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Slowmation: Helping Students Address their Misconceptions in Physical Science

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Slowmation:
Helping Students Address their Misconceptions in Physical Science

By

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B.S., New Mexico Highlands University, 1994

Plan B Project

Submitted in partial fulfillment of the requirements for the degree of Masters in Science in Natural Science Science and Mathematics Teaching Center in the University of Wyoming, 2015

Laramie, Wyoming

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Abstract

High school students come to science class with misconceptions that are often difficult to correct. The research suggests that students must address their misconceptions directly in order to correct them (NRC, 2008). It also indicates that students have a difficult time relinquishing their misconceptions because this is how they make sense of their surroundings (Gooding & Metz, 2011). The purpose of this action research project was to determine if Slowmation, a technology-based pedagogical strategy, would help students address specific misconceptions in physical science more effectively than using traditional teaching strategies such as teacher lecture and book work. Slowmation allows students to design and create narrated stop-motion animation explaining science concepts using the five representations defined by Slowmation. The data from this project indicated that the use of Slowmation was able to help students address specific misconceptions in physical science, phase changes of matter. In addition to the study, limitations are discussed, additional ideas for future research are given, and specific representations of Slowmation that helped students relinquish their misconceptions in physical science are examined.
Dedicated to my mom, Sheila; my husband, Hugh; my children, Elizabeth, Stephen, and Amanda; and my students
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Chapter 1

Introduction

Background

I teach in a small rural school in which the middle school (grades 6 through 8) has a population of 35 students and the high school (grades 9 through 12) has 45 students. In my district, some students may have me as their science or math teacher for five to six years. Therefore, I have had ample opportunity to observe students’ misconceptions in science. Keeley (2012) stated:

Preexisting ideas held by students that are contrary to modern scientific thinking about the natural world are generally referred to as misconceptions. Today there is tremendous interest among practitioners in learning how to use various tools and techniques to elicit students’ misconceptions in science... All misconceptions are major barriers to learning… Students do not come to the classroom as blank slates…According to constructivist theory, when new ideas are encountered, they are either accepted, rejected, or modified to fit existing conceptions. It is a cognitive dissonance students experience when they realize an existing mental model no longer works for them that makes students willing to give up a preexisting idea in favor of a scientific one. (p. 12)

It is extremely difficult for students to relinquish their misconceptions. Students may have read about a science concept, participated in teacher-led discussions in class, shared in questions and answers, and conducted an experiment or an investigation. However, when questioned later in the year about a particular science topic, an overwhelming majority of students revert to their initial misconceptions rather than remembering the scientific thinking
they learned within specific instruction. For example, students may incorrectly recall the primary colors of light as blue, red, yellow or that one can only balance an egg on its end during the Equinox.

A college student recently shared his video of Claymation (an animation creation using digital photos and clay models) with me. He believed he would have had a better understanding of the science concepts had he used Claymation in high school. After I heard this, I decide I would try this technique with my students.

I introduced Claymation to my students in the 2013 summer school session. I used this small group (n=4) to pilot this technique. I assigned these students a graphing Claymation project. They had to use Claymation to explain independent and dependent axes, calculate the slope of a line, and then demonstrate their understanding of the difference between a positive and negative slope on a graph.

The students and I found the process of Claymation to be very time consuming, but the end project was well worth the time it took to produce. I noticed that the students were engaged and when they were done with the Claymation they had a tangible understanding of the meaning of slope and how they could make a real life connection to this math term. The connection they made was of a set of stairs, coupled with the importance of the steepness, and the ability to walk up and down the stairs. This was also how they determined rise over run. Slope was a concept that I had been teaching to these students for a year without success. With the aid of the Claymation project, it took the students three days to comprehend rise over run and the importance of this equation. I credit this to the students’ being able to construct their own ideas about slope and communicate with each other during the project. During the photo session, the students corrected each other as they created the Claymation.
I taught the same students from summer school in my physical science class the following year and when we discussed slope in class they recalled their Claymation project from summer school. They said, “Remember when the clay figure was climbing up the steep slope... or ...when the clay figure was moving down the steps, the slope it was negative.” It was apparent to me the value of the Claymation graphing project because of my students’ ability to later recall and apply these concepts in science.

After working with Claymation I researched this technique and found another method, Slowmation, which seemed to be more practical for teaching science concepts. Slowmation evolved from Stop-motion and Claymation (a form of Stop-motion) but it requires a tenth of the time to construct. An example of a simple version of Stop-motion is to take a pad of post it notes, draw on them in a sequence, and then flip through the frames to create an action scene, such as a ball bouncing or some type of motion.

**Statement of the Problem**

All people have pre-conceptions and misconceptions regardless of age, gender, nurturing, social, or economic status (Gooding & Metz, 2011). Most misconceptions are acquired at a young age when children try to process and understand how to make sense of the natural world. Other misconceptions are acquired through the incorrect interpretation of others’ explanations. Such misconceptions have been replaced with new ideas, or have occurred because additional knowledge, which may not have been accurate, has been acquired.

“The Slowmation… encourages learners to create their own narrated stop-motion animation to explain content knowledge” (Hoban, 2005). Self-teaching within the learner’s own experiences helps students engage in metacognition (reflection on one’s own learning) that may challenge previous misconceptions.
The focus for this research paper was to investigate a pedagogical strategy called Slowmation. Examples of Slowmation include the famous scene in The Matrix, when Keanu Reeves dodges bullets being shot at him, or the now vintage California raisin commercial, “I heard it through the grape vine”. Both of these are examples of Slowmation because the animation or film-making involves thousands of pictures synchronized to provide an image that imitates the science behind the actual scenes. The scene can have clay models, paper models, computer images, people, etc.

Slowmation is not limited to what is used in the process of creating a video. The process of slowmation, in the education realm, is engaging, constructive, and fun for students of all ages. This pedagogical strategy is a project-based approach that introduces ways for the students to construct meaning by actively constructing experiences that challenge their own misconceptions.

In this paper, when the word Slowmation is capitalized, it refers to the technology-based pedagogical strategy and when slowmation is not capitalized it refers to the students using the process of slowmation to build a project.

**Purpose**

A common problem among science teachers is how to address and reconstruct knowledge in regard to students’ misconceptions. The overarching question is how to address these misconceptions using pedagogical strategies that the students find motivating and are also efficient and effective. Thus, the focus of this research is the use of Slowmation, which enables students to create a multimodal representation of concepts (Hoban & Nielsen, 2011) that will reduce scientific misconceptions. A secondary focus is to inform teachers as to what they can do to effectively bring student-led pedagogical strategies into the classroom to address common science misconceptions.
The research involved assigning a slowmation project to students in a physical science class that allowed them to create their own definition of physical science phenomena. In turn, this gave students an opportunity to test their misconceptions in a way that is both project-based and student-led. The results were evaluated to determine if this pedagogical strategy was effective in correcting students’ misconceptions in physical science.

Research Question

This action research project addressed the following questions: (a) Which Slowmation representations, [5Rs] (research, chunking sheet, models, photos, or narration), help students address their misconceptions in physical science and (b) In what ways does Slowmation, as a pedagogical strategy, assist with helping students overcome misconceptions about science concepts in physical science?
Chapter 2

Literature Review

Misconceptions in Science

When students enter the science classroom in middle or high school, they arrive with misconceptions about science. Page Keeley, an expert in research-based teaching and learning, wrote several books and journal articles relating to science curriculum, science misconceptions, and formative assessments. Keeley (2012) stated:

All misconceptions are the same. The word misconception is frequently used to describe all ideas students bring to their learning that are not completely accurate.

It is important to understand that the word misconception is a general way of lumping together students’ scientifically inaccurate or partially accurate ideas.

All misconceptions are major barriers to learning. (p. 12)

In an earlier book, Keeley (2008) explained that replacing these misconceptions with accurate scientific knowledge could be difficult.

Scientific knowledge constructed. To support this replacement process, K-12 science teachers themselves must first understand how scientists construct scientific literacy. Taking Science to School: Learning and Teaching Science in Grades K-8 [Taking Science to School] (NRC, 2007) was written for this purpose and explains how students learn science, how it can be taught, and how teachers can prepare or modify their science lessons so that each lesson takes advantage of understanding the science concepts. Taking Science to School (NRC, 2007) noted that:

Science is both a body of knowledge that represents current understanding of natural systems and the process whereby the body of knowledge has been
established and is being continually extended, refined, and revised. Both elements are essential: one cannot make progress in science without an understanding of both. Likewise, in learning science one must come to understand both the body of knowledge and the process by which this knowledge is established, extended, refined, and revised. (p. 26)

Students and teachers must understand that constructing scientific knowledge is a process that takes years to develop. When scientists engage in the scientific process, they document evidence through numerous investigations and trials in order to analyze, evaluate, and defend their results (NRC, 2007). If inconclusive results lead to research that is not valid, new questions are developed, and science continues to move forward. Keeley (2012) concurs and believes that students who understand this process need to revisit the cycle of inquiry until the idea matures in their understanding. Thus, it is essential that science teachers give students multiple learning opportunities with support and proper modeling with regard to the cycle of inquiry. This can take place through data analysis, conducting multiple trials, and validation of the scientific process.

**Scientific literacy.** *Ready, Set, Science!: Putting Research to Work in K-8 Science Classroom* [Ready, Set, Science!] (NRC, 2008), a document that was written for mid-level teachers, administrators, and parents, emphasizes the practical side of how students best learn science. It includes strategies and instructions for teaching science effectively. This book identifies four strands for developing scientific literacy. These are, (a) understanding science explanations, (b) generating scientific evidence, (c) reflecting on scientific knowledge, and (d) participating productively in science (NRC, 2008).
In order to understand science explanations, strand one states that students need to know, use, and interpret scientific explanations of the natural world (NRC, 2008). Students who are proficient in strand one do not memorize science content. Instead, they are able to provide a scientific explanation of why a certain science concept can be applied to a specific scenario, and they can also defend and justify reasons for the scientific relationship.

In strand two, students generate scientific evidence. This strand states that students should gain knowledge and skills needed to build and refine models and explanations, design and analyze investigations, and construct and defend arguments with evidence (NRC, 2008). The main focus is scientific practice, whereby proficient students can ask questions, carry out investigations, evaluate data collected, and use results to develop a model or to determine the need for additional data.

Strand three focuses on how scientific knowledge is constructed in order to understand that science is a way of knowing (NRC, 2008). Proficient students are able to analyze their own scientific ideas and develop new ones, as they understand the scientific knowledge. They learn how to alter their science misconceptions to match scientific knowledge and make meaning of the natural world.

Students who are proficient with strand four participate productively in science. This strand calls for students to understand the appropriate norms for presenting scientific arguments and evidence (NRC, 2008). Students are able to work with lab equipment, figure out how to represent their data, describe how they collected the data, and then explain how they interpreted the results.

Students who are able to successfully negotiate the four strands of scientific literacy from Ready, Set, Science! (NRC, 2008) are better prepared to confront their misconceptions.
“Students’ knowledge and experience play a critical role in their science learning, influencing all four strands of science understanding” (NCR, 2007, p. 2).

Pre-conceived science ideas. Pre-conceived science ideas are those that have been developed over time (NRC, 2007). Beginning in infancy, humans build an understanding of the natural world and they continue to reevaluate this understanding based upon personal experiences as well as information from a myriad of sources.

Regardless of one’s theoretical orientation, by the time children enter elementary school, no one would argue that their minds are empty vessels awaiting enlightenment in the form of instruction. They come to school after years of cognitive growth in which they have developed a wide range of ways of understanding and reasoning about the world around them. (NRC, 2007, p. 53)

Educational consultants Gooding and Metz (2011) believe that “… once the information is learned—whether correctly or incorrectly—it is difficult to edit or delete” (p. 34). First, students hold onto misconceptions if nothing in the natural world has challenged their opinion. Second, the longer students hold onto a misconception, the more difficult it will be for them to relearn.

Just as importantly, teachers need to understand the types of misconceptions that hinder students’ science literacy. Science Teaching Reconsidered: A Handbook [Science Teaching Reconsidered] (NRC, 1997) identifies five types of science misconceptions: (a) preconceived notions, (b) nonscientific beliefs, (c) conceptual misunderstandings, (d) vernacular misconceptions, and (e) factual misconceptions.

Five types of misconceptions. Preconceived notions are popular conceptions rooted in everyday experiences (NRC, 1997). For example, a student who thinks that, when water boils,
the bubbles are filled with air or oxygen, does not understand that water vapor produces the bubble in boiling water (Gooding & Metz, 2011).

A second type of misconception is one of nonscientific beliefs. These include views learned by students from sources other than scientific ones, such as religious or mythical teachings (NRC, 1997). An example of this could be when a student believes that the Great Flood, as described in the Bible, was the sole reason for the extinction of species (DiSpezio, 2010).

Conceptual misunderstandings make up the third type of misconceptions. In this situation, scientific information is presented to students in a way that does not require them to confront paradoxes and conflicts resulting from their own preconceived notions and nonscientific beliefs (NRC, 1997). For example, a student might believe that objects float in water because they are lighter than the water, or that the changes in seasons are caused by the Earth’s distance from the Sun, rather than the axial tilt (Gooding & Metz, 2011).

A fourth misconception is that of vernacular misconceptions. These types of misconceptions arise from the use of words that mean one thing in everyday life and another in a scientific context (NRC, 1997). In this case, when students are told that the Torrey Valley in Wyoming was created when the glaciers retreated, the word “retreated” could be misinterpreted in such a way that it was equated with a meaning they had learned in social studies regarding a military retreat. A better definition for “retreated” would be melted and sublimated (DiSpezio, 2010).

The final misconception listed focuses on factual misconceptions. These are falsities, often learned at an early age and retained unchallenged into adulthood (NRC, 1997). An example of a factual misconception is that of the image, and corresponding misconception, of a
rocket exploding in outer space. Hollywood films and various television shows depict such explosions as making tremendously loud sounds as the sound wave travels through space. While this makes scenes in these movies more entertaining, sound needs a medium to be heard; and there are no mediums in a vacuum. In addition, oxygen, which is also not present in space, is necessary for fiery explosions, thus compounding the misconceptions.

Once students’ misconceptions have been identified, the next step is to try to “fix” the misconception. Keeley (2012) stated that teachers should delve further into understand the types of misconceptions students have and then determine how to address them.

**Origin of misconceptions.** Students acquire science misconceptions from a variety of sources. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* [The Framework] (NRC, 2012) states that inaccurate science concepts come from adults, media, and other educators. If students process the misinformation in order to make better sense of the natural and designed world, it becomes extremely difficult for them to forfeit the resulting misconception (NRC, 2012). At other times, Gooding and Metz (2011) believe that students may simply have misunderstood what they heard.

Textbooks also give misleading information either through illustrations or written text (NRC, 2012). For example, an illustration of the planets in our solar system may be inaccurately scaled in order to fit on the page. Another example could be when textbooks provide incorrect written information such as water is a “good conductor” of electricity (Gooding & Metz, 2011). In this case, a clarification of distilled water versus tap water needs to be addressed, as the former would not be a good conductor due to the purity of the water. Lastly, the belief that information in print (including electronic text) must be true is a misconception that should be challenged by teachers (NRC, 1997).
Finally, there are times when topics are introduced when students are not developmentally or psychologically ready to learn them (Gooding & Metz, 2011). The authors recommend that teachers choose their lessons, textbooks, and Internet sources wisely by assessing the age and comprehension level of the students.

While misconceptions can be corrected, teachers must keep in mind that since they are individualized paradigms, their owner must correct them (Gooding & Metz, 2011). As a result, it may take several efforts before the student truly relinquishes a misconception, if they do at all.

**Students’ Misconceptions Identified**

Teachers can use several methods to identify students’ misconceptions in science. Michael DiSpezio (2010) in his article stated, “To address misconceptions, teachers first need to uncover them” (p. 16). Teachers must be pro-active when addressing misconceptions by cuing in on students’ misconceptions as they arise, beginning with formative pre-assessment.

Here, the role of the pre-assessment goes beyond uncovering what students do not know and is expanded to identify what was misconceived. The first step involves asking students to verbalize what they know, using the students’ own conceptual model or a scientific hands-on model (DiSpezio, 2010). The teacher can continue probing by questioning students’ responses in order to identify what they do or do not know.

The authors of Science Teaching Reconsidered (NRC, 1997) recommend that once the teacher has identified students’ misconceptions, the next step is to provide a forum for them to confront their misconception. One type of forum is to have the students sketch or describe a science phenomenon and then analyze these for misconceptions. Another forum could involve the teacher presenting a difficult science concept to the class and then revisiting that concept a week later to determine students’ conceptions.
In order to help the students address their own misconception and make new conceptual representations, Gooding and Metz (2011) recommend that teachers provide the following opportunities in their classroom: (a) discrepant events, (b) inquiry-based activities, and (c) other mind-on experiments. O’Brien (2010), described a discrepant event as one that can cause counter intuitive outcomes for the student. For example, a needle will pop a filled balloon, but a long wooden skewer with a lubricated tip will not.

In addition, inquiry-based activities provide the students with opportunities to ask and answer their questions (NRC, 1997). The teacher can pose the question, “How does exercise affect heart rate?” Then the students can create an inquiry-based activity to address the question.

A mind-on experiment focuses on core concepts (NRC, 2006). Tony Leavitt, a NASA education specialist, designed an experiment named “Touchdown”. The student’s mission is to make a model of a NASA Curiosity Rover using a paper plate, cup, notecards, rubber bands, and tape that will secure a Ping-Pong ball during the rover landing. Students had to use core concepts of physics to complete the project.

Again, metacognition plays a significant role. If students are encouraged to think about why they have a particular understanding of the concept—and seriously reflect on those thoughts—they may recognize the discrepancy. Consequently, they may be able to reach a new and better scientific understanding based on the evidence presented (Gooding & Metz, 2011).

After being provided with multiple opportunities to explore misconceptions, students may proceed to the next step, being able to replace the misconceptions with accurate scientific concepts. Allowing the students to defend their ideas by posing questions that engage them in higher level thinking will help replace the old concepts with the new (DiSpezio, 2010). Carefully crafted questions help the teacher assess and guide students to new understanding by
constructing an environment where the “ah-ha” moments occur and allow for conceptual change (Gooding & Metz, 2011).

**Slowmation, a Technology-Based Pedagogical Strategy**

Ready, Set, Science! (NRC, 2008) presents three types of conceptual change: (a) elaboration on a pre-existing concept, (b) restructuring a network of concepts, and (c) achieving new levels of explanation. Teachers can help their students make these conceptual changes and address their misconceptions in science by using Slowmation, a technology-based pedagogical strategy (Hoban, 2005). Hoban (2008) noted that, “Slowmation is very good for challenging misconceptions because students revisit the concept so many times during the creation and also because the hands-on nature makes them think about it in different ways” (p. 48).

Slowmation helps students improve their science concepts while addressing their misconceptions, while at the same time by allowing students to make intentional observations through a series of individual pictures. In this way, the students actually assess what is occurring in a step-by-step process that isolates material the teacher wants the students to focus upon. This creates an environment for learning new material while exposing false ideas (Hoban, 2010).

**The Mechanics of Slowmation**

**History.** In 2007, Garry Hoban, a professor at the University of Wollongong in Australia conducted a study to better understand the elementary school learning community. A new teaching approach, called Slowmation, had been developed three years prior to this study and was defined as follows:

Slowmation is a new form of Stop-animation that is similar to Clay animation involving students researching information, scripting, storyboarding, designing
models, photographing digital still images of small manual movements of the
models, and creating an i-Movie with narration.  (p. 48)

In the educational realm, the slowmation process is preferable to Claymation because it
forces the creator (student) to revisit the science concepts multiple times and Slowmation takes
one sixth of time to create a project. Claymation requires 40 to 60 frames for every minute of
video compared to 20 to 30 frames for every minute of Slowmation video. Slowmation involves
students starting at the beginning of the project with researching the concept, scripting,
storyboarding, modeling, and taking digital images. After all that is completed, they create a
movie complete with narration (Hoban, 2008).

Gary Hoban shared the pedagogy of Slowmation with veteran teachers at an in-service in
2007. Hoban chose this elementary school because the teachers were eager to try new
pedagogical strategies, such as Slowmation, and the principal had bought the necessary
technology needed to facilitate a slowmation project. These teachers taught kindergarten
through sixth grades and were asked to produce two Slowmation videos per grade level in the
content areas of mathematics, language arts, science, or social science classes. These successful
Slowmation videos were presented to the school community at a parent night (Hoban, 2008).
Next, the study was expanded to include pre-service teachers at the University of Wollongong to
inspire these teachers to use Slowmation in their classrooms.

Pre-service teachers and their Slowmation projects. The research of Hoban and
Nielsen (2012), at the University of Wollongong, also demonstrated that the pre-service teachers
involved in the project developed a deeper understanding of the science content when they
created a Slowmation. Starting in 2007, Hoban and Nielsen had pre-service teachers develop
over 600 Slowmations in a three-year period. The professors wanted to encourage these pre-
service teachers to experience their own new ways of learning science in their primary science methods course using the 5Rs (Hoban and Nielsen, 2010).

According to Hoban and Nielsen (2012), the slowmation process provided a means for all pre-service teachers to make a narrated animation as a multimodal representation to explain a science concept. Pre-service teachers indicated that they found the project to be highly engaging and enjoyable. They preferred Slowmation to conventional types of assignments, such as exams or essays. It also provided a means for them to address their own misconceptions in science during the photo session or narration portion of the project.

Vratulis, Clarke, Hoban, and Ericson (2011) conducted additional research in 2010 with Slowmation and pre-service teachers in Canada. The researchers found that the pre-service teachers really enjoyed using Slowmation in their teaching-methods class and the hope was to continue this pedagogical strategy in the classroom. However, when the pre-service teachers were in their own classrooms, researchers found the pre-service teachers did not use Slowmation. Reasons given by the pre-service teachers were lack of technology support in the classroom, unease about handing over control and allowing the students to learn concepts via Slowmation, and “loss” of teaching time with students who were poor readers. The veteran teachers did not want to take time to learn and then teach new techniques to their students. The research concluded that in order for Slowmation to be successful, teachers (veteran and pre-service) must be willing to learn and try new pedagogical strategies. Also, the teachers must have the support of school administration to supply the class with the appropriate technology and allow time for the teachers to apply new strategies.
**The 5Rs teaching approach.** Hoban and Nielsen (2010) conceptualized five representations, which they called the 5Rs. These are strategies that students need to know and be able to use to be successful when creating a slowmation project.

Research has shown that learners not only find the process of creating Slowmation engaging, but the creation process helps them to develop an understanding of a concept because they reflect upon it in multiple ways. This is because in creating a representation, students make meaning as they are thinking about the relationship between what they are making (the “representation”) and the concept or object they are trying to represent (the “referent”). (p. 33)

Representation One (research) includes the background students’ need before designing an animation to explain a concept (Hoban & Nielsen, 2010). To gain this knowledge, students access the Internet, library, and/or science books to complete their research. Students who research and evaluate their own information develop a better command of science concepts. Teachers act as facilitators for the students in the process.

The second representation of the 5Rs is the development of a storyboard or chunking sheet. In this phase, students take the information from the first representation (research) and design a storyboard in which the concepts are broken down into several scenes and placed in a coherent sequence (Hoban & Nielsen, 2010). Students condense these ideas and facts into six summaries with each summary forming a frame. In turn, this becomes the outline for their Slowmation.

During Representation Three, students create 2-D and/or 3-D models to represent the chunks or parts of the concept represented. Not only is this the creative piece for students, but it is also a time where students often alter their ideas as they brainstorm with one another and seek
clarification (Hoban & Nielsen, 2010).

Representation Four involves digital photography. The models are manually moved to show change in their concept demonstration. During this phase, students determine how to manipulate the models’ movement so that their storyboard depictions of science concepts match their photo images. Before they go on to the next concept, they review the pictures for accuracy of the science concept. They also learn how to use the camera and how to take Stop-motion photos. Hoban and Neilson (2010) found that trial and error is a factor in this phase and contributes to concept formation.

Representation Five is a synthesis of the previous steps as students download their photos to a computer, upload them into the software, edit them, and add the narration. During the editing and narration, students make corrections and address any scientific misconceptions. Students are responsible for ensuring that all the parts fit into a cohesive whole (Hoban & Nielsen, 2010).

Finally, each of the five representations has its own semiotic system meaning-making statement. As each representation is designed, students revisit the science concepts and demonstrate their understand. Furthermore, Hoban and Nielsen (2010) stated, “Asking the students to create an animation that explains a science concept engages them in learning about the concept because they need to understand it before they can explain it” (p. 37). They found that once the students completed their Slowmation using the 5Rs, they could relinquish their misconceptions in science.

**Relating the four strands to Slowmation.** The four strands for learning science proposed by Ready, Set, Science! (NRC, 2008) connects well to Slowmation, in that the slowmation process allows students to practice and harness strands three and four directly.
Recall that strand three helps students to recognize that predictions or explanations can be revised on the basis of seeing new evidence, learning new facts, or developing a new model. “It allows students to reflect on the status of their own knowledge” (p. 20). When students use the slowmation process, 5Rs (research, chunking sheet, models, photography, and narration), they learn how to analyze and reconstruct their scientific beliefs into scientific facts that help them address their misconceptions of the natural world. Slowmation then connects the learner to strand four which states that, “proficiency in science entails skillful participation in a scientific community in the classroom and mastery of productive ways of representing ideas, using scientific tools, and interacting with peers about science” (p. 21). As students practice interacting with peers about science ideas and learn to present scientific evidence using Slowmation, they participate in their own scientific community.

The main challenge for teachers is to build on students’ embodied knowledge and understanding of their natural world and to assist them to confront their misconceptions in order to create new understanding of their natural world (NRC, 2008). Understanding that science is a way of thinking and knowing, that also includes participating productively in science by asking questions, solving a problem(s), and interpreting data, are all ideas facilitated through the use of Slowmation. Students’ science concepts will evolve due to instructions, experiences, and maturations. Slowmation can be used to help provide such instruction and experiences by bringing students face to face with their own knowledge and misconceptions, forcing them to revisit science concepts again and again in the process.

**Conclusion**

Replacing students’ science misconceptions and teaching students how to use scientific knowledge can be difficult. More importantly, this process must begin with the teachers
themselves: they must understand how to assess and address the numerous issues that students have with regard to science (NRC, 2008).

According to Next Generation Science Standards [NGSS] (Achieve, 2013) students’ engagement in scientific argumentation is critical if students are to understand the culture in which scientists live and how they themselves can apply science and engineering for the benefit of society. Students who are better prepared in science will be more successful in college and career readiness. Slowmation offers students a non-threatening technique to have disagreements and challenge each other’s misconceptions.

The NGSS (Achieve, 2013) also states that K-12 science education must shift from the focus of knowledge to the focus of putting knowledge to use. In other words, science classes need to move away from lecture, note-taking, reading, and test recall. Instead, students need to be able to make connections about science content and the process of science. Slowmation allows students to engage in their own learning while offering a technology-based pedagogical strategy that can help students address their own science misconceptions.
Chapter 3

Methods

Objective

The objectives of this action research were to determine which (a) Slowmation representations helped students address their misconceptions and (b) ways Slowmation assisted with pedagogical strategies that helped students overcome their misconception in physical science. Slowmation is a technology-based pedagogical strategy that assists students with organizing, finding, and assessing reliable information using technology. When Hoban and Nielsen (2010) asked students to create a project using the slowmation process, they noted that students were engaged and pursued an understanding of science concepts while utilizing the 5Rs (research, storyboard, models, editing, and narration) of the slowmation process. Hoban and Nielsen (2010) also found that the majority of students had addressed their misunderstanding of science concepts, during the narration of their projects.

In this action research, a same-group comparison-treatment methodology was used. Students were presented with science content similar in difficulty from two different curricular units. The two units were taught using two different strategies. The treatment strategy was the use of Slowmation and covered the concepts of states of matter. The comparison strategy was teacher lecture and book work of chemical classifications of matter. Pre- and post-assessment of both units were used to assess the effectiveness of these two strategies.

This chapter describes the population studied, how the instructor prepared and planned the curricular unit for the treatment strategy using Slowmation and how the students were taught the slowmation process. It also explains how the interview groups were determined and how the data was collected and analyzed.
Setting and Population

School location. This study took place in a town in a rural western state with less than 1,000 residents. The United States Forest Service and the public school district are the major employers in this town. The population experiences a boom and bust economy depending on seasonal employment centered on construction, tourism, and recreational activities. At the time of this study, 20% of the town’s population was unemployed, 30% employed seasonally, and 50% employed year round. There are many outdoor opportunities available nearby, such as fishing, horseback riding, hiking, cross country skiing, hunting, hot springs, petroglyph sites, geology, wildlife observation, and dude ranches.

Student population. The population for this study came from the local public high school, which had an enrollment of 45 students. This study’s participants consisted of 13 freshmen enrolled in a physical science class taught by the researcher. This particular class had 40% female and 60% male students. Of the students in this sample, there were no English language learners (ELLs) but 15% (n=2) of the students were identified with disabilities. One special education student was enrolled with a learning disability in science and the other had an Individual Education Plan (IEP). The summary of the participant population is shown in Table 1.
Table 1

A Summary of the Student Population in Freshman Physical Science Class

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students enrolled in physical science 2013-2014</td>
<td>13</td>
</tr>
<tr>
<td>Caucasian students enrolled</td>
<td>13</td>
</tr>
<tr>
<td>Male students</td>
<td>8</td>
</tr>
<tr>
<td>Female students</td>
<td>5</td>
</tr>
<tr>
<td>Male student with Individual Education Plan (IEP)</td>
<td>1</td>
</tr>
<tr>
<td>Male student with Specific learning disability</td>
<td>1</td>
</tr>
</tbody>
</table>

The projects and assessments given were integrated into the regular curriculum. All students and parents signed consent and assent forms. Students were told the project was voluntary and that their work would be used to help the teacher better understand if the slowmation process addressed their misconceptions in science. Students were allowed to opt out at any time and were not named or identified in this project, nor did they receive incentives for participating. Appendix A contains samples of the assent and consent letters.

Curriculum Planning

Teacher Preparation. Before beginning this research project, I felt it was necessary that I understood how to use the 5Rs (research, storyboard, models, editing, and narration) and produce a project using this process. Instructions for teaching the strategies are available at http://www.slowmation.com. This site provides samples of preservice teachers’ projects.
YouTube® was used to find additional examples of Slowmation. After viewing several projects that used the slowmation process, I began to make my own.

To begin, I downloaded and printed a chunking sheet available at [http://www.slowmation.com](http://www.slowmation.com). This sheet helped outline and organize the slowmation process. The chunking sheet has six frames for the creators to use to make sketches of their ideas. Opposite the frames are lines to write down thoughts about narration or how to proceed with movement for the animation portion. The chunking sheet (or storyboard) acts as a cue card and gives the creator tangible ideas of how to arrange their thoughts before they take pictures of the models. I found it beneficial to sketch the pictures in color. This helped me decide what materials I needed for my project. An example of a student’s chunking sheet is represented below in Figure 1 and 2.
Figure 1. Example of Student’s Chunking Sheet

the 9 ball has stored mechanical energy than the person playing hits it using chemical energy going to motion energy.

the Newton's cradle has stored mechanical energy than when you pull the balls and let it go it has motion energy.

When you strike the match it has chemical energy than after it burns it has thermal energy.
Once the chunking sheet was complete, I made the characters and the background scene for my project. The instructions from http://www.slowmation.com show that when taking pictures of the scene, the camera is placed directly above the scene. However, I placed the props
on the desk directly in front of the iPad. I found this set-up to be easier and faster when taking pictures and moving the props represented in Figure 3.

Figure 3. iPad Set-Up for Taking Pictures

After the necessary 200 pictures were taken, I downloaded them into iMovie, set the speed for the frames, edited as needed, and added the narration. The process was time consuming because I had to learn how to manipulate the tools within the iMovie. Such as, how to calibrate the picture frames, edit pictures, and sync the narration with the picture frames. However, I learned a great deal about technology and enjoyed viewing the end project. After I worked with iMovie and explained my frustrations to the technology teacher, she researched and found a free application (app) for the iPads named Stop Motion™. This iPad app made
producing a slowmation project easier and reduced the time to create a slowmation project by a third.

**Student preparation.** The next step was to have the students practice producing projects using their iPads. At this point in the course, the students were studying Newton’s Three Laws of Motion. Rather than assigning bookwork or lecture, students were assigned a project. They were to use the 5Rs (research, storyboard, models, editing, and narration) of the slowmation process to complete this project.

1. **Representation One:** Students gathered background information about Newton’s Three Laws of Motion. They researched these Laws using the Internet or science books.
2. **Representation Two:** Students used the chunking sheet to outline what they portrayed as the target concepts of Newton’s Three Laws of Motion.
3. **Representation Three:** Students made 2-D and 3-D models and backgrounds, using materials of their choice, for the projects.
4. **Representation Four:** Students took digital still photos of their models and background. They manually moved the objects to show motion in their project.
5. **Representation Five:** Some students used Stop Motion™ and others used iMovie to edit and narrate Newton’s Three Laws of Motion.

Students were provided with six class periods (five hours total) to complete this project and were allowed to use miscellaneous objects from the classroom. They could help each other with taking pictures or editing, however each student had to make his or her own project and present it to the class. Appendix B contains the grade sheet for the project.
Classroom Arrangement for Slowmation

In order to assess how the 5Rs (research, storyboard, models, editing, and narration) of the slowmation process could enhance my teaching in science, I set up the classroom in the following manner:

Every student worked independently at his or her own workspace. Individual workspace was essential, because moving or manipulating a set can cause disruption to the scene being produced.

1. Friends were not allowed to work next to each other in order to reduce the amount of distractions.
2. Students brought in material or used what was available in class to create their projects.
3. Every student was equipped with an iPad, which included both the iMovie and Stop Motion™ app. All students were allowed access to MacBook Air computers for editing.
4. Students were given two weeks to complete the project.
5. At the beginning and end of every class period, students were debriefed on their learning.
   In these debriefing sessions we discussed how the slowmation process worked. They shared new techniques and obstacles in their experiences.
   Once the students practiced producing three projects using the slowmation process, the next step was data collection.

Instruments and Treatments

**Assessment.** Students took a pre-science Measurement of Academic Progress (MAP) test. In 1973 educators and researchers from Oregon and Washington state school districts developed this test. It is used in in many states nationwide to assess students’ academic progress in language arts, math, and science concepts. The school being studied in this action research
project, administrated the MAP test district-wide in both September and May of every school year. Additionally, at the beginning of every lesson, I administered a pre-assessment to my physical science students in order to evaluate their understanding of physical science concepts. Appendix D includes sample questions from the assessment.

**Comparison treatment.** Chemical classification of matter was the comparison treatment given to the students. First, the students were given a pre-assessment, then took notes from a lecture, and were assigned review questions from the chapter in the science book. The next class period, students conducted a lab investigation consisting of identifying different types of matter and wrote their results. Students took a post-assessment at the end of the lesson. The assessment covered the following concepts, types of matter and how they are classified. Finally, six students were interviewed after the lesson to evaluate their understanding of matter. Appendix E includes sample questions of the post-interviews of chemical classification of matter. These students were asked if their misconceptions about chemical classification of matter had been addressed and at what point. The schedule of classroom activities is shown in Table 2.

Table 2

*Schedule of Classroom Activity Without the Use of the Slowmation Process*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Allotted time to complete the activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-assessment chemical classification of matter</td>
<td>No limit</td>
</tr>
<tr>
<td>Students note taking during lecture</td>
<td>40 minutes</td>
</tr>
<tr>
<td>Students answered chapter review questions</td>
<td>Homework</td>
</tr>
<tr>
<td>Investigation of chemical classification of matter activity</td>
<td>50 minutes</td>
</tr>
<tr>
<td>Post-assessment on chemical classification of matter</td>
<td>No limit</td>
</tr>
<tr>
<td>Students interviews (n=6)</td>
<td>10 minutes per student</td>
</tr>
</tbody>
</table>
**Treatment.** The treatment involved replacing the lecture and book assignments with a project using the slowmation process. The students were given a pre-assessment relating to phase changes of matter. Next, they produced and presented a project about phase changes using the 5Rs (research, storyboard, models, editing, and narration) of the slowmation process. After that, students conducted an investigation to determine and graph the phase change of water from a solid, to a liquid, and then to a gas. Then, the students were given a post-assessment relating to phase changes. Finally, six students were interviewed after the lesson to evaluate their understanding of phase changes. Appendix F includes sample question of the post-interviews of phase changes of matter. They were asked if their misconceptions had been addressed and at what point. A schedule of the classroom activities is shown in Table 3.

Table 3

*Schedule of Classroom Activities With the Use of the Slowmation Process*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Allotted time to complete the activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-assessment phase changes</td>
<td>No limit</td>
</tr>
<tr>
<td>Students researched phase changes</td>
<td>50 minutes</td>
</tr>
<tr>
<td>Students produced a project using the 5Rs</td>
<td>100 minutes</td>
</tr>
<tr>
<td>Students presented their projects</td>
<td>40 minutes</td>
</tr>
<tr>
<td>Phase change experiment using ice</td>
<td>50 minutes</td>
</tr>
<tr>
<td>Post-assessment chemical classification of matter</td>
<td>No limit</td>
</tr>
<tr>
<td>Students interviews (n=6)</td>
<td>10 minutes per student</td>
</tr>
</tbody>
</table>
The amount of classroom time for the comparison treatment verses the Slowmation treatment was not the same. Students were allowed two class periods for the comparison treatment and they were allowed five class periods for the Slowmation treatment. The slowmation projects required more class time because it was a new strategy for the students and I needed to be available if they had any problems with the Stop Motion™ app or iMovie. Also, students needed time to manipulate their models and take pictures of their scenes. While the comparison treatment had no student-led activities. The comparison treatment consisted of lecture, bookwork, and investigation.

**Interviews.** Students were interviewed after the treatment in order to understand where their changes in misconceptions of matter occurred. Six students were selected according to their academic performances in both language arts and physical science. I wanted to verify or dispel my assumption that better readers could address their misconceptions during representation one, research. Of the six students selected to be interviewed, two students were labeled high-level, with language arts MAP scores of 240 or above, pre-science MAP scores of 225, and a letter grade of A (100% to 90%) or B (89% to 80%) in both language arts and physical science. The second set of students (n=2), were referred as mid-level, had language arts MAP scores between 230, pre-science MAP scores of 220, and language arts and physical science grades at a B (89% to 80%) level. The final set of students (n=2), were identified as low-level, had language arts MAP scores between 220, pre-science MAP scores of 215, and language arts and physical science grades between a C (79% to 70%) or D (69% to 65%). Table 4 outlines the demographics of students interviewed.
Data Collected

Quantitative data. For this action research project, pre- and post- science concept assessments were given to the students to evaluate their understanding of physical science. The assessments were scored on a 4-point scale for both the comparison-treatment and the treatment using the slowmation process. Advanced = 4, represented the student completely understood the concept, proficient = 3, represents the student understood the concept, basic = 2, represents the students did not understand the concept, below basic = 1, the student wrote down information that did not relate to the concept.

The data collected in this action research of the slowmation process was:

1. MAP Science assessments
2. MAP Language Arts assessments
3. Pre- and Post-Physical Science assessment
4. Language Arts and Physical Science class grades
5. Student evaluation of the project
6. Interview responses (n=6)
The timeline of student data collection is shown in Table 5.

Table 5

*A Timeline of Data Collection Based on Action Research of Slowmation*

<table>
<thead>
<tr>
<th>Data Topics Collected</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP Science Assessment Test Scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Lexile Level</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Physical Science Assessment Score</td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Physical Science Assessment Score</td>
<td></td>
<td></td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grades from Students Lab Reports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Science Semester Grade</td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language Arts Semester Grade</td>
<td></td>
<td></td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students’ Written Evaluation of Slowmation</td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students’ Interview Questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Qualitative Data.** Finally, after the students completed their post-assessment, six pre-selected students were interviewed individually. The interviews were conducted to identify when the students became aware of their misconception and if they had actually addressed it. Appendix E contains examples of post-interview questions for chemical classification of matter and Appendix F phase changes of matter.

While the students created their slowmation projects, observations of how the students acquired their information, helped one another, and at what point, if at all, they addressed their misconceptions were collected. Appendix G contains an example of teacher’s reflections and observations sheet.
Chapter 4

Results

Purpose

The purpose of this project was to determine if the technology-based pedagogical strategy using Slowmation helped students address physical science misconceptions, specifically the understanding the phase changes of matter. Quantitative data collected in this project included pre- and post-concept assessments in the physical science course and pre- and post-science concepts MAP scores. The data from the 13 participants was used to make these determinations. Qualitative data was also collected during two sets of student interviews to understand student perceptions of change in their misconceptions about the topics. Finally, the researcher took observations during each treatment.

Quantitative Data

Pre- and post-assessments for classification of matter. In the comparison-treatment, all physical science students (n=13) were given the pre-assessment for the chemical classification of matter. There were three categories in this assessment: (a) give an explanation of matter, (b) create a flow chart to represent understanding of matter, and (c) classification of the types of matter. During the pre-assessment, some students became confused about the meaning of flow chart and whether or not this would affect their class grade. Both questions were addressed during the assessment session. The table that follows outlines the data from the pre-assessment, which was scored on a 4-point scale, explained in Chapter Three.

All students scored at a basic or below basic level on the first pre-assessed category, give an explanation of matter. This means they were not able to explain that matter is anything that takes up space and has mass. The second category on the pre-assessment asked the students to
create a flow chart that showed the classification of matter. Nine of the thirteen students scored basic on this question. The confusion over the definition of a flow chart could have contributed to some of the low scores on those items. Additionally, after the pre-assessment, the two students who scored advanced on the flow chart admitted they had used their cell phones to Google the information. The third category asked students to classify the types of matter such as water, salad dressing, and aluminum. All students were proficient in classifying types of matter.

The post-assessment was given to all students after the teacher lectured, assigned bookwork, and completed a hands-on activity. The post-assessment showed all students improved in their understanding of matter. Two students showed improvement from below basic to basic. The matter flow chart indicated 77% of the students were proficient and all students were proficient or above when classifying the types of matter. There was an increase of 38% in the number of students that were advanced in identifying classification of matter.

Additionally, a conceptual misunderstanding that the students did not address was matter is comprised of chemical properties. All students answered a question incorrectly about the properties of water and indicated that hydrogen and oxygen were not chemical properties of water. Students also incorrectly responded that when sugar is dissolved in water it is not a mixture. However, these same students did correctly identify that when sugar is mixed with water it is a homogenous solution. This tells us that students understand that the solute dissolves readily into the solvent make a homogeneous solution. However, they do not fully understand that a mixture is a solution and it comprises of a solute and a solvent. The results of the pre- and post-student assessment scores of classifying matter are shown in Table 6.
Table 6

*Pre- and Post- Student Assessment Scores Chemical Classification of Matter without Slowmation*

<table>
<thead>
<tr>
<th>Science Concepts Identified</th>
<th>Percentage of students who scored Advanced (4)</th>
<th>Percentage of students who scored Proficient (3)</th>
<th>Percentage of students who scored Basic (2)</th>
<th>Percentage of students who scored Below Basic (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Explanation of matter</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>85%</td>
</tr>
<tr>
<td>Matter flow chart</td>
<td>15%</td>
<td>77%</td>
<td>15%</td>
<td>8%</td>
</tr>
<tr>
<td>Classifying types of matter</td>
<td>0%</td>
<td>38%</td>
<td>100%</td>
<td>62%</td>
</tr>
</tbody>
</table>
**Slowmation pre- and post-assessments.** The data in Table 8, below, shows pre- and post-assessment scores for those students who used the process of slowmation. Students were questioned regarding the states of matter. The first question was to list the four states of matter. The pre-assessment showed 85% of the students knew the four terms for states of matter. Another question on the assessment asked the students to give examples of the states of matter. Four students gave incorrect examples and scored basic, one student scored advanced with all answers correct, and nine students scored proficient. Two students, who scored proficient, incorrectly listed blood for an example of a plasma state of matter. In the third question, only two students scored proficient by explaining a phase change of water from solid to liquid, while the rest scored basic or below basic.

After the slowmation project all students scored as proficient or advanced when naming the four states of matter and 92% were proficient or advanced when giving examples of four states of matter. The student who scored basic in explaining the phase change of water did not complete the project. The results of the pre- and post-student assessment scores of four states of matter are shown in Table 7.
Table 7

Pre- and Post-Student Assessment Scores Four States of Matter using Slowmation

<table>
<thead>
<tr>
<th>Science Concepts Identified</th>
<th>Percentage of students who scored Advanced (4)</th>
<th>Percentage of students who scored Proficient (3)</th>
<th>Percentage of students who scored Basic (2)</th>
<th>Percentage of students who scored Below Basic (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Named 4 states of matter</td>
<td>31% 100%</td>
<td>54% 0%</td>
<td>15% 0%</td>
<td>0% 0%</td>
</tr>
<tr>
<td>Gave examples 4 states of matter</td>
<td>8% 54%</td>
<td>62% 38%</td>
<td>30% 8%</td>
<td>0% 0%</td>
</tr>
<tr>
<td>Explained phase change of water</td>
<td>0% 62%</td>
<td>15% 30%</td>
<td>77% 8%</td>
<td>8% 0%</td>
</tr>
</tbody>
</table>
Qualitative data

Students’ interviews. After the students completed their post-assessment regarding classifying matter, six pre-selected students (described in Chapter Three) were interviewed individually. The purpose of interviewing students was to understand where their perceptions of changes in misconceptions about matter occurred and if there was a difference between the levels of students (high, med, low) of how they identified their misconceptions. All students (n=6) stated that their misconceptions were addressed during the lecture in the comparison-treatment. The students felt that neither the lab investigation nor the bookwork had any affect on helping address their misconceptions. They believed once they heard the information they understood the science concept and they did not need to answer questions from the section review or complete a lab investigation.

Once the students (n=13) completed their post-assessments for the treatment, four states of matter, the same six pre-selected students were interviewed. The results from when students (n=6) addressed their misconceptions were very different during the post interview. The high-level gave descriptive reasons for their understanding. One student described, “During the photo shoots of the scenes (representation three) I noticed that my previous understanding was wrong about solids. I now understand that the molecules in the solid are moving, but because they are some compact, I can’t see them vibrate.” The high-level group (n=2) stated that they became aware of their misconceptions during representation three because they had to physically make the models for the Slowmation in order to explain the science concept.

The mid-level group (n=2) stated that they became aware of their misconceptions during representation one, research. They thought their misconceptions were addressed during representation one because they had to research additional information in order to understand
what they had initially read. One student stated, “I had to watch a video so I could understand how lightening is made and why it is called as a plasma. I still don’t completely understand plasma but I have a better understanding of what causes it to happen”.

The low-level group (n=2) indicated their misconceptions were addressed during representation five, during their narration. Their misconceptions became apparent when they played the Slowmation and heard themselves explaining the information incorrectly. The student told me, “I use to think kinetic energy only happened when I shot a basketball or fell down. When I had to explain kinetic energy in my narration, I realized it could also relate to motion on the molecular level. Just because I can’t see it or feel it, doesn’t mean it isn’t happening.” The results are shown in Table 8.
Table 8

*Interviewed Students Addressed Their Misconceptions Using Slowmation 5Rs*

<table>
<thead>
<tr>
<th>Student</th>
<th>Slowmation 5Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>Representation</td>
</tr>
<tr>
<td></td>
<td>One-Research</td>
</tr>
<tr>
<td>High A</td>
<td>●</td>
</tr>
<tr>
<td>High B</td>
<td></td>
</tr>
<tr>
<td>Mid-Level C</td>
<td>●</td>
</tr>
<tr>
<td>Mid-Level D</td>
<td>●</td>
</tr>
<tr>
<td>Low-Level E</td>
<td></td>
</tr>
<tr>
<td>Low-Level F</td>
<td></td>
</tr>
</tbody>
</table>
Teacher Observations during Slowmation Process.

The teacher made observations as students worked through the process of the 5Rs (research, chunking sheet, models, photos, and narration). During representation one, the students acquired background knowledge about science concepts, specifically naming the four states of matter, examples for each, and how a phase change (liquid to solid) occurs. The students who struggled with these concepts learned quickly to ask their classmates to explain the information. All students (n=13) used the Internet to obtain information, either written or short video, regarding the states of matter and phase changes. The teacher observed that the students addressed their lack of understanding but did not address their misconceptions during representation one.

During representation two, 23% of the students (n=3) addressed their misconceptions when they made the chunking sheet. These students were observed making several modifications to the pictures or wording until the scene demonstrated the correct science concept. One student stated, “I really had to think through this process. I had to go back over the reading so I could get an idea of what to draw. I wish I had a partner to help with the ideas and how to pronounce some of the words. But I have to admit that when I finally understood the idea of a phase change, it made sense to me. Now I understand why the temperature of water remains constant when it changes from a liquid to a gas”.

Students did not address misconceptions in representation three, when they created models, or representation four when they took digital photos that explained the states of matter. I did not observe any ‘ah-ah’ moments. I noticed that during representation three and four, students had an understanding of what they were creating, how to manipulate the scenes, and took boundless pictures for their slowmation projects.
Representation five required students to edit and narrate their animation. It was during this representation that 54% of the students (n=7) were noted to have addressed their misconceptions. I heard one student say during the editing, “I wish we had taken notes instead of working on this project. I don’t have to think as much when I take notes”. Another student commented on how the narration was difficult at first using the Stop Motion™ app. However, once this student became familiar with this app and listened to the recording, he or she realized the mistakes in the narration and correct them. The student said, “It was a major ah-ah moment”. Some students, 15% (n=2), addressed their misconceptions during the presentation. One student stopped the Slowmation and said, “Wait, that’s not right. What I meant to say was the Aurora Borealis is an example of a plasma and not a gas”. Finally, one student did not address any misconceptions. This may have occurred because this student did not complete the slowmation project. The table below shows that representation two and five of the slowmation process helped students address their misconceptions in phase changes of matter. The results are shown in Table 9.
### Table 9

**Teacher Observations of When Students Addressed Their Misconceptions**

<table>
<thead>
<tr>
<th>The 5Rs Process</th>
<th>Number of students who addressed their misconceptions (n=12)</th>
<th>Student comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representation one: research</td>
<td>0</td>
<td>Reading the concepts were difficult compared to taking notes.</td>
</tr>
<tr>
<td>Representation two: chunking sheet</td>
<td>3</td>
<td>I had to go back over the reading so I could get an idea of what to drawn.</td>
</tr>
<tr>
<td>Representation three: models</td>
<td>0</td>
<td>I enjoyed making the models.</td>
</tr>
<tr>
<td>Representation four: photos</td>
<td>0</td>
<td>I had a lot of fun taking pictures and moving the clay.</td>
</tr>
<tr>
<td>Representation five: narration</td>
<td>7</td>
<td>It was weird to hear myself say the wrong information.</td>
</tr>
<tr>
<td>Present project to the class</td>
<td>2</td>
<td>Wait, that’s not right. What I meant to say was…</td>
</tr>
</tbody>
</table>
Chapter 5

Conclusion

Summary

The aim of this action research was to determine: (a) Which Slowmation representation, 5Rs (research, chunking sheet, models, digital photos, and narration), help students address their misconceptions in physical science and (b) In what way does Slowmation, as a pedagogical strategy, assist with helping students overcome misconceptions about science concepts in physical science?

As discussed in the Literature Review (Chapter Two), there are conceptualized representations, the 5Rs teaching strategy, that students need to know to be successful when creating a slowmation project (Hoban & Nielsen, 2010). The results of this action research indicated that representations two and five helped students overcome misconceptions in physical science, and that Slowmation was, indeed, a better method for students to address misconceptions as opposed to teacher lecture and bookwork. When students use the slowmation process they are able to improve and modify their understanding of science concepts.

This chapter examines why the slowmation process was a better pedagogical strategy than teacher lecture or bookwork and why representations two and five helped students address misconceptions in physical science, specifically phase changes of matter. The chapter also discusses the treatments used and the limitations of this action research. Finally, recommendations for future research in the technology-based pedagogical strategy using Slowmation are offered.
Discussion and Implications

Addressing students’ misconceptions using teacher lecture verses slowmation project. When comparing teacher lecture to the slowmation project, there was a notable difference in students’ abilities to address their misconceptions in physical science. Students (n=6) who were interviewed indicated that during the comparison-treatment, without Slowmation, the students believed they identified their misconceptions during the teacher lecture. However, according to the data of the post-assessment in Chapter Four, students improved their score from basic or below basic to proficient in understanding the classification of matter. However, these students did not address their physical science misconceptions about chemical classification of matter.

During the treatment strategy, using the slowmation process, students were able to address their misconceptions. As indicated in Chapter Four, the results of the post-assessments showed a higher percentage of students scoring advanced on the four states of matter using the treatment strategy, Slowmation, than in comparison-treatment, without Slowmation. According to Hoban and Nielsen (2010), when students are asked to create an animation that explains a science concept, it engages them in learning because they need to understand the concept before they can model it. The pre-assessment for classifying the states of matter asked the students to explain how water changes from a liquid to a solid state. A majority (n=11) of these students scored at the basic level or below. The post-assessment showed that 12 out of 13 students had addressed their conceptual misunderstanding about phase changes. One student did not complete the project and scored basic level on the four states of matter. Even though this student watched the other slowmation projects, this student was not able to address his or her misconceptions.
This could be an indication that the hands-on process and narration of Slowmation would have assisted the student with his or her misconception of states of matter.

Some examples of questions asked in the comparison-treatment assessment (classification of matter) included classifying the types of matter such as water, aluminum, and air. Another question was to create a flow chart representing the classification of matter and give examples for each. The Slowmation-treatment assessment (phase changes of matter) asked the students to explain the four states of matter and give examples for each. Students were also asked if water could directly change from a solid to a gas. Appendix C includes sample questions from the assessment. The results of the pre- and post-assessments comparing the comparison-treatment without Slowmation, versus second treatment with Slowmation, are shown in Table 10.

Table 10

<table>
<thead>
<tr>
<th>Percentage of students who scored:</th>
<th>Pre-assessment scores</th>
<th>Post-assessment scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Comparison-Treatment</td>
<td>Slowmation Treatment</td>
</tr>
<tr>
<td>Below Basic(1) or Basic (2)</td>
<td>57%</td>
<td>43%</td>
</tr>
<tr>
<td>Proficient (3)</td>
<td>38%</td>
<td>44%</td>
</tr>
<tr>
<td>Advanced (4)</td>
<td>5%*</td>
<td>13%</td>
</tr>
</tbody>
</table>

*This student used a smart phone to Google the information.
**This student did not complete the slowmation project.
**Representation two and five helped students address their misconceptions.** Creation of the slowmation project provided an authentic learning opportunity for students to present their ideas using multiple representations (Kervin, 2007). Students made meaning of the content when they constructed their own representations of science concepts using multi-modal representations (Hand, 2009). By constructing their own representations in an authentic project-based application, students were able to visualize and represent their own ideas in a way that led to conceptual change.

When interviewed, students (n=6) were asked at what point during the slowmation process they thought they had addressed their misconceptions. The high-level students (n=2) believed their misconceptions were addressed during representation three, making the models for the project. This group thought if they constructed the models for the slowmation project, they understood the concepts and had addressed their misconceptions.

During the mid-level students’ interviews (n=2) they believed they had addressed their misconceptions during representation one, researching the topic to be studied. These students thought they understood the concepts because they had read the material and they could create a chunking sheet that explained their ideas. Mid-level students thought that if they understood the science concept, they also had addressed their misconception.

During my observations I noted that the students interviews and my observations of when they addressed their misconceptions were not the same. I believe this is due to the fact that I was observing their behaviors and saw when they actually realized they had a misconception. Also, some of the students came up to me after they created their narration and asked if I really understood particular science concept. One concept my students were intrigued by and
frequently asked me, “Did you know that in science there are two types of plasma? One is in your blood and the other is an example of lightning”.

Both the mid- and high-level students (n=4) did not address their misconceptions until they had to verbalize their understanding during representation five, editing and narration. This was when their “ah-ha” moment occurred. I observed the students body language change when they realized their misconception. After the students addressed their misconception they had to share the information with a classmate. They were surprised to find that everyone had their own unique misconception. Additionally, two high-level students did not address their misconceptions until they presented their Slowmation to the class. During their presentations they stopped their Slowmation and said, “No, that’s not right. What I meant to say was…” As stated by Hoban and Nielsen (2010), students make corrections and address any misconceptions in science during the editing and narration process of Slowmation.

The low-level students also thought narration of the project in representation five, editing and narration, allowed them to address their misconceptions. During the interviews, theses two students admitted they struggled with the research and would have liked a partner to work with during this project. They said they had to ask other people (teachers, students, parents) for help because the text was too difficult to understand.

However, during the teacher’s observations, the low-level students addressed their misconceptions during representation two, chunking sheet. Once again, I observed the students’ body language and their frustration as they struggled with the six diagrams for the chunking sheet. I could see the joy and relief on their faces once they understood the science concepts and created images that represented their idea on the chunking sheet. These students knew that they
had to reject their previous notions and replace them with new meaning in order to understand the science concepts.

**Students address their misconceptions during representation five.** Although the students attained most of the science content information during representation one, research, new understanding was acquired during each of the other representations. This was why most students did not address their misconceptions until representation five, editing and narration, because they had to build their understanding of science in order to address their misconceptions. This matched the suggestion of Hoban and Nielsen (2012) gave, that it would be valuable to revisit the concept through the construction of each representation that influenced conceptual change.

**Slowmation assists with pedagogical strategies.** Slowmation assists with pedagogical strategies by permitting the students to revisit the concepts of phase changes and allowing them to address their misconceptions when they are ready. While the comparison-treatment (lecture, bookwork, and investigation) did not give the students’ time to reevaluate their understanding of the science concepts taught during the lesson of chemical classification of matter. A possible reason for students not addressing their misconceptions was because they did not have multiple representations allowing them to reexamine their scientific understanding of chemical classification of matter.

The Slowmation strategy allows the student to “fix” their misconception by using the multi-modalities of researching, outlining, creating models, filming, narrating, and editing their understanding of the science concepts. Since the student had to revisit and reassess their understanding of science concepts using the 5Rs, they were able to “fix” their misconceptions in phase changes of matter. This helped verify the purpose of this research question: In what ways
does Slowmation assist with pedagogical strategies to help students address their misconceptions in physical science?

The students discovered that Slowmation motivated them to learn about science concepts and challenged them to address their misconceptions. For example, in the student interviews they stated that they appreciated being challenged during representation one and they had to research the science content until they could make their own meaning of the concept. According to Gooding and Metz (2011) students hold onto misconceptions when there is nothing to challenge their misconceptions. This action research project helped me understand a better pedagogical strategy, Slowmation, for assisting students to address their misconceptions in physical science.

**Limitations**

**Sample population.** One major limitation in this action research project was the sample size. The population of this classroom was 13 students. There was only one physical science class taught at this school. A sample of five different classes with a minimum population of 15 students would have been ideal for collecting data. In order to maintain a reliable data sample, a larger sample size and heterogeneous ethnic population could be used to represent a high school student population.

Another major limitation was the time allowed to conduct the research. In this study, there was only one treatment of Slowmation given to the class. In order to truly identify the effects of Slowmation, several treatments should have been conducted and compared to teacher lecture. This could help determine if Slowmation was truly a better pedagogical strategy that aided students in addressing their misconceptions in physical science.
MAP scores. When beginning this action research, science concepts MAP scores were going to be used to quantitatively identify if Slowmation helped students’ address their misconceptions in physical science. MAP scores were not used because too much time passed between the first set of MAP tests in September and the second set in May. Therefore, the scores could not quantitatively distinguish if students’ misconceptions had been addressed after the Slowmation treatment.

Pre- and post-assessments. Students were very concerned that the assessments would affect their science grade. Even after I explained that the assessments were for research purposes only, two students used their smart phones to Google the information so they would have the correct answers on the assessment. This caused the data from the first treatment, without Slowmation, to be inaccurate. Refer to Table 10.

Another limitation was how the questions were written for the assessments. For example, students did not remember what a flow chart was and had a difficult time creating one. In the pre-assessment they were asked to explain a phase change of water. Students thought a phase change of water was changing to another material, such as water changing to air. Instead, the questions should have been piloted with other students to evaluate the reliability of the assessments.

Comparison of the schedule of classroom activities between teacher lecture versus Slowmation. The amount of classroom time given to the two treatments, teacher lecture versus Slowmation, was not alike. Refer to Table 2 and 3 in Chapter Three. The scheduled time for teacher lecture was 50 minutes, a class period, and the time allowed for the slowmation project was 190 minutes. The slowmation project took more time because this was a relative new strategy for the students to learn science concepts. The physical science students had created
only two slowmation projects before this study began. Another reason why the slowmation project received more classroom time was because the students were responsible for their learning of science concepts. Students were given 50 minutes (one class period) to complete research, representation one. Then the students were given 100 minutes (two class periods) to complete representation two (chunking sheet), representation three (models), and representation four (photos). Representation five (narration) was completed at home where back ground noise could be eliminated.

**Recommendations for Future Research**

From the teacher observations, representation five, editing and narration, was identified as the level in which most students (n=9) addressed their misconceptions. Additional research can be conducted to see if this is correct. An example would be to eliminate students presenting their slowmation project to the class. This treatment would analyze whether or not the students’ misconceptions were indeed addressed during the narration of the Slowmation. Another recommendation would be to remove the narration from representation five of the Slowmation. Students would create the Slowmation, present to the class, and narrate as the film played.

As described in Chapter Two there are five types of misconceptions described by Taking Science to School (NCR,1997). Another research idea might include, identifying the types of misconceptions the student has and use Slowmation as a treatment to see if the student was able to relinquish the misconception.

For this action research, the students had to complete representation one by researching the science concepts using the Internet and creating individual Slowmations. Additional ideas for research would be to give the students the information or have them work in groups to complete the project. If given the research, does this hinder the students’ curiosity about the
concepts? If students work in groups, does this change the dynamics of how the misconceptions are addressed?

**Conclusion**

Over the past 30 years, research studies have shown that integrating digital technology creates positive affects on students learning (Wallace, 2004). This action research also showed some positive effects of Slowmation in physical science. It allowed the students to address their misconceptions in a creative, motivational, and non-threatening manner. Hoban and Nielsen (2010) stated that each of the five representations are models that fit together as a coherent whole. This allowed the students to rethink the concepts and challenge misconceptions as they moved through the representations.

Slowmation increased students’ awareness of their science misconceptions, helped them address their misconceptions, and increased their understanding of science concepts. Table 10 showed that when students used Slowmation they scored advanced on the post-assessment and they addressed their misconceptions in science. Slowmation is a technology-based pedagogical strategy that assists students with organizing, finding, and assessing reliable information using technology. It is a hands-on process that challenges students to problem solve. This teaching strategy offers multiple modalities, differentiated instruction, and allows students to identify and challenge their misconceptions in science.

Prior to this action research project, I did not realized how difficult it is for high school students to relinquish their misconceptions in science. After completing project, I understand the five types of misconceptions, how to assess and help students’ address their misconceptions in science. Based on this action research I plan to continue the use of Slowmation in the science classroom to help students address their misconceptions.
References


Immordino-Yang, M. Damasio, A., (2007). We Feel, Therefore We Learn: The Relevance of Affective and Social Neuroscience to Education. International Mind, Brain, and Education Society and Blackwell Publishing Inc. 1(1), (p. 3-10).


Appendix A

Assent Letter

General purpose of the study:
My name is Samantha Schwessinger. I want to tell you about a research study I am conducting as part of my master’s program at the University of Wyoming. A research study is usually done to find a better way to treat people or to understand how things work. In this study, I want to find out more about teaching science concepts and using the process of slowmation to teach those methods. I will use these results to improve your learning and my teaching methods in our science classroom.

Procedure:
We will conduct the study in our science classroom. I will begin the study by giving you a pre-assessment. We will discuss physical science content, take notes, read, run experiments, and use slowmation to explain science content. Finally, I will give you a post assessment. We will do this for about an hour in class and some nights you will have homework. We will do this everyday for about eight weeks.

Disclosure of risks:
Your participation in this study has minimal risks. A risk is something that may cause stress and frustration. One thing that may cause stress is the research task, working in groups, creating a storyboard, and narration of the slowmation. We will work together so you will not feel stressed or frustrated.

Description of benefits:
There are no direct benefits for you participating in this study. The indirect benefit is that I will understand teaching science content better and improve your learning strategies in our science classroom.

Confidentiality:
I will protect your confidentiality on any work I analyze by removing your name and putting a code (pseudonym) on your work so that only I will know who did the work. I will not use your name, age, or gender in my final paper or when I share your work. I will keep your codes and names separate.
Your work will be kept in the locked classroom and on my computer that is protected by a password.

Freedom of consent:
I understand that my refusal to participate or my withdrawal at any point will not affect my course grade or class standing.

Questions about the research:
If you have questions about the research study, you can talk to Mrs. Schwessinger. This is my contact information:

Samantha Schwessinger
PO Box 188
Dubois, WY 82513
(307) 455-2488

If you have questions about your rights as a research subject, please contact the University IRB Administrator at 307-766-5320.
Assent to participate:

Name: ___________________________________________________________________

Signed Name: ___________________________________________________________________

Date: ___________________________________________________________________

____ I want to be in the study. I know that I can stop being in the study by telling Mrs.
Schwessinger.

____ I do not want to be in the study.

Video recording:
I will be using a camera to record our lessons. This way I can watch what I am teaching and how
you are learning. Only my professors at the University of Wyoming and I will look at these
recordings.

____ Yes, Mrs. Schwessinger can record me during lessons.

____ No, Mrs. Schwessinger cannot record me during lessons.
Consent Letter

General Purpose of the Study:
This year I will be looking at how slowmation (slow-animation) could be used to improve my students’ understanding of physical science content. This research is one of the requirements for my master’s degree program through the University of Wyoming. You are being asked to allow your student to take part in a research study. This document has important information about the reason for the study, what your student will do during the study, and the way I would like to use your student’s information.

The purpose of this study will be to study the effectiveness of slowmation (slow-animation) and how it be used to correct students’ misconceptions in science. The study will look specifically at teaching of science content, see if the student has any misunderstanding in the science content area, and have them create slowmation to see if this can correct students’ misconceptions.

Procedure:
The study will take place in the 9th grade science classroom at Dubois High School in Fremont County School District #2. Fifteen students from ages 14 – 16 years old will participate. The study will be conducted in the same way as normal classroom instruction that happens in the 9th grade classroom.

Samantha Schwessinger, the 9th grade physical science teacher will be conducting the study. All students will receive the same instruction using activities from the school district’s approved science curriculum. I will give various assignments including: in class worksheets, reading from the science textbook, lecture notes, research, experiments, homework, slowmation, and post-assessments. These activities will happen on a daily basis in Mrs. Schwessinger’s physical science classroom. Students will participate in class and homework assignments for eight weeks during the second semester of physical science.

Data will be collected by classroom observation, collection of student and teacher journaling, student writing samples, student pre and post assessments, student’s slowmation creation, and other student work samples.

Disclosure of risks:
Student subjects are at minimal risk during participation. One risk is anxiety from the research and writing process. Students may also breech confidentiality by talking to others. The researcher will do her best to make sure the breeches of confidentiality are minimal. These risks are similar to the risks that may take place in a regular high school classroom. Other risks might include students sharing information about the study with other students and adults outside of the classroom. However, this information should not affect the study. Student participation will not affect their grades. Students will not be treated differently for participating or not participating in the study.

Description of Benefits:
There are no direct benefits for the students participating in the research. The indirect research benefit is the student participants’ teacher will improve her teaching and understanding of students’ misconceptions about science. Student participants might benefit by learning the process of slowmation and how it can be used as a tool to teach content.
Confidentiality:
Student subjects will not be identified by name, appearance, age, and gender. Pseudonyms or codes will be used to protect student identity. All student work will be kept in a locked file cabinet in a locked classroom. Research and student work with specific student names will only be shared with Mrs. Schwessinger’s faculty advisors at the University of Wyoming. Data will be stored on a password-protected computer and in a locked file cabinet and in a locked classroom. Any codes used to identify students will be kept separate from student work. Data will be stored for no more than 3 years and then destroyed. Only the Primary investigator and faculty supervisors will have access to data. Data will only be used for this particular study.

Freedom of consent:
Student participation in this study is voluntary. The refusal to participate will not have any negative effects on the students’ grades. Students will not be treated differently for participating or not participating in the study. Students may end participation in the study with a verbal statement to the researcher. Parents may also withdraw their children from the study by a verbal statement. Students who withdraw from the study will not be treated any differently than students in the study.

Questions about the research:
The principal investigator can be reached at the following address:

Samantha Schwessinger
PO Box 188
Dubois, WY 82513
(307) 455-2488

Having read the above and having had an opportunity to ask any questions, please sign below if you would like your student to participate in this research. If you have questions or concerns about your student’s rights as a research participant, please contact the University of Wyoming IRB Administrator at 307-766-5320.

Parental consent required for all subjects under 18 years of age:
As parent or legal guardian, I hereby give my permission for (student’s name)
______________________________________ to participate in the research described above.

(printed name of participant)

____________________________________________
Printed name of parent/legal guardian

____________________________________________          ______________________
Parent/legal guardian signature                                                      Date

Consent of audio and video recording:
Lessons during the study may be recorded for teacher reflection.
_____ Yes, my child can be recorded during lessons.

_____ No, my child may not be recorded during lessons.
Appendix B

Grade Sheet for Slowmation

Slowmation phase change:
This project has to be created using Slowmation on your iPad. You will be graded daily on what you complete, your iPad is charged, and present (6). You will be docked points if you are playing games or not working on your project. This paper must be turned in for your participation grade.

- Name the four states of matter and give examples for each (10). Include how the intermolecular force and kinetic energy affects matter (5).
- How do pressure, temperature, and volume affect these states (5)?
- Give examples of phase changes from solid ⇔ liquid ⇔ gas (5).
- Slowmation is accurate with scientific information (5).
- The project shows movement (5).
- The project is creative (5).
- The project has narration (10).

<table>
<thead>
<tr>
<th>Day</th>
<th>Slides (2)</th>
<th>iPad charged (.5)</th>
<th>i-Pad present (.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix C

Pre- and Post-Assessment for chemical classification of matter

Give an explanation of matter. You can make diagrams.

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
Create a flow chart that represents the classification of matter using the following words: homogeneous solution, element, pure substance, heterogeneous solution, matter, mixture, colloid, and compounds.

Using the flow chart you created for matter and answer the following:

How would you classify water?

How would you classify aluminum?

How would you classify blood?

How would you classify oil and water mixed together?

How would you classify Kool-aid™?

Your four-year-old niece wants you to explain what happens when you put a tray full of water in the freezer and it become ice in a few hours. Use the science terms in your explanation.

_____________________________________________________________________________
Appendix D

Pre- and Post-Assessment for phase changes of matter

Name the four states of matter from the highest energy level to the lowest.
_____________________________________________________________________________
_____________________________________________________________________________

Explain how the four states of matter differ and/or similar to one another. Please use scientific
terms. Include examples for each. You can use diagrams.
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Your four-year-old niece wants you to explain what happens when you put a tray full of water in
the freezer and it become ice in a few hours. Use the terms that you have learned in your
explanation to your niece.
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Explain______________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
Appendix E

Post-interview questions for chemical classification of matter lesson

How did the lecture help you understand the four states of matter?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what they said:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How did the homework help you understand the four states of matter?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what they said:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How did the investigation help you understand the four states of matter?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what student said:</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tbody>
</table>
What do you understand about…(fill in with student’s misconception)?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what student said:</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

How do you learn information about scientific ideas?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what student said:</th>
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<tbody>
<tr>
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</table>

What do you like about science?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what student said:</th>
</tr>
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<tbody>
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</table>
Appendix F

Post-interview questions for phase changes of matter lesson

What do you understand about… (fill in with student's misconception)?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what they said:</th>
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</table>

While conducting the research portion of the slowmation project what did you learn?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what they said:</th>
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<tbody>
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While conducting the picture taking and set up of slowmation, what did you learn?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what student said:</th>
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</table>
While conducting the narration portion of slowmation what did you learn?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what student said:</th>
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What was easy and/or fun about the slowmation project?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what student said:</th>
</tr>
</thead>
</table>

What was difficult and/or frustrating about the slowmation project?

<table>
<thead>
<tr>
<th>Student’s thoughts:</th>
<th>My thoughts about what student said:</th>
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</thead>
</table>
## APPENDIX G

**My reflection and observations of Today’s Lesson**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Students task in class today</th>
<th>Observations of class activities</th>
<th>Reflection of the activity</th>
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</thead>
<tbody>
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