the mistakes you made. You could see what was right and what you needed to change. We saw the shadow following the Sun and it should have been the other way round" (Student 2.4).

When asked what aspect helped the most, the students talked about the conversations they had while watching and listening to their own and the other group's Slowmation. The two students who had to re-film their shadow stick example added further evidence to the usefulness of the process. Further discussion revealed the positive and negative aspects of the Slowmation process:

“It was fun and you got to use the camera, using other things in the classroom” (Student 1.1).

“It was fun, except when we mucked up we had to do it again” (Student 1.2).

“I liked the computer stuff and going out on the oval” (Student 1.3).

“It’s always fun and you’re learning in a fun way” (Student 1.4).

“It was fun because we get to take pictures and do stuff that you don’t usually get to do at school, it taught you as well while you were making it” (Student 2.1).

“I liked being able to correct my mistakes”(Student 2.3).

“You could see the mistakes and you could see what was right and what to change” (Student 2.4).

“Some of the things on the computer buggered it up. It froze and all our stuff we had done got deleted and we had to do it all again. Sometimes we’d have arguments” (Student 1.1).

“We had to do the Moon and the Sun, how far they are away and see how they look the same size. We had to do that twice” (Student 1.2).

“Sometimes the planning gets into an argument if it’s not going how you want it to be. We just kept on going with one idea and adding the other ideas in” (Student 1.3).

“It was hard to show some of the scenes- you had to go in other places to do it and you had to have the lights off and it was hard to do it” (Student 1.4).

“Writing everyone else’s narration was hard” (Student 2.1).

“The computers kept playing up and freezing. Sometimes your group never cooperated properly” (Student 2.4).

The comments generated by the interviews and discussion provide evidence that this is an authentic and productive learning experience for students.

Key Finding 6.25
Students perceive value in the creation of a group Slowmation, recognising that the process has helped their science understandings through having to engage in discourse and through re-visiting their multimodal representation.

Summary

This chapter followed the storyboarding and Slowmation activities in the Evaluate phase of the unit. It looked at the finished Slowmations and their narration and compared Engage and Evaluation phase diagrams. It analysed student interview transcripts which revealed reflections on their work and understandings.

It is evident that at the beginning of the storyboarding process not all students had fully comprehended the concepts covered during the Explore, Explain and Elaborate phases of the *Spinning in Space* unit of work (KF 6.2). In both groups there was much sharing of individual ideas of how to represent the phenomenon of day and night, what resources and materials to use and what level of narration or dialogue would take place in the narration. The storyboarding process provided the students with a meaningful context to construct and develop their own and each others' science understandings (KF 6.8) with many examples of students building on each others' knowledge and of self correction. The Slowmations and associated narrations provided evidence that the students were able to collectively demonstrate the science outcomes of the unit, *Spinning in Space*, including the understanding of the size, positions and movements of the Earth, Moon and Sun, why the Moon looks the same size as the Sun, how the spinning of the Earth results in day and night and the associated phenomenon of changing shadows (KF 6.15 and 6.23). All of the students' Evaluation phase diagrams displayed understandings not evident in their Engage-phase diagrams, indicating development of conceptual knowledge (KF 6.19). In addition there is evidence of students talking about other associated phenomena such as the appearance of the Moon from the Earth, the tilt of the Earth and eclipses.

There is limited evidence of substantial discourse about the concepts covered in *Spinning in Space* unit and few if any extended utterances during the initial stages of filming and animation (KF 6.9 and 6.12). However, at varying stages in the process, the students in both groups, reflected through their ideas, thought aloud, shared and adjusted their individual and combined understandings. The process of storyboarding afforded opportunity for substantive discourse and the use of subject specific language (KF 6.3, 6.6, 6.14 and 6.16). There is also evidence that students also appreciated the value of having ground rules for discussion (KF 6.20 and 6.25).

There seems to be little verification of an increase in awareness of forms of representation used by scientist (KF 6.22), however, evident during the storyboarding process, were opportunities for multimodal representation, re-representation and use of the conventions of science representation (KF 6.1, 6.4, 6.5 and 6.7). Furthermore there is clear indication of the social construction of understanding through multimodal re-representation (KF 6.10, 6.13 and 6.17) with the process requiring the students to think about their understandings in a way not available through other modes of representation (KF 6.11). Rather than standing alone as verbal representations of the phenomena the narrations complemented the representations (KF 6.15) and the animated nature of the Slowmation allowed students to demonstrate their understanding of moving objects in a way not available through other modes of representation. For the students in Group 2 the process also contributed to improved science diagram literacies (KF 6.18).

There are a number of assertions to be drawn from the key findings which link directly to aspects of the research questions; conceptual understandings, substantive discourse and opportunities for multimodal representation. It is however difficult in many ways to separate the process of discourse and other forms of representation in the development of conceptual understanding. Creation of the Slowmation required students to reflect through their ideas, with the cooperative learning process providing the opportunity for substantive discourse which adjusted their individual and combined understandings. There was general consensus among the students that the process of making a Slowmation was beneficial to their learning. Specifically they noted the benefits of peer support, discourse, problem solving, visual aid and opportunity for review and reflection.

The following chapters will provide further discussion, a conclusion and implications arising from this study.

CHAPTER 7 DISCUSSION

The aim of this study was to investigate how the implementation of a student-created Slowmation within a Primary Connections unit, *Spinning in Space* (Australian Academy of Science, 2006) influenced student learning of science. Chapter 2 reviewed the literature related to the issues surrounding contemporary science education, the notions of socio-cultural theory, the place of the Primary Connections resource in developing scientific literacy, the importance of substantive discourse and its relationship with multimodal representation and where Slowmation as a teaching and learning tool fits within these contexts. Chapter 4 set the context in which the study took place and Chapter 5 described evidence of students developing conceptual understandings through their discourse and use of multimodal representation in the Engage, Explore, Explain and Elaborate phases of the unit. Chapter 6 described events during the students' construction of their storyboard and Slowmation in the Evaluation Phase. Key findings emerged from the analysis of transcripts of dialogue taken from audio and video recordings, student work samples, the finished Slowmation and from student reflective discussions. This chapter discusses the key findings from the preceding chapters in terms of contemporary research literature and generates assertions that answer the research questions.

Learning in a Social Context

Contemporary teaching and learning theories offer the underlying premise that students construct meanings in a social context and this supports them to individualise and internalise understandings (Reiber & Robinson, 2004; Robbins, 2007; Vygotsky, 1987, 1978). Key findings from Chapter 4 suggest that the educational and social environment in which this study took place was typical of small rural primary schools in Western Australia (KF 4.1and 4.2) and provided a sound educational and social environment in which to explore the research questions (KF 4.3, 4.4 and 4.5). The Primary Connections teaching resource uses the 5Es model (Bybee, 1997) as a framework to scaffold stages of inquiry in a social constructivist paradigm with a collaborative learning strategy to support learning in a social context. The *Spinning in Space* unit, (Australian Academy of Science, 2006) provided an appropriate curriculum context for analysing the effectiveness of animated representation as a teaching, learning and evaluation tool (KF 4.6).

There was evidence in the transcripts of discussion that the creation of the Slowmation involved students in social construction of knowledge through a complex process of multimodal re-representation facilitated through substantive discourse (KF 6.10, 6.11, 6.13 and 6.14). In a fine example of social constructivism in action, with reference to the dialogic nature of meaning making and the complications afforded by the fluid nature of language (Mortimer & Scott, 2003) it was observed during the course of this study, that the words spinning, revolving and rotating could each have a different meaning dependent on the student's prior understanding and the context in which the word was being used. Is the Earth revolving, spinning or rotating around the Sun? The dialogic process of social learning allowed the students to generate common meanings for spinning, rotating and revolving, with guidance from the content expert (the teacher) to create a Slowmation which demonstrated the key understandings about day and night as accurately as the medium and the developmental stage of the students would allow (KF 6.14 and 6.16). Further evidence of socio-cultural theory in-action was provided by the students themselves, who recognised that making a Slowmation was beneficial to their learning (KF 6.20 and 6.25), "they noted the benefits of peer support, discourse, problem solving, visual aid and opportunity for review and reflection" (Chapter 6, p.117).

Assertion 7.1 Student created Slowmation involved students in social construction of knowledge through a complex process of multimodal re-representation facilitated through substantive discourse.

Student Engagement

The theory underpinning this research informs us that learning takes place in a social context (Vygotsky, 1978). It is important to recognise that in order to learn within that social context, students need to be engaged with the learning process. Research is indicating that students across developed countries are becoming disengaged from schooling and from education in general (Angus et al., 2010; Tytler, 2007). Furthermore, this is not a phenomena associated just with socio-disadvantaged groups or with students with learning or behavioural difficulties but also includes a large group of students who are compliant in class, who do not interfere with the learning of others nor draw unnecessary attention to themselves. Such students do not progress well and are at risk of "restricting their academic progress" (Angus et al., 2010, p. 112). During this research it was observed that creating a Slowmation engaged all of the students at many levels, they were engaged in discourse around the topic content, they were engaged in model making, in filming and in generating various modes of representation (KF 6.17). When asked, "What did you like about making the Slowmation?" responses included;

> "It was fun and you got to use the camera, using other things in the classroom."
>
> "I liked the computer stuff."
>
> "It's always fun and you're learning in a fun way."
>
> "It was fun because we get to take pictures and do stuff that you don't usually get to do at school, it taught you as well while you were making it."
>
> "I liked being able to correct my mistakes."
>
> "You could see the mistakes and you could see what was right and what to change."
>
> (Post Slowmation production interviews May 2010)

These post Slowmation production comments reveal that the students enjoyed using the tools, recognised benefits in relation to their own knowledge acquisition and were truly engaged in the learning process.

Assertion 7.2 Students enjoyed the process of creating a Slowmation, which motivated them to engage in the learning process.

Such interpretations are supported by Hoban who reports that, "involving children in making Slowmation movies appears to improve their engagement in science lessons" (2005, p. 30). Another study from Norway by Wikan, Mølster, Faugli and Hope (2010) observed that students involved in digital multimodal text production worked better collaboratively and were more focussed than students involved in traditional project work. Their conclusion was that "group processes have improved because more discussion and interaction are required to produce the final product" (p. 232) and making a digital multimodal text "involves many steps which offer the opportunity to strengthen collaborative and creative group-based learning" (p. 232). Such observations also applied to student creation of a Slowmation, which is a collaborative effort using digital technologies and multimodal representations. It has been suggested that use of technologies provide a culturally appropriate tool for engaging students (Alloway et al., 2006) and the group created Slowmations have resulted in sustained and lengthy engagement with science for the students involved in this study (KF 6.2, 6.5, 6.6, 6.7, 6.10, 6.11, 6.13 and 6.14). Yung and Tao (2004) suggest that student-to-student dialogue may improve students' confidence in science, therefore it might be concluded that the discourse afforded by collaborative construction of a Slowmation also allowed students to gain confidence in science and thus increase their engagement with the subject.

For quality learning to take place, students need to be engaged in the learning process. If the issues facing science education regarding achievement, science understandings, interest and engagement (ACARA, 2010c; Lemke, 1998; Lyons, 2006; Thomson et al., 2008) are to be addressed there needs to be a range of more "varied and open pedagogies" (Tytler, 2007, p. 67) made available to teachers and students. Observations during this study indicate that student-created Slowmations in a science context positively engage students in the learning process.

Assertion 7.3

By generating the need for collaborative learning, requiring discussion, interaction and using digital technologies, creating a Slowmation affords the opportunity to deeply engage students with the process of learning science.

Student Discourse

The literature makes it clear that student dialogue is fundamental to student learning (Cox et al., 1999; Mercer, 1995; Vygotsky, 1978) and many studies have focussed on the variances in dialogue between teachers and students (Barnes, 2008; Bennet, 2001; Cox et al., 1999; Goodrum et al., 2001; Hackling et al., 2010; Kurth et al., 2002; Lemke, 1998; Lyons, 2006; Mercer, 1995, 2008; Mercer, Dawes, Wegerif, & Sams, 2004; Mortimer & Scott, 2003; Norris & Phillips, 2003; Simon et al., 2008). It is recognised that there are different types of discourse taking place in classrooms, some more conducive to learning than others. Mortimer and Scott (2003) generated a model to describe the different dimensions of interactive, non-interactive, dialogic and authoritative communication and Hackling, Smith and Murcia (2010) refer to that model to illustrate the need for varying communicative approaches depending on the phase of inquiry. Yung and Tao (2004) stress the importance of appropriate classroom discourse on the affective domain of learning and recognise the need to develop this domain to increase students' confidence in science study.

During the Engage, Explore, Explain and Elaborate phases of the *Spinning in Space* inquiry there were opportunities for varying modes of discourse (KF 5.2). It was necessary for the teacher to engage in more interactive-authoritative dialogue because of the nature of some of the activities. However, because this study aimed to research the students' discourse during the construction of the Slowmation, in the Evaluative phase of the inquiry, the teacher/researcher deliberately took on the role of non-participatory observer whenever possible during this phase. It was observed that as students explained a concept, asked each other questions, challenged ideas and had to re-explain or modify their understanding, they were engaged in conversational threads that afforded opportunities for shared meaning making and use of science language (KF 6.3 and 6.6). The Slowmation required an agreed construction to explain the concepts developed in *Spinning in Space*, with the finished Slowmation and its narrative being the collective understanding of the group. The peer tutoring that took place through the discourse enabled all students to develop sound conceptual understandings; the stronger students having to refine their explanations, using discourse and other modes of representation, to bring the less able students along the journey (KF 6.1, 6.2 and 6.3). The questions posed by the weaker students forced the others to think more deeply about the concept because in order to explain it they had to understand it clearly (Mercer, 1995).

One of the objectives of this study was to look for evidence of substantive discourse (Mercer, 1995; Newmann & Wehlage, 1993). It was evident during the construction of the Slowmation storyboard that there was considerable interaction around the ideas of the set topic (KF 6.14), the talk was predominantly about the subject matter and there was evidence of higher order thinking as students re-represented their knowledge and ideas to explain the concepts of day and night to each other and to a wider audience (KF 6.5). Evident in the transcripts during the course of constructing their Slowmation, students were engaged in disputational, cumulative and exploratory talk (Mercer, 1995) and displayed links between verbal and visual representations (Lemke, 1998) as they reasoned in varying degrees throughout the process (KF 6.16).

Students initially displayed great difficulty working within the ground rules of discussion but with teacher guidance were soon able to follow the requirements (KF 5.1 and 5.2) and at the conclusion of the programme, students reflected on the positive aspects of having ground rules for discussion, best illustrated by the comment from a student in Group 2 who said, having ground rules for discussion, " gives everyone a chance to share their ideas and it helps the group so they can understand a little bit more" (KF 6.24).

The pre-Slowmation phases of the unit provide evidence of students engaging in sustained conversation around a topic and the task of creating a Slowmation lent itself initially to non-science based technical discussion regarding filming, modelling and animation technique (KF 6.9 and 6.12). However, at various stages during the construction of their storyboard and Slowmation, students were reflecting on their science ideas, thinking aloud, sharing and adjusting their understandings of the concepts, with frequent use of subject-specific language (KF 6.3, 6.6 and 6.14). Increasing science understandings and use of science language indicate that the process of creating the Slowmation afforded opportunities for the students to develop their scientific literacy through sustained conversations between each other with many exchanges of dialogue (KF 6.20 and 6.25).

Assertion 7.4 The process of creating a Slowmation afforded a variety of opportunities for students to engage in substantive discourse which supported development of science understandings and mastery of the social language of science.

During the course of this study, through the literature reviewed and from analysis of student engagement and interaction, it is evident that discourse is not separate from, but one of the multiple modes of representation. The importance of substantive discourse is that, in contemporary Australian educational culture at least, it is the predominant tool used for mediating between the other modes.

Multimodal Representation

This study investigated how knowledge is constructed and re-constructed in a social situation through the use of speech and other representational tools. It needs to be recognised that there are numerous interactions between representational modes and such representations and re-representations are strongly interrelated. Discourse is one representational mode which is also a tool that mediates between other modes. There are physical modes of representation, variously described as gestural, embodied, kinaesthetic, modelling and role play, as well as representational science literacies such as spoken science specific language, written reports, graphs, tables and diagrams which include captions, arrows and annotations (Prain, Tytler, & Peterson, 2009). During the storyboard phase of constructing their Slowmation, students were continually using and moving between various modes of representation to share and clarify their developing ideas (KF 6.1, 6.4, 6.5 and 6.17). Figure 15 (below) demonstrates how student discourse facilitates the development of understanding through opportunities to represent, reflect, discuss and re-represent via the collaborative process of creating a Slowmation.

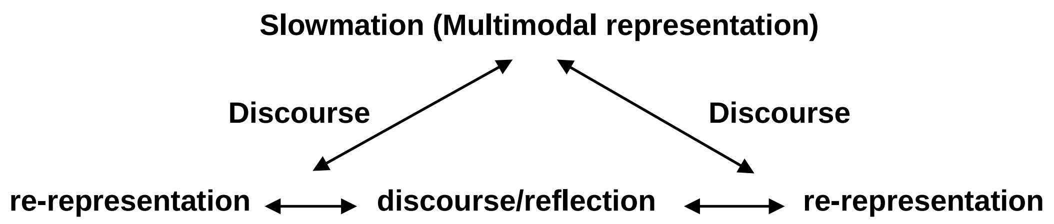


Figure 15. Re-representation through discourse during construction of Slowmation

The processes of representation, reflection and re-representation of the concepts go continually back and forth within the group, via the representational process of discourse, which continually modifies the group and individual understanding of those concepts, culminating in the animated and narrated representation. Students are using discourse to share their understandings and learn new concepts as they are learning and practising the means to represent those concepts.

Assertion 7.5 Collaborative creation of a Slowmation facilitates rich opportunities for students to use discourse as a representational form to generate and mediate between other representational forms.

Murcia and Sheffield (2010) argued that, “In order to understand the values, languages and practices of the discipline, students need to experience multiple representations and explorations in the classroom” (p. 19). Ainsworth (1999) suggests that multimodal representations motivate learners, support learning and lead to the acquisition of deeper understandings. Tytler, Peterson and Prain (2006) argue that “constructing and refining representations is a core knowledge construction activity within science, and should therefore be a major emphasis in the science classroom” (p. 17). Prain et al. (2009) suggest the need;

> for a representational-rich learning environment that encourages students to have many opportunities to represent and refine ongoing understandings, both verbally, and in two-dimensional and three-dimensional modes. This would entail children being challenged to make, question, explain, modify, coordinate, and justify representations as they clarify key concepts. (p. 805)

During the process of creating a Slowmation, students were sharing and refining their understandings, mediating through the representational form of spoken language to generate other representational forms such as writing, diagrams, gesture and finally a narrated animation. They were making a collaborative representation and having to question, explain, modify, coordinate, and justify representations between each other as they clarified key concepts individually (KF 6.11).

Assertion 7.6
The creation of a Slowmation engaged students in substantive discourse as they constructed and refined their conceptual understandings using multiple modes and multimodal representations.

Murcia (2010) advises that, “Science as a discipline is multimodal. That is, it involves the negotiation and production of meanings in different modes of representation” (p 19). Students were observed using a variety of representational modes to generate and communicate understanding during all phases of the unit. The discourse is scattered with examples of students using their hands, bodies, models and found objects to indicated movement, represent the Sun, Earth and Moon and to develop and explain their understandings (KF 5.3, KF 6.1and KF 6.2). The older students of Group 2 began to make diagrams, which included arrows and annotations and to write down their ideas. In this group there was also evidence of self-correcting, indicating the use of language as a tool for exploring and clarifying their understandings (Barnes, 2008).

Students moved between modes of representation, those of speech, animation, gesture and role play to clarify their own and each other's understandings during the storyboarding activity. Often students were observed picking up a pencil, eraser or other object to represent the Sun, Earth or Moon and to use the objects as models or tools, as they explained positions and movement. Occasionally students would stand up and use their whole bodies to explain the rotation of the Moon around the Earth or the Earth around the Sun and to show the spinning of the Earth. Such kinetic representation appears to increase learning opportunities for particular students, lessening their reliance on written or spoken texts which are not necessarily their strengths (Research journal, April 2010). There is also evidence of interplay between various modes of representation, with students slipping and sliding between representations, as described in Figure 15, while they developed their conceptual understandings (KF 5.3 and KF 6.1). This is demonstrated in the following examples from Group 1 storyboarding:

Student 2	You could do this, this is what I'm saying, say that's the Earth (*points to diagram on paper*).
Student 2	You do this, you go round, wooo, like (*demonstrates physically*).
Student 3	(commenting on Student 2's diagram) Isn't the Moon supposed to be on there?
Student 2	There's the Sun and there the Moon comes (*both students are using their hands and their pencils to show this phenomenon to each other).*
Student 2	You could do this, this is what I'm saying, say that's the Earth (*demonstrating on paper*).
Student 3	Say this is the Sun (*holds up eraser*) and this is the Earth (*uses finger*) rotating around that while the Moon is going around the Sun.
Student 1	The Moon goes around the Earth while the Earth goes around the Sun (*demonstrating with hands*).

(Transcript Group 1 Storyboarding April 2010)

The younger Group 1 students used kinaesthetic representations more often than the older students in Group 2, demonstrating the differential developmental needs of students to utilise different representational modes to develop their conceptual understanding (Carolan et al., 2008).

While representation of an understanding can take on many forms, there are modes of representation that are related specifically to science and shared with other learning areas such as Mathematics or the Social Sciences. Tables, diagrams and graphs for example have their own conventions that need to be learned and understood. As students are learning new science concepts they also need to learn new languages of representation (Carolan et al., 2008). The *Spinning in Space* resource provides opportunities for this to occur during all five phases. The students' initial diagrams revealed a limited range and understanding of science-specific representation (KF 5.3 and 5.12) but through the Engage, Explore, Explain and Elaborate phases there was evidence of developing understanding of the parts of a scientific diagram and recognition of a diagram as a method of sharing knowledge or information (KF 5.6 and 5.8). At the beginning of the unit, in the Engage phase, all the students were able to use models such as different size balls, to show relative sizes and positions of the Sun, Earth and Moon (KF 5.7 and 5.8). At the conclusion of the first four phases of the unit, all students had utilised both diagrammatic and written representational skills to share their understandings (KF 5.14). All of the students' Evaluation phase diagrams displayed little improvement in science diagram literacies beyond those literacies developed up to the Elaborate phase, but did display science understandings which were not evident in their Engage phase diagrams (KF 6.4).

The main purpose of this study was to explore the impact of constructing a Slowmation on students' learning, through discourse and other modes of representation. The Slowmation provided opportunities to use subject specific representational literacies alongside other modes of representation as students refined their understandings. There are three phases to the Slowmation process; storyboarding, filmmaking and narration. The storyboards from both groups provided evidence about the students' abilities to represent science phenomena using diagrams. Students depicted the Sun, Earth and Moon and drew arrows to indicate movement. The sequences of drawings provide a representation of changes in position, size relationships and observed phenomenon. This form of representation provided a context and visual cues for discourse and allowed the students to share and clarify their understandings as evident in the interplay between gesture, graphic and oral modes of representation; and in the development of understandings demonstrated by both groups (KF 6.1, 6.4, 6.5 and 6.17).

Filming the Slowmation involved making models, photographing them frame by frame and then manipulating the frames in a software programme. While there is limited evidence of substantive discourse during this stage of the Slowmation process (KF 6.9 and 6.12), there is much to be taken from the students' manipulation of models during the filming process. Video shows students pointing and adjusting positions of models as they developed the most appropriate representations for filming, providing evidence of students moving between embodied and model-based representations and supporting non-verbal forms of representation. Students also experimented with frame rates and sequence when editing as they strove to fine-tune their representation of the Earth spinning to result in day changing into night. Creation of the Slowmation required students to represent and re-represent their ideas, with the cooperative learning process providing the opportunity to think aloud, share and adjust their individual and combined understandings, mediated through substantive discourse (KF 6.11 and 6.14).

Assertion 7.7

Opportunities for the students to develop their science understandings were provided by the various modes of representation used by the students, mediated through discourse and through the multimodal characteristic of the Slowmation process.

It is evident at the beginning of the unit that students were unfamiliar with some graphical representational literacies, but when supplied with a framework were able to use tables and graphs (KF 5.3 and KF 5.18). Students' initial diagrams displayed few of the accepted conventions of science diagrams and only the older students provided evidence of improved science diagram literacies in their Evaluation phase diagram (KF 6.18), with improved use of arrows and annotations and refined detail in drawings. The conflicting role of teacher-researcher resulted in relevant graphical literacies not being explicitly taught to the students as guided by the Primary Connections resource and therefore the post-Slowmation production interviews revealed little development of graphical representational awareness (KF 6.22). Although the Slowmation process did not explicitly teach students about graphical representational literacies in science, there is evidence that students used these literacies during their construction of the Slowmation. The Slowmation itself is a multimodal representation, including diagrams, speech, written and animated representations and students were engaged in using these representational tools, reviewing them, repeating them and re-representing ideas. The evidence indicates that students improved their science understandings through social construction of understanding using the multimodal re-representation required of the Slowmation. Creating the Slowmation afforded opportunities for the students to think about their understandings in ways not available through other modes of representation and the animated nature of the Slowmation allowed students to demonstrate their understanding of the relationships between moving objects.

In their study of teachers' perspectives about using multimodal representations in science learning, Prain and Waldrip (2008) observed that "teachers face considerable challenges in focussing on multimodal representation in learning in science" (p. 20) and the complexities generated by having students with differing levels of experience, expertise and understanding "entailed a range of complex implementation issues" (p. 20). The observations in this study were that Slowmation distinctly engaged the two groups of students in substantive discourse and the use of multimodal representations. There was a three-year age range between students in each group and diverse levels of experience, expertise and understanding. Slowmation itself, as a form of multimodal representation, became a mediator for other forms of representation.

Assertion 7.8 Slowmation as a form of multimodal representation became a mediator for other forms of representation between students of different developmental stages and creating a Slowmation generated many opportunities for students to use a variety of graphical representational modes to share and develop their understandings and literacies of science.

Science Understandings

The key purpose of science education is the development of students' scientific literacy (MCEETYA, 2006) and a key component of scientific literacy is that of conceptual understanding (Tytler, 2007).The conceptual understandings in this case being associated with the relationships between the Sun, Earth and Moon.

The Engage phase of the unit provided baseline information regarding students' levels of understanding which concluded that most of the students were unable to comprehensively describe the relationships between the Sun, Earth and Moon (KF 5.4 and 5.5). During the Explore, Explain and Elaborate phases, the students developed their understandings through engagement with the inquiry learning processes. The students' individual levels of understanding were varied across the groups at the conclusion of these pre-Slowmation phases with this variance interpreted as being commensurate with the mixed ages of the students (KF 5.7 and 5.9). It was also evident that not all students had fully comprehended the concepts covered during the Explore, Explain and Elaborate phases. Most students were able to describe the shapes of the Sun, Earth and Moon, most students had an acceptable concept of their relative sizes and most could describe why the Sun looks the same size as the Moon when viewed from the Earth. After the investigation into shadow changes, all students were able to describe the phenomenon of lengthening, shortening and changing directions of shadows during the day. There were some students who still had misconceptions regarding the cause of day and night on Earth, others who were unable to explain how the apparent movement of the Sun is a result of the Earth spinning on its axis and there were still misunderstandings evident regarding the movements of, and the relationships between, the Sun, Earth and Moon (KF 6.2). There was clearly room for further conceptual development prior to and during the construction of the Slowmation.

It is generally accepted that learning in a social context allows an individual to internalise understandings that were developed on the social plane of the classroom (Cox et al., 1999; Reiber & Robinson, 2004; Vygotsky, 1978) and Chapter 6 described evidence of students sharing and exploring their ideas and understandings. During construction of the Slowmation, students were engaged in substantive discourse, using dialogue, drawings, models and gesture to represent and re-represent their understandings, they responded to each others' comments, built on ideas and rejected others. One group of students recognised their mis-representation of shadow-changes and then collaboratively modified their animation to articulate their improved conceptual understanding. Such evidence supports the assertion that the process of creating a Slowmation provided a meaningful context in which students could re-construct and extend their own and others' understandings (KF 6.7 and 6.8). The completed Slowmations provided evidence of students' achievement of the unit's intended learning outcomes (KF 6.15, 6.23 and

6.19) as identified for Level 2 and Level 3 of the National Scientific Literacy Progress Map (MCEETYA, 2006). The students' Slowmations show the shapes, sizes, positions and movements of the Sun, Earth and Moon, they demonstrate how day and night are the result of the Earth spinning on its axis (Level 3) and re-represent their shadow-stick investigation to describe the apparent movement of the Sun across the sky from East to West (Level 2). All the students exhibited the following understandings mandated in the Australian Curriculum for Science (ACARA, 2010a):

- Year One; recording short and longer term patterns of events that occur on Earth and in the sky, such as the appearance of the Moon and stars at night, the weather and the seasons.
- Year Five; modelling the relative size of and distance between Earth, other planets in the solar system and the Sun, and
- Year Seven; predictable phenomena on Earth are caused by the relative positions of the Sun, Earth and the Moon.

The students in the study group ranged from Year 4 to Year 7 and in their Slowmations were able to animate patterns of events that occur on Earth and in the sky, modelling the relative sizes of the Earth, Moon and Sun and were able to show how predictable phenomena on Earth are caused by the relative positions of the Sun, Earth and the Moon. Furthermore the students had internalised the concepts, as evident in their individual evaluative diagrams which displayed understandings not apparent in their earlier diagrams (KF 6.19).

A part of the OECD definition describes a scientifically literate citizen as a person who, "possesses scientific knowledge and uses that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues" (OECD, 2007, p. 12). Development of scientific literacy for a young student includes resolving intellectual conflict between their every day observations and abstract science. In Chapter 5 it was questioned whether students were having difficulty coming to terms with the representation of the day/night concepts or whether they were coming to terms with their observation of the Sun moving and their developing cognitive knowledge that the Earth spinning on its axis makes the Sun appear to move. Robbins (2007) observes that "Many researchers and academics have reported on challenges associated with changing children's existing views of the world" (p. 60) and argues that because students “ may hold multiple views at any one time, consideration should be given to programming longer timeframes for learning than is often presently employed” (p. 61). Fleer and Ridgway (2007) observe that in young children, cognitive development includes the separation of everyday, observed or perceived scientific reality and academic or abstract science. They draw on Vygotsky’s (1987) analytical framework to explain how children move between connected and unconnected conceptual development, leading to understanding. The phenomenon observed during the pre-Slowmation phases may well be a representational development process but the cited research suggests that it is highly likely to be associated with the dialectical relationship between science concept and observed phenomenon. Fleer and Ridgway (2007) suggest that teachers can generate learning experiences that progress the student toward more abstract science concepts while maintaining intellectual connection with observed phenomenon. While the research of Fleer and Ridgway is primarily centred in early childhood education, Primary Connections which is embedded with social constructivist theory, allows for this dialectical conceptual development through its inquiry based learning model and the associated activities. The process of creating a Slowmation, along with the representational and discourse experiences it provides, further fosters growth in conceptual awareness and scientific literacy. Creating a Slowmation also adds to the timeframe provided for students to shape and internalise their understandings.

The *Spinning in Space* unit afforded opportunities for the students to draw evidence based conclusions and construct understanding. Creating a Slowmation has given students additional opportunity to engage in the development of their scientific literacy and science understandings. It was evident in the finished Slowmation that they had enhanced their scientific knowledge, they had identified questions as evident in their discourse and they had explained scientific phenomena. Creating the Slowmation led students to deeper understanding of the relationships between the Sun, Earth and Moon (KF 6.8, 6.15 and 6.23).

> Assertion 7.9
>
> The process of creating a Slowmation extended opportunities for individuals to shape their own conceptions through identifying and challenging alternative conceptions, which resulted in increased science understandings for all students.

Theoretical Model

The observations emerging from this case study can be linked to form a new theoretical model (Figure 16), evolved from the conceptual framework (Figure 3) and illustrating the place of student-created Slowmation in science teaching and learning.

The Slowmation process was embedded in the inquiry-based *Spinning in Space* teaching sequence, which involved students in a culture of collaborative learning (A 7.1). Social constructivist and socio-cultural theory frame the model with notions of socially mediated and collaborative meaning making on the social plane and internalisations of understandings using language as a cultural tool.

The requirement to collaborate in the creation of Slowmation as a representational form necessitates engagement by all members of the group. In addition, the process of creating a Slowmation further engages students by recognising contemporary student culture through the utilisation of digital technologies, motivating the students to engage in the learning process (A 7.2 and 7.3). Thus engaged, the students become involved in substantive discourse in order that the Slowmation represented the groups' collective understanding of the science concepts (A 7.4). The substantive discourse became the tool for students to move between multiple modes of representation as they engaged in the construction of a new representation of their collective understanding. This new representation was multimodal and it mediated between other representational forms (A 7.5 and 7.6). The Slowmation was a moving representation of the groups' collective understanding.

While the activities in the *Spinning in Space* unit were the vehicle for developing the science concepts and specific literacies of science, creating the Slowmation further engaged students in refining their scientific understandings and literacies. The finished Slowmation provides evidence of improved learning and becomes a tool for students to reflect on their own and others' understandings (A 7.7, 7.8 and 7.9).

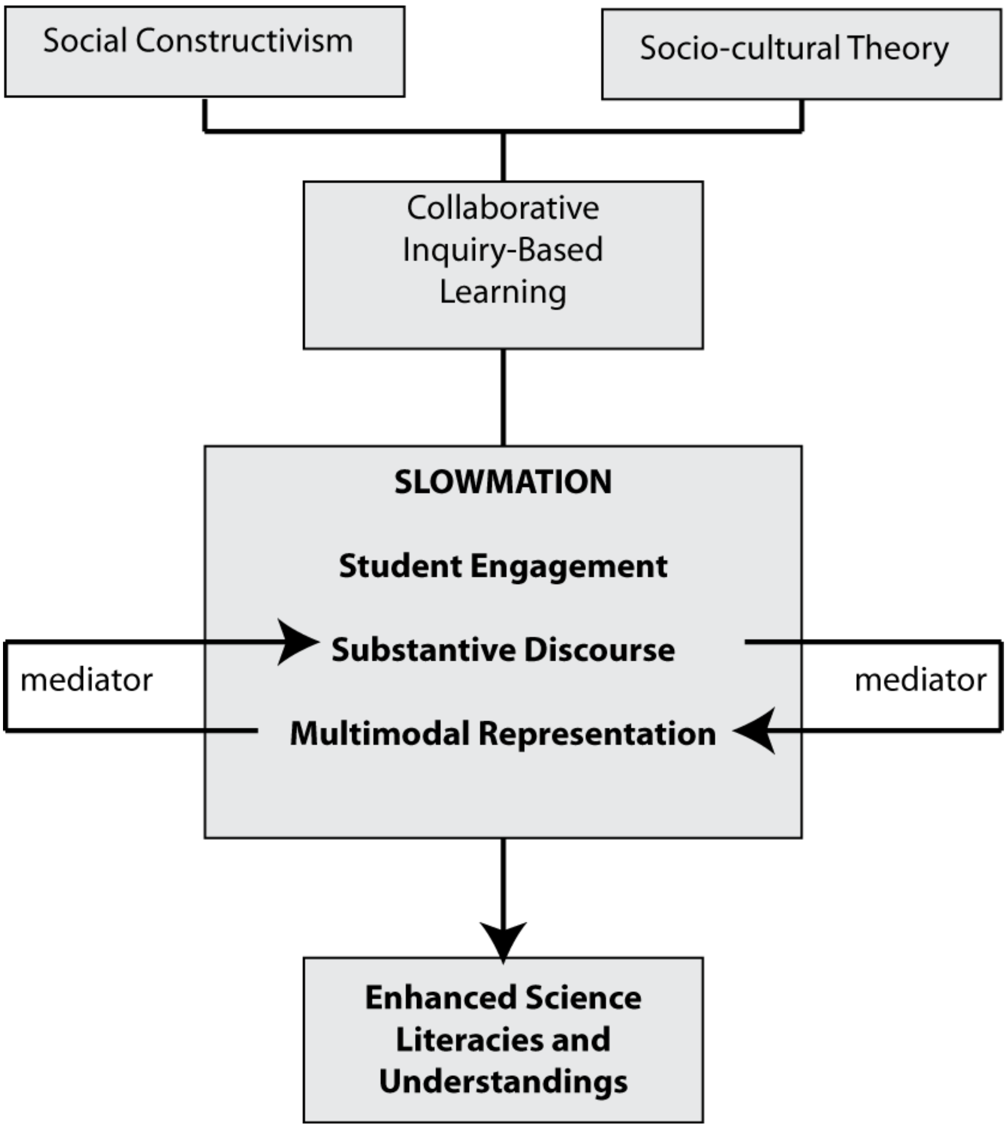


Figure 16 Theoretical Framework.

Slowmation is a social-constructivist teaching tool which engages students in substantive discourse and multimodal representation to enhance science understandings.

CHAPTER 8 CONCLUSIONS AND IMPLICATIONS

Data analysis generated a number of key findings and in Chapter 7 these findings were interpreted to generate nine assertions. This chapter returns to the research questions, drawing a number of conclusions which provide answers to those research questions. In addition, this chapter also includes discussion related to some of the implications that became apparent as a result of the research, which adds to the significance of this research and contributes further original knowledge to the field.

Conclusions

Research Question 1.
How does construction of a Slowmation engage students in quality discourse and use of subject specific language?

This study, through analysis of video and audio transcripts, provides evidence to confirm that student engagement in the construction of a Slowmation afforded extended opportunities for students to engage in substantive discourse (A 7.6), as defined by Mercer (2008) and by Newman and Wehlage (1993). Furthermore this discourse supported the development of science understandings, evidenced in the Slowmations themselves (A 7.9) and mastery of the social language of science, which included the use of subject-specific language (A 7.4). There is also evidence to support the observation that collaborative creation of a Slowmation facilitates rich opportunities for students to use discourse as a representational form to generate and mediate between other representational forms (A 7.5).

Research Question 2.
What opportunities are generated for students to use and create representational modes which demonstrate their science literacies?

During this study there was substantial evidence, through analysis of video recordings and transcripts of discussions, that the process of constructing a Slowmation afforded rich opportunities for multimodal representation and re-representation of science understandings (A 7.5 and 7.6). Students were observed using a variety of representational modes to share and develop their understandings and literacies of science as they worked together on their storyboard and as they constructed their Slowmations (A 7.8). The Slowmations themselves are representations in their own right and include within them, other representational forms, such as models, diagrams and spoken and written text. The Slowmation process has also afforded opportunities for the students to experience the multidimensional nature of scientific literacy (Hackling & Prain, 2008; Murcia, 2010), which includes the inquiring nature of science, the science concepts and the impact of the science phenomena on daily life, as evident in the finished Slowmations. The students' improved literacies of science are evident in the static and animated diagrams used within the Slowmation, as well as in the use of science specific language during discourse and in the narration (A 7.5). In addition it was observed that the multimodal characteristic of the process increased opportunities for learning (A 7.7) which resulted in improved science understandings for those students who may not have otherwise grasped some of the complex science concepts (A 7.9).

Research Question 3.
What impact does student-created Slowmation have on students' science understandings?

It is evident from this study that student creation of a Slowmation combined social constructivist pedagogies in a way that allowed for students to build their knowledge at a collective and an individual level (A 7.1). It is well recognised that student engagement is a major key to successful learning (Angus et al., 2010) and by generating the need for collaborative learning, requiring discussion, interaction and using digital technologies, creating a Slowmation afforded the opportunity to engage all students with the process of learning science, using digital cultures with which they are familiar and which they enjoy (A 7.2 and 7.3). This in-depth information-technology rich process provided great opportunities for student discourse to facilitate interplay between various modes of representation and connect representational literacies to the development of conceptual understandings (A 7.8). The finished Slowmations provided evidence of improved collective learning, with individual improvement evidenced in individual evaluative diagrams (A 7.9). The Slowmations demonstrated understanding of the key science outcomes of the Primary Connections; *Spinning in Space* unit and aspects of the Australian Curriculum for Science (A 7.7, 7.8 and 7.9). The Slowmation also became a useful tool for students to reflect on their own and others' understandings as evident from reflective discussions.

Contribution to Knowledge

There has been other research into student-created stop motion animation and Slowmation, the results of which are suggesting that there are positive outcomes of such pedagogy. Pre- service teachers have reported improved science understanding through the process of creating a Slowmation (G. Hoban, 2007) and Gravel (2008) asserts that creating a stop motion animation “helps students to better understand processes by helping them break down changes over time” (p.1). This research has added to such evidence and has described how the students themselves recognised the benefits of the process to their own learning. Without exception, students indicated that they enjoyed making their Slowmation, which generated a desire to engage in the learning process (A 7.2). By providing depth and richness to the learning experience the Slowmation process has engendered positive student engagement and with student engagement recognised as an important issue in contemporary education (Angus et al., 2010), such a finding has much significance.

Wegerif, Mercer and Dawes (1998) and Murcia and Sheffield (2010) suggest that within appropriate pedagogical frameworks, multi-media technologies can be used to stimulate discourse and facilitate collaborative learning to achieve given curriculum outcomes. This research supports the addition of Slowmation to the repertoire of interactive multi-media pedagogy and has provided observations and evidence which supports the argument that such appropriate interactive multi-media pedagogy deserves a regular place in the teaching of particular concepts in science and perhaps too in other learning areas.

It is evident from this study that Slowmation has a beneficial impact on the teaching and learning of primary science, facilitated through several key benefits: The process engages students in multimodal representation, re-representation and substantive discourse; it allows increased reflection time on a particular science concept; animation adds additional benefit of being able to represent a moving or changing phenomenon and the processes have a power to engage students in a rich learning experience. The construction and refinement of their Slowmation motivated and engaged the students in learning and through the use of multimodal representation, mediated through substantive discourse and supporting constructivist learning, lead to the acquisition of deeper science understandings. The mediating effects of discourse, gesture and graphical representation on each other, in a cycle of repeated re-representation had an empowering and positive influence on the development of student learning (A 7.7).

Implications.

As in all research, implications have arisen from this study, which were unforseen prior to the journey and which provide additional observations that bear some significance for research and for teaching, learning and assessment.

Implications for Research

Ainsworth (1999) suggests that “Multiple representations and multi-media can support learning in different ways” (p. 131) but that further studies are required to “inform the design of the next generation of multi-representational learning environments” (p. 152). This study has provided just one opportunity to do this and there are many questions opened up by this research that invite further research. How does the process impact in science in a different context, such as different demographic population, different age groups, different sized groups and could the process be beneficial across other learning areas? This last question has some significance as we move into the implementation of the Australian Curriculum, which clearly favours integration across learning areas (ACARA, 2009) and the development of generic capabilities.

In this case study, the Researcher was the teacher and implications arose from conflict between the role of teacher and the role of Researcher. An initial issue was the difficulty the Researcher had maintaining the role of teacher. While the teacher wanted to correct at points of error, the researcher wanted to stand back to observe where the students would take a particular idea (Research journal May 2010). As the study progressed the Researcher recognised that the teacher role was being compromised by acting as an observer only and not attending to points of error at particularly opportune times. It was also apparent that some salient explicit teaching points were not covered. While this became fascinating in terms of the discourse afforded between students it did not attend appropriately to the learning needs of some students who would have benefitted at that point in their development of particular science concepts. It was apparent throughout the process that there were many opportunities for monitoring student understanding and for correcting conceptual errors. It is evident that the Researcher must remember to maintain the role of teacher whenever necessary, to intervene in ways that facilitate learning and that the learning needs of students should have the first priority. An important implication for classroom research conducted by teacher-researchers is that the role of teacher should not be compromised by the research role, with “careful consideration given to the role of the Researcher within the research activity” (Robbins, 2007, p. 61).

It is important to recognise the context of this study, which was characterised by a small rural community, small school and small class taught by the school principal. The case study methodology provides rich descriptions of the context, the teaching and learning and learning outcomes. Any attempts to generalise from the analysis and make general interpretations of the data would be ill advised. Drawing parallels with similar contexts however, “may be entirely possible” (Bell, 2008, p. 202). Further replication studies are needed before generalisation is possible.

Implications for Teaching: **Principles for practice**

The Australian Curriculum (ACARA, 2009) recognises that there needs to be greater integration of Information and Communication Technologies into other learning areas and the national vision for ICT in schools suggests among other things, a need for coordinated planning, new learning resources and developed teacher capabilities (DEEWR, 2008). This study, which by its small referent size cannot be over-generalised, has shown an example of the successful use of contemporary technologies to engage students in a rich learning experience, providing learning opportunities that utilise quality discourse practice and multimodal representations to enhance learning outcomes. However, the implications arising from this study, suggest that while Slowmation can successfully be used to scaffold quality learning experiences, for the process to be as effective as possible there are particular principles that need to be embedded into classroom practice. Murcia and Sheffield (2010) argue that Interactive whiteboard technology is an effective tool for enhancing students learning opportunities but is “only as effective as the pedagogy [surrounding its use]” (p. 11). Wegerif, Mercer and Dawes (1998) also support the notion that the benefits of student discourse and of multi-media technologies, are enhanced by appropriate planned pedagogies being integrated into regular classroom culture. Like-wise, student-created Slowmation has the potential to truly benefit learning if surrounded by research-proven effective pedagogy. Such pedagogies include collaborative learning and the explicit teaching of discourse practice, representational literacies and higher order thinking skills, including metacognition. There is also opportunity for further introduction of evolving technologies, which include improved software availability, graphic tablets, mobile phones and interactive whiteboards.

The whole process, from storyboarding, filming, editing and production provides opportunities for collaborative learning. The Primary Connections teaching resources embed the practices of collaborative learning but this study provides some evidence that student success would be enhanced by explicit teaching of the processes, skills and rules of collaborative teaching and learning (Bennet, 2001).

While student created Slowmation provides opportunities for substantive discourse in the classroom (A 7.4, 7.5 and 7.6), evidence from this study suggests that student skills in these areas, plus their achievement of science outcomes would further benefit from explicit teaching of the modes of discourse and of the skills and ground rules for class discussion. Well researched frameworks for such teaching are readily available (Mercer et al., 2004) and the structures surrounding the teaching of philosophy in primary classrooms have also proven to enhance students' skills in questioning, thinking and talking (Trickey & Topping, 2004).

It was of interest that none of the students interpreted Slowmation or other types of animation as a form of representation or useful for communicating science ideas (KF 6.22) despite the fact that Slowmation in itself is clearly a multimodal representation. Teaching students how to create a Slowmation provides further opportunity for explicit teaching of the literacies of representation. Teaching resources and curriculum inform teachers that students need to be taught the literacies of science-specific representation. In addition, explicitly teaching students about the multiple modes available to share knowledge, alongside questioning and discourse strategies that facilitate switching between modes of representation will be beneficial to student learning.

As we prepare students for the ever changing technologies of the world before them there is a need to "meaningfully include technologies into teaching and learning [which] requires educators to fundamentally re-think what they do and how they do it." (Moyle & Owen, 2009, p. 50). Student created Slowmation does just this and with costs of software continually dropping and programs becoming more advanced and simpler to use (Hoban & Nielsen, 2010), there also exists the prospect of introducing other technologies to generate or enhance student created Slowmation. Music, soundtrack and web-publication, as well as other forms of animation could be considered, such as Flash (Adobe™) animation techniques, and Picture Stories (Microsoft™). In the time since this study was undertaken, further developments in technology have already provided better and more seamless integration of the processes involved, with subsequent animation being made by the same students using software facilities on Mac-laptops.

Further implications arise when consideration is given to the notions of learning styles. Slowmation benefits students with a variety of learning styles but could not be said to cater for all. It is the domain of the individual teacher who knows the students in their class to structure activities to suit the needs of all students.

Final Note

In a world where many demands are placed on teachers to be accountable to national standardised testing, there appears from observation to be less willingness to undertake new and innovative pedagogies than there may have been in the past. Time and resources are becoming limited in schools, with other politically and less educationally driven agendas taking the energy from an aging teaching population. Organisation and resource requirements for Slowmation, while less demanding than that for teaching traditional stop-motion animation, still serve as a barrier to implementation, as is lack of support from school administration and cost centre managers. A year after a workshop with 6 teachers, only 1 has actually had their students create a Slowmation, the others citing lack of resources and time within the curriculum as the inhibitors.

The evidence from this study suggests that the process of creating a Slowmation provides great opportunities for enhancing students' learning opportunities and increasing their scientific literacies. The finished product also provides an effective means for teachers to assess student understandings. The process of creating a Slowmation engaged the students and engaged students are in a strong position to learn the skills, understandings and literacies required of them. The success of the process persuades this Researcher to encourage the use of this innovative pedagogy and to partner it with other effective principles of practice.

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