TEACHING AND LEARNING SCIENCE THROUGH SONG: EXPLORING THE EXPERIENCES OF STUDENTS AND TEACHERS

by

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(Under the Direction of David Jackson)

ABSTRACT

This qualitative, multi-case study explored the use of science-content music for teaching and learning in six middle school science classrooms. The researcher sought to understand how teachers made use of content-rich songs for teaching science, how they impacted student engagement and learning, and what the experiences of these teachers and students suggested about using songs for middle-school classroom science instruction. Six teachers who volunteered to participate in this study and their students, from three suburban middle schools in Georgia, were included in the study. Data gathered included three teacher interviews, one classroom observation and a student focus-group discussion from each case. The data from each unit of analysis were examined independently then synthesized in a multi-case analysis, resulting in a number of merged findings, or assertions, about the experience. The results of this study indicated that teachers used content-rich music to enhance student understanding of concepts in science by developing content-based vocabulary, providing students with alternative examples and explanations of concepts, and as a sense-making experience to help build conceptual understanding. These students overwhelmingly found that their

teachers' use of science-content songs engaged them by providing both situational and personal interest, and as a mnemonic device for remembering key concepts in science. The use of songs has relevance from a constructivist approach as they were used to help students build meaning; from a socio-cultural perspective in terms of student engagement; and from a cognitive viewpoint in that in these cases they helped students make connections in learning. Of interest is the difference in how teachers and students saw the purposes for learning in science, based on how songs were used for teaching and learning science in this study. The results of this research have implications for science teachers and the science education community in developing new instructional strategies for the middle school science classroom.

INDEX WORDS: Science education, Instructional strategies, science songs, sense-making activities

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DEDICATION

This work is dedicated to all the young people, whom I have had the opportunity to teach over the years, that have inspired me to become a better teacher.

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There are a great many people who I owe a great deal and without whose help I could not have finished this research study or degree. First I'd like to thank my administrators and my peers in the Forsyth County School System who supported me through this process, especially those teachers who volunteered to participate in my study. Second, I would like to acknowledge the support and guidance given by the professors who served on my committee, especially Dr. David Jackson, who saw potential in my research from the beginning, for his direction and Dr. Jori Hall for her guidance in methodology. I also must acknowledge the support and guidance given by Dr. Norm Thomson, who has mentored me in many ways, and both Dr. Tom Koballa and Dr. Shawn Glynn who also served on my committee. Next, I need to acknowledge Dr. Tim Slater who has been my mentor and provided opportunities over the past twelve years that have given me the confidence to undertake this challenge. I would like to recognize my family and closest friends who have provided unlimited support and encouragement. The patience and understanding from my parents, children, family and friends while pursuing this degree has been more helpful than they know. Finally, and most of all, I must acknowledge my husband, who in more ways than I can count, has been "the wind beneath my wings."

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CHAPTER 1: INTRODUCTION

Music is the heartbeat of every adolescent. Students can be found in every middle school today that carry their favorite tunes to school on MP3 players. Even through music is a part of every day life for most young people, it is seldom used to engage and help students learn in the secondary science classroom. Songs can transfer knowledge and elicit emotion, and have the potential to reach students in ways other teaching strategies cannot. Song lyrics can be used to carry information; music can elicit memories, and melodies can activate recall of thoughts and ideas (Jourdain, 1997; Jensen, 2000). There is an entire genre of science content-based music, rich in content and available for teaching science concepts that is largely ignored by educators. Songs available for learning science are designed for all grade levels and include information about principles, facts and concepts included in the science curriculum. Jenson (2005) summarizes why educators should include music in the curriculum: its social nature, emotional impact, ability to carry a message, accessibility, and relevance. Lyrics, rich with information and embedded in music, are more likely to be remembered. "Songs, specific melodies, rhythms, and tones all have the potential to engage content learning in this way" (Jensen, 2000, p.84).

Studies that utilize science songs as a teaching strategy in the secondary science classroom are virtually nonexistent. However, some conclusions can be drawn about the benefits of using songs to teach from a limited number of studies in neuroscience and musicology about the power of song in aiding recall. In a study by Calvert and Tart

(1993) a melody selected from the 1970's *Schoolhouse Rock* television series was used to determine if text was remembered better when embedded in music or learned verbally. The researchers found that the songs were powerful mnemonic devices that allowed for improved recall and were useful as a strategy to encode, retrieve and rehearse information (Calvert and Tart, 1993). Wallace (1994) conducted research in which four different treatment groups were set up to determine if recall of text could be improved with the use of music. This study concludes that the "melody of a song can indeed make a text more memorable as compared with hearing the text out of the context of the melody" (p.1481).

Research exploring the value of content-based music in the classroom is more difficult to find. In one of the few studies conducted in an education setting, researchers used songs as a teaching strategy in kindergarten, second and fifth grade classrooms across multiple content areas. Findings indicated that there were gains in subject matter knowledge, and student participation in class activities increased, when content-based music was implemented as a teaching strategy (Campebello, et al. 2002). An extensive review of the research yielded no studies related to the use of science songs as a teaching strategy in the secondary science classroom.

When used as a teaching tool, music has the potential to engage students and enhance learning in the science curriculum. This study was designed to explore the experiences of teachers and students when science-content music is used as a teaching strategy in the middle school science classroom in order to better understand the phenomenon and its potential use in science education.

Defining Science-content Music

Because there is no existing body of literature, a definition of science-content music must be generated from other sources, including the songs themselves. The most familiar science-related song of our age is Tom Lehrer's "The Elements," first recorded in 1959. This song is widely recognized in our society and lists the elements of the periodic table that were known at the time it was composed. "The Elements" song is used often in science classrooms by many educators and is an example of hundreds that a teacher might use when including science-content music as a teaching strategy. The Science Songwriters Association (Crowther, 2008) is one of many web-based resources available for science teachers and lists more than thirty different artists who compose and produce science-related songs covering all aspects of science education. Songwriters who belong to this organization compose music or retool existing melodies with content-related lyrics for use in teaching science. A second resource, the Math and Science Song Information Viewable Everywhere (MASSIVE) database, maintained by Crowther (2008), provides an online resource for hundreds of songs that is searchable by title, performer or keywords. Using this resource a science educator could locate multiple science-content songs to be used in the classroom on any given topic. This genre of music is not limited to a minimal number of songwriters or songs that can be used in the science classroom for teaching.

One example of a song written by a science-music composer comes from Professor Boggs, a.k.a. Larry Morris (2005), who sings "Hey Avogadro" about gas laws includes the following in the song's chorus:

> Hey Avogadro – give me a mole – I need just enough gas to fill a cubical hole. It's got twenty-two point four liters inside, but for temperature and pressure you got to be my guide. Avogadro, you've got the number you see, you're sayin' P, V, equals n, R, T. (Morris, 2005)

Morris' song about the rock cycle teaches, "Three kinds of rock are under your feet, How do they form and rearrange? Igneous from liquid, sedimentary from grains, Metamorphic from the mighty heat & pressure change…." (Morris, 2010)

Both of these songs illustrate that science-based music is rich in content and concepts. This genre of song includes information about principles, facts and concepts included in science education. Some songs involve changing lyrics to familiar tunes, such as Lehrer did in "The Elements," sung to the tune of "The Modern Major General" by Gilbert and Sullivan (Wells, 2005), while some songwriters compose melodies to fit original lyrics. These songs are generally written to a catchy beat, and are often musically composed for "musical imagery repetition," a term coined by Bennett (2002) to refer to songs that get stuck in the head. Devices used in science-content songs to gain the attention of the student often include metaphor, rhyme, imagery and humor.

Based on the examples given and resources available, science-content music can be defined as *a genre of songs, either existing tunes rewritten with new lyrics or original musical compositions, designed to teach and explain science-related concepts through verse, with a well-defined melody and/or rhythm.*

Rationale

Music is a common thread through culture and experience. Songs can transfer knowledge and emotion, and have the potential to reach students in ways other

teaching strategies cannot. Jensen (2000, 2008) advocates the use of songs for teaching and learning based on new understandings in about how the human brain works and brain-based learning theory. Diamond and Hopson (1998) believe there is great potential for educators to improve instruction based on neuroscience, and encourage teachers to begin developing strategies and techniques utilizing current findings from neuroscience. “Teachers can scarcely wait twenty years for a neuroscience of learning to emerge with proof enough for the highly meticulous” (Diamond and Hopson, 1998, p.87). Critical of the current curriculum standardization model and high-stakes testing system of teaching, Caine and Caine (2001) encourage the use of brain-based research for instruction to provide a model for natural teaching methods that improve learning. The rationale for using science-content music comes from an understanding of brain-based learning theory and could provide an effective teaching strategy for science teachers that engages students and helps them learn content material and science concepts.

Using multiple case study research methodology this study was designed to explore the experiences of students and educators who participate in this study to better understand the use of science songs for teaching and learning. Case study research, as a form of qualitative inquiry, involves “investigating a phenomenon to get at the nature of reality with regard to that phenomenon” (Patton, 2002. p. 215). The rationale for using case study methodology is that it is designed to contribute to knowledge through ideas that emerge from the experiences of individuals as documented by interviews, observations and documents (Patton, 2002). Basic patterns are identified from experience for the purpose of understanding, describing and explaining a phenomenon.

Pilot Study

During the fall of 2009 a pilot study was conducted in which eleven former students of the researcher were interviewed to explore student opinions, perceptions, and attitudes about past experiences with science-content music in the classroom. In order to fully explore and triangulate the interview data three different methods were implemented for data analysis. The primary method of analysis was an open coding, inductive approach to compare and contrast the experiences of all eleven participants in this study, as described by Saldana (2009) and Charmaz (2006). A second method utilized for data analysis was based on procedures for phenomenological analysis, as outlined by Hycner (1985). For this analysis three of the eleven interviews were selected based on the detail offered in student responses to interview questions, and as the oldest of the interviewees they provided the most retrospective stories about the experience. During these interviews the students provided more lengthy responses to questions with less probing, allowing for more of their stories to unfold naturally. Finally, in order to preserve voices of the formers students interviewed for this study, a poetic representation was constructed from interview data as an alternative form of data analysis. Constructing poetic representations as a form of data analysis allowed the voices of the study participants to emerge in a meaningful way and to communicate "findings in a multidimensional, penetrating and more accessible way" (Cahnmann, 2003, p. 35).

Merging the results of these three types of analyzes, a number of themes emerged to support additional research into using science-content music as a strategy for teaching and learning. The results and conclusions of the pilot study helped ground

and guide the proposal for this research. Table 1 presents a summary of those findings. The most prevalent theme to appear in all three methods of data analysis relates to engagement. For these study participants, the use of science content songs has a universal appeal, draws students into learning in a unique way and provides a common culture of learning with other students. Ten of the eleven participants discussed how much they enjoyed learning through song and that it was a novel learning experience. Generally, these interviewees found the use of science content songs for learning to be engaging because it was novel, fun, provided variety and got their attention. Through the use of patterns in melody and beat, and devices such as humor, wit and metaphors in the lyrics, these students spent more time engaged with the science concepts presented in songs. While science songs seem to have universal appeal to most of the interviewees, not all liked the experience.

A theme that emerged through both inductive analysis and the alternative analysis is that the study participants thought science songs provided a complex mnemonic device for learning and studying. The songs and their embedded content were easy to remember because they could be cued with the lyrics, melodies, references to the metaphors used in the lyrics, or just by bringing up the main topic of a song. One interviewee reported, “If we can remember the rhythm or the melody of a certain song, we can remember the words a little easier, too.” A final theme that emerged in the analysis was that the use of science songs provided a conceptual scaffold to improve deep understanding for these students. The interview data suggest that songs helped connect concepts, helped build background knowledge, and gave students a starting place to build on for conceptual development. Through learning and

understanding the songs, interviewees used them as a foundation on which to construct deeper conceptual understanding of the concepts they were learning.

TABLE 1: Emergent Themes from the Data Analysis of the Pilot Study

THEME	SUPPORTING DATA
RQ1: Engagement **THEME:** Science-content music has a Universal Appeal	10 out of 11 talked about engagement, 1 didn't like 5 out of 10 talked about importance of music in their lives Universal Appeal based on: • Novel experience; provided variety • Fun • Attracted and maintained student attention
RQ 2: How Students Make Use of Songs **THEME**: Science-content music is Complex Mnemonic Device	9 out of 11 said it helped • 1 negative example changed his mind during interview All 11 participants able to recall specific songs & info Use as a Mnemonic Device based on: • Recall examples • Reports that it help remembering • Cues in melody, lyrics, rhythm • Use of analogies in lyrics
RQ 3: Assists Learning **THEME:** Science-content music Provides Conceptual Scaffold and Connects Learning	Use of songs go beyond factual recall: • Connects Ideas • Builds background knowledge • Starting place to build on for conceptual development • Importance of lyric analysis for understanding

Because the former students who participated in the pilot study found that science-content music improved engagement, formed a mnemonic device for learning, and provided a conceptual scaffold for new knowledge, this study was designed to build on those conclusions by looking at the phenomenon in other classrooms. The research questions that this study asked were an outgrowth of those results and provided more information about the experiences of teachers and students when science-content music is interwoven into the curriculum.

Purpose Of The Study

The purpose of this study was to interpret the experiences of students and teachers when science-content music was used as a strategy in the middle school science classroom. Insights about teaching and learning with science music were sought to explain, describe and understand the experiences of teachers and students. Middle school science teachers who participated in this study implemented lessons that incorporated science-content music using implementation strategies suggested by research. Teachers and students shared their experiences and insights about the use of science songs for teaching and learning to provide information about the potential for using music in the science classroom.

Research Questions

According to Creswell (2007) and Yin (2009) research questions guiding case study inquiry should address "how" and "why" questions to better understand a phenomenon. Research questions that ask "what" are appropriate if the intent is to explore and illuminate an event (Yin, 2009). With these criteria in mind, the following research questions were used to guide this study:

- In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?
- How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?
- What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?

CHAPTER 2: REVIEW OF THE LITERATURE

The implications for research with science-content music come from various frameworks within neuroscience and educational theory. Brain-based learning theory uses recent findings about how the brain works to suggest numerous ways science educators can employ music and song as a teaching tool. Music's potential as a teaching strategy based on neuroscience comes from an understanding of how it is processed in the brain and its role in memory storage and retrieval. In music, lyrics and melodies are chunked together into patterns of rhythm and verse to enable longer passages to be retained in memory. The combination of melody and lyrics provide multiple neural pathways to store, access and retrieve memories. When two events are linked together in memory, the recall of one prompts the other (Sousa, 2006).

Caine and Caine (2001) suggest that new discoveries about intelligence based on brain based learning theory are important in understanding how children learn and should be the basis of teaching strategies implemented in the classroom. The use of content-rich songs should be included as one of many "complex activities and ongoing experiences in which the curriculum is embedded" (Caine and Caine, 2001, p. 19).

Lerman (2001) describes a curriculum program developed by Columbia College in Chicago that employs an arts-enriched approach to learning science for all levels of students. This program has used art, music, drama, dance and sports to help students explore, experience and express science since the 1980's. Research has shown that student achievement in science is higher and students have shown greater interest in

science as a result of this program. Lerman (2001) summarizes the benefits of this art-enriched science curriculum, “students retain their knowledge of science many years after they graduate and attribute this accomplishment to the fact that they used art, music, dance and drama to internalize the learning process” (p. 5).

History of Music in the Curriculum

From ancient times music has been used as a device for learning and remembering information. “For thousands of years, knowledge was imparted from generation to generation through the medium of singing and chanting” (Armstrong, 2000, p.59). Songs have always been part of an oral tradition for passing down stories, history, information and lessons throughout most preliterate cultures. Stories and poems were sung by Griots in West Africa, Ashiks in the Middle East, Bakhshi in Central Asia, Troubadours in France, Naghal in Iran, Biwa-hoshi in Japan, Kikuyu in Kenya, Jali in parts of Indonesia and Bards in the British Isles for the purpose of transmitting information. Many of these song-tellers had special instruments and their format ranged from the singing of epic tales and news to choral and response storytelling (Sheppard, 2009). When the earliest institutions for learning were established, music was a part of their curriculum. Music was included in the curriculum at Takshashila University in northwest India, which was established in 700 BCE, along with subjects such as science, astronomy, math, archery and agriculture (Brahmaviharidas, 2010). The first western schools established by Pythagoras in 529 BCE (O’Connor & Robertson, 1999), Plato in 387 BCE (Norfleet, 2010) and Aristotle’s Lyceum in 335 BC also provided for the study of music in the curriculum (Dirks, 1996).

The importance of music in these first recorded educational programs demonstrates that it has always been considered an important part of learning across all cultures.

When Charlemagne established schools for the purpose of teaching the clergy in the ninth century the seven liberal arts became the core curriculum, which had two divisions. The trivium included grammar, rhetoric and logic, while music was considered part of the quadrivium, which encompassed math, geometry and astronomy. These subjects became the foundation for all the educational programs in the European universities that arose beginning in the eleventh century, including ones at Bologna, Oxford and Cambridge (Kries, 2000). Song schools, first begun in Europe during the Middle Ages for common children, taught them to sing, play instruments, read, write and dance. Songs were used to teach reading and grammar since textbooks were rare, and music and math were often taught together (Watson, 1908).

In 1875 Colonel Francis W. Parker was hired as superintendent of the Quincy Massachusetts school system to help improve the schools. There he introduced a new curriculum model that encouraged the use of songs for learning based on their connection to subjects being studied (Parker, Cooke & Stilwell, 1901). The results of his changes included not only greater levels of enthusiasm for learning, but also an improvement in student achievement (Edwards, 1935). In 1882 Colonel Parker moved to Chicago where he brought the concept of child-centered learning as he implemented his ideas into the schools there (Wilson, Gary & Greene, 1988). Parker's students included the two children of John Dewey. Francis Parker's ideas for teaching laid the foundation for the Progressive era in education, led by John Dewey after the turn of the century. In the lab schools that followed, songs were introduced about life experiences

and children were encouraged to craft their own compositions based on their daily activities (Shiraishi, 1995).

The advent of radio in the 1920's brought a new use for music in the curriculum. According to an article in the Pittsburg Press, elementary students in Oakland, California were part of an experiment where penmanship was taught via the airwaves using rhythmic music. Geography lessons were also delivered from the radio with music signaling the beginning and end of each lesson ("Penmanship," 1925). The use of music in education further broadened its scope to be taught in conjunction with film, dance, theater, swing, jazz and drama in the 1930's and 1940's. By the 1950's folk songs also made their way into the content area curriculum. In an article that appeared in the September 20, 1958 issue of the *Christian Science Monitor,* a teacher in Massachusetts sang folk songs to teach history. Mr. Bonyum found music engaged his students in learning and used these songs to learn history. He eventually made a record and created a curriculum that correlated to the songs for use in other classrooms (Gustafson, 1958).

Television further facilitated the use of songs for learning. One of the most successful efforts to harness television for learning occurred in the late 1960's with the premiere of *Sesame Street.* This show debuted in the fall of 1969 and was aimed at development of cognitive and literacy skills for pre-schoolers. In the research and development stage for the show it was found that that segments using lively music were considered most appealing to children (Anderson & Levin, 1976, p. 811). In 1973 the use of music in educational television expanded in a new direction with the premiere of *Schoolhouse Rock.* These short cartoon videos were televised on Saturday morning

and used catchy melodies to teach concepts related to math, science, social studies and grammar (Calvert and Tart, 1993).

In 1974 an article reporting new ways to integrate music into the curriculum appeared in *Daytona Beach News Journal*. A program piloted in Columbus, Ohio integrated music into every subject of the curriculum across all grade levels. Math, language arts, science and history all used songs and elements of music to enhance the curriculum. A similar program in California was also piloted where students analyzed lyrics and learned about sound waves with music. In New York and Evanston, Illinois students composed songs and musical productions. Whether students were singing about history, analyzing songs or writing their own compositions; new ways to use music as part of the curriculum were being implemented all over the country ("Music education," 1974). The history of music in the curriculum provides evidence that music has been historically a useful tool to enrich the curriculum in all subject areas.

Music and the Brain

Recent advances in cognitive neuroscience have provided a wealth of information about the brain and how it encodes, stores and retrieves information. The human brain is divided into four different structures, each with a unique role in brain function. There are a trillion nerve cells in the brain that allow for more than a quadrillion connections. It is these connections among neurons that form the matrix of human memory within the brain's complicated structures.

The most basic of brain structures, the brain stem, lies at the base of the spinal cord and regulates automatic body functions. The limbic system is found buried deep within the brain and is thought to be a structure that developed early in human

evolution. Called the 'old mammalian brain,' this part of the brain is composed of four structures including the thalamus, hypothalamus, hippocampus and amygdala. The thalamus, where initial sensory input is first processed, forwards signals to other parts of the brain and is involved in connecting emotion and cognition. The hypothalamus regulates hormones. A critical component to processing memory, the hippocampus, converts information from working memory to long-term memory. When memories are intertwined with emotions, the amygdala is activated and encodes for long-term memory storage (Sousa, 2006).

The most evolved structures in the human brain are the cerebrum and cerebellum. The cerebellum is a deeply folded and highly organized structure located below the cerebrum and behind the brainstem. Thoughts, emotions and senses are coordinated here to support cognitive processing. The cerebrum, which makes up eighty percent of the human brain, is divided into four lobes, each with a different role in cognition (Sousa, 2006). The cerebrum and cerebellum are divided into two hemispheres, left and right. Each side is specialized for specific functions, although there is some overlap between the two halves. The left side is generally involved in speech, sequential and analytical processes. The right hemisphere processes patterns, music and spatial relationships. Jensen (2008) warns that the left-right distinctions are an oversimplification of our current model in understanding how the brain works and can differ according to gender, occupation and handedness. For example, while most people process musical melodies and rhythms in the right hemispheres, this function migrates to the left-brain in accomplished musicians. Therefore, any teaching theory based solely on left-right distinctions should be considered outdated.

There are three types of memory involved in processing information. Sensory input is processed first in the thalamus, which must filter and screen for relevance. As a sensory stimulus enters the brain, neurons are fired to direct the incoming information to the correct processing area where it is stored in short-term memory for up to thirty seconds. Information is prioritized with emotional data receiving the highest priority. Sousa (2006) summarizes, “emotions consistently affect attention and learning” (p.44) and strengthens the neural network that encodes emotionally laden memories. Because of the physiological response that the brain has when emotions are involved, learning and emotions are intertwined. Emotions are biological responses to stimuli and when activated, insure that students will be more likely to attend to and remember associated content. When emotions are connected to sensory data, neural connections become stronger. Humor, stories and songs are all excellent devices for activating an emotional response, getting attention and encoding multiple neural connections (Sousa, 2006). The more pathways created, the more solid the memory. Any activity that encodes multiple memory routes will result in enhanced learning. Content embedded in music and songs is effective in activating multiple neural networks (Jensen, 2008).

Working memory is processed in the frontal lobes and temporarily holds a limited number of “chunks” of information for conscious processing. In music, lyrics and melodies are chunked together into patterns of rhythm and verse to enable longer passages to be retained in memory. While processing sensory information, the longer a stimulus is held in working memory, the more likely it will be found meaningful and be encoded in long-term memory. As information is moved into long-term memory, intricate neural connections are made, based on relevance and past experience. From a

physiological perspective, memories are formed when a series of neurons repeatedly fire together in a sequence or pattern. The more frequently these neural connections are activated together, the stronger the memory. The greater the number of connections made and attached to a memory, the more likely it is to be stored in multiple neural networks, allowing for different methods of retrieval.

Retrieval of information stored in memory occurs when dormant neurons are triggered. The more pathways that have been established, the more ways there are to access memory. In music, melody and lyrics work together to cue each other for memory retrieval (Sousa, 2006). Neuroscience also suggests ways in which educators can improve recall. By providing memory cues, neural networks are triggered. When multiple neural paths have been established, memories can be accessed using more than one stimulus. For example, in songs, melodies and lyrics can provide recall cues for each other. "Music aids memory because the beat, melody and harmony serve as 'carriers' for the semantic content. This is why it is easier to recall the words to a song than a conversation" (Jenson, 2000, p.73).

The most important implication for learning from the field of neuroscience involves the activation of emotions when learning. "It is the reason that advertisers package so much of their message in stories and scenes that are intended to tug at the heart and kindle basic emotion" (Caine & Caine, 2001, p.47). Any instruction situated in emotion binds and improves learning (Jenson, 2008). Neuroscientists have begun to unlock the mystery of why music activates emotion. As a listener processes sensory input from music, the brain uses patterns of familiar schema based on experience to predict what will come next. There is a never-ending cycle of listen and predict, listen

and predict, as a musical piece is played or sung. “Music sets up anticipations and then satisfies them” as the listener searches for expected patterns (Jourdain, 1997, p.312). When variations in expectations provide surprise, an emotional response occurs and the amygdala is activated. Composers use bridges and other musical devices to control expectations by deliberately and methodically breaking established patterns (Levitin, 2006). Emotional responses to music enhance memory by focusing attention to establish stronger and multiple neural connections (Jensen, 2000). Melodies used in science-content songs can be used to carry science content information, and because of the emotional response elicited by music, “there’s a greater likelihood that the brain will encode it in long-term memory” (Jensen, 2008, p.75). Music is emotionally powerful and memories encoded in an emotional state are stronger and offer multiple paths for encoding and retrieval.

Jenson (2005) summarizes why educators should include music in the curriculum based on our current understanding of how the brain works. Its social nature, emotional impact, ability to carry a message; accessibility and relevance are all cited. In listing ways to implement a music-rich curriculum, Jensen suggests using songs and melodies to introduce content, build community, enhance learning, assist in memory and convey information (2005).

Musical Imagery Repetition

Music’s special capacity for involuntary recall means that is that it is possible for science-content songs to become ‘stuck’ in the head. Tunes that are overly repetitive, simple in nature but have unexpected elements can become “earworms” (Cunningham, Downie & Bainbridge, 2005). Bennett has coined the phrase ‘Musical Imagery

Repetition' (MIR) to describe this phenomenon and defines it as "previously heard music that, while consciously unintended, repeats uncontrollably and pervasively in thought" (2002, p.2). Music is encoded into memory using an organized and structured format based on relevance. Important notes get priority for encoding, while the brain establishes certain entry and exit points in the stored memory of a musical selection. This phenomenon explains why when remembering part of a song, the brain "backtracks" to a natural starting point rather than recalling the lyrics or melody mid-phrase. These melody echoes are generally small pieces of a song equivalent to the capacity of working memory, approximately fifteen to thirty seconds in length (Levetin, 2006). These "earworms' can be powerful for voluntary or involuntary memory activation and are a commonly reported occurrence (Liikkanen, 2008).

Musical Imagery Repetition episodes can occur up to sixty years after the song was last heard and the chorus is the most likely part to become an earworm. Research by Bennett (2002) has provided some insight into melodies that become earworms. In order for a song to become an earworm, Bennett has suggested the 'Rule of Nine' hypothesis; a song must be of average complexity, with the chorus repeated three times and the song heard three or more times. When science-content music has the ability to become 'stuck in the head,' it becomes a mnemonic device to enhance learning in the classroom. Farnsworth (as cited by Bennett, 2002) states that when music is used as a mnemonic device, it can facilitate learning.

Music and Mnemonics

Storr (1992) cites evidence from several researchers that songs, as a form of communication, most likely preceded verbal language in prehistoric man and music has

been a powerful form of communication throughout history. “Preliterate societies relied on songs and poems to convey information, perhaps because the rhythmic structure that characterizes these forms of communication are easier to remember than is the verbal form that characterizes written speech” (Sloboda, cited in Clavert and Tart, 1993, p. 245). According to Storr (1992), “the mnemonic power of music is still evident in modern culture. Many of us remember the words of songs and poems more accurately than we can remember prose” (p.21).

Belleza (1981) defines mnemonic devices as “learning strategies, which can often enhance the learning and later recall of information” (p.247). These memory aids cue recall of information using visual images, or words in the form of sentences and rhymes, and work by building associations within cognitive structures. Mnemonic strategies have been utilized for thousands of years to help learn speeches and other forms of prose. Bruning, Schraw, Norby and Ronning (2004) identify stories, rhymes and songs as specific mnemonic devices associated with visualization and language devices. According to Hodges (1982), songs and rhymes are “ready-made mnemonics” (p.27), suggesting both can be used in content areas to make recall of information easier.

Peterson and Thaut (2007) suggest, “music provides a helpful mnemonic for verbal learning throughout life and most notably during early development and in educational settings” (p. 217). In a study conducted by these researchers, subjects were asked to recall information presented either verbally or musically while brain activity was monitored using electroencephalogram (EEG) technology. Conclusions from the study indicate that the brain responds different to music, and that music and

songs can be effective mnemonic devices for facilitating student engagement (Peterson & Thaut, 2007).

The use of science-content music as a teaching strategy to help students understand, learn and engage in science has been overlooked in research as well as in the curriculum. Recommendations for implementation of science-content music into the curriculum include using simple, catchy melodies emphasizing key ideas that are embedded in the lyrics, choosing songs that repeat the chorus at least three times and contain a bridge, humor, metaphor or other device for attention and surprise. Playing the song a minimum of three times enables musical imagery repetition, allowing for easy recall. Songs can be played at any point in the learning process and can be the focus of a lesson or used to supplement it to enhance and enrich learning (Wallace, 1994; Bennett, 2002; Jenson, 2005; Crowther, 2006).

Multiple Intelligences

There are differences in how each child's brain works, and in how people acquire and represent knowledge. To reach out to students with varying intelligences, teachers should "expand their repertoire of techniques, tools and strategies beyond the typical linguistic and logical ones predominantly used in U.S. classrooms" (Armstrong, 2000, p.38). Music, art, story and humor are but a few methods by which teachers can engage their students emotionally in the content being presented and provide multiple stimuli for encoding and recall of memories. In his groundbreaking book, *Frames of Mind* (1983), Gardner applied new understandings about brain function to develop a theory of human intelligence. Based on potentials and capacities inherent in biology and psychology (Gardner, 1999), eight different intelligences, or ways of solving

problems and producing products, eventually emerged. The criteria for defining what is and is not considered an area of intelligence is related to evolutionary history, neuroscience, psychology, and "end-state" performances. The intelligences defined by Gardner currently include linguistic, logical-mathematical, spatial, interpersonal, intrapersonal, naturalist, bodily-kinesthetic and musical.

Musical intelligence is but one of the eight identified human potentials, but develops first in children. While not every child will be reached through music, there are connections that can be made through the use of music to other intelligences. Song lyrics involve linguistics in rhyme and analogies, rhythm and beat invite kinesthetic movement, and melodies provide a unique link between math and music in pattern and form (Armstrong, 2000; Gardner 1999). Using science-content music in the classroom allows teachers to embed information in melodies for instruction. Additionally, to develop Musical Intelligence, students can be allowed opportunities to demonstrate learning by composing their own content-rich songs.

In applying multiple intelligences theory to education, Gardner advises that there is no single instructional model advocated. Rather, multiple approaches to instruction should be developed for content area learning. Instruction based on this theory does not define a single teaching method, but establishes support for diverse learning styles, includes choice in assessment options and provides a significant role for the arts in meeting the needs of both students and teachers (Gardner, 1999).

Nature of Learning

Brain-based learning theory provided the theoretical framework for understanding how science-content music can be used for learning, but constructivism provides some

insight into how songs are used to build knowledge. According to Kahveci & Ay (2008), there are several common elements shared by constructivism and brain based learning theories. These approaches "have emerged out of two different fields but had commonalities in their implications for education" (p. 127). The principles that are shared by constructivism and brain based learning include the importance of meaningful learning, recognition that there are individual differences in how people learn, there can be multiple representations in learning, personal and environmental factors affect learning and finally, affective components influence learning (Kahveci & Ay, 2008). Brain-based learning "crosses and draws from multiple disciplines" (Jenson, 2008, p.4) encouraging multiple representations on which students can construct knowledge. Songs will resonate with some learners more than others, as there are differences in how children learn, a cornerstone of constructivist learning theory.

Constructivism as a theory for building knowledge is based on the understanding that learning occurs through experience to make sense of the world. When students are exposed to new experiences they integrate it with prior experience to build onto existing knowledge structures or to reconstruct them. According to Fox (2001) the tenets of constructivism are that learning is an active process of constructing knowledge; and while it is personal in nature, it is built through a social process in order to make sense of the world. Pellegrino, Chudowsky and Glaser (2001) discuss learning in terms of cognitive theory, which is based on constructivism in that it describes learning as an active process by which knowledge structures are built as students are exposed to new experiences and information. The role of prior knowledge is critically important in developing conceptual understandings. Cognitive learning theory is also

connected to brain-based learning theory in that it describes how mental structures, or schema, are built through interactions of experience with memory and cognition. In this study, student learning is considered to be constructed through the interpretation of and interaction with songs presented during teaching. Science-content music provided a novel learning experience, which students used to help construct new knowledge.

Songs and Science Instruction

Banilower, Cohen, Pasley & Weiss (2008) in *Effective Science Instruction: What does Research Tell Us?* identify characteristics of effective instruction based on a synthesis of the research. The purpose of this publication is to inform policymakers, instructional leaders and educators for improvements in science education. The recommended characteristics begin with the importance of motivating students and stimulating their interest in any new content that will be covered in a unit or set of lessons. This can be done in a number of ways, including providing a real-world context or asking an interesting question that will spark their curiosity. The second element that is described in this document is to elicit students' prior knowledge. Students bring a knowledge base to learning that is based on experiences that is important to understand as new content is introduced. Some of their ideas can help learning; others can hinder it. Third, students must be engaged intellectually with the content through experiences connected to the learning goals. These can range from hands-on lab activities to well-developed, interactive lectures. The fourth element of effective instruction is for students to use evidence to make and evaluate scientific claims. Finally, the last element involves students participating in sense-making activities designed to help them connect ideas and organize their new knowledge into existing frameworks.

Research from differing traditions on how students learn provides the basis for these recommendations on effective elements of instruction. Conceptual change research is based on science as a process of constructing knowledge through the development of gradually improving models. Learning, according to Duschl, Schweingruber and Shouse (2007) in *Taking Science to School*, is a result of the interaction between experience and instruction. Conceptual change, constructivism and cognitive or brain-based learning theories all inform the recommendations for effective science instruction made by Banlower, et al. (2008) by addressing experiences and how they are processed as the foundation for learning. These learning theories are included in the conceptual change research tradition. Conceptual change theory establishes the importance of considering prior knowledge and providing experiences that will help students build new knowledge networks. Insights from cognitive learning theory suggest the importance of getting students engaged and emotionally connected to learning, as well as using metacognitive strategies to help build the networks promoting conceptual change.

Although the authors of *Effective Science Instruction* specifically refer to the influence of conceptual change theory in informing current recommended practices, the influence of socio-cultural research can also be seen in the recommended characteristics of instruction. According to this perspective learning is a social process by which "individuals are actively engaged with others in attempting to understand and interpret phenomena" (Driver, Asoko, Leach, Mortimer & Scott, 1994). Furthermore, students can only participate effectively in the process of science if they understand the language of science. Research in the socio-cultural tradition also informs the elements

of instruction by stressing the importance of emotions and engagement in teaching and learning. Engagement is defined as "the student's psychological investment in and effort directed toward learning, understanding or mastering the knowledge, skills or crafts that academic work is intended to promote" (Newmann, Wehlage and Lamborn, 1992 p.12). Newmann (1992) indicates that active involvement, commitment and concentrated attention to learning are all part of engagement. Engagement is critical for learning, according to Schlechty (2002), and students learn more when authentically engaged. The socio-cultural perspective informs the effective elements of instruction through research that aligns with learning the language and discourse of science for participation as well as addressing motivation and engagement of students in learning.

In *Effective Science Instruction* the authors discuss the debate between traditional teaching methods and active, hands-on instruction. Students can learn regardless of the technique, as long as they are "motivated to learn and intellectually engaged in activities and/or discussions focusing on what they already know" (Banlower, et al. p. 5). Additionally students must evaluate evidence, make sense of new ideas and connect concepts presented while learning. Effective learning activities can include interactive lectures, inquiry based labs and other innovative techniques that engage students in learning. Prensky (2001) refers to students who are coming to our schools today as part of a generation of digital natives and suggest that new technologies can help engage and motivate learning. Today's students "have spent their entire lives surrounded by and using computers, videogames, digital music players, video cams, cell phones, and all the other toys and tools of the digital age" (p. 1).

Music speaks to the current generation of digital learners in novel ways. These students download songs instantly from the Internet, tune into MTV while studying, carry tunes with them to school on MP3 players and listen to music while working. Science-content music and can be used to enhance learning if integrated into instruction effectively based on a conceptual change research perspective, which includes elements from both cognitive and constructivist learning theories. Science songs are rich in content and can be used to engage students and help them construct knowledge in different ways. Songs carry content information in the lyrics and have the potential to help students become familiar with the language of science. Music is a part of the culture of digital natives and in this way is also related to socio-cultural aspects of learning. Using recommendations from *Effective Science Instruction,* science songs can be used to introduce new content by asking questions related to the theme of songs presented in the engagement phase of instruction. Lyrics can be analyzed as one of a series of experiences designed to build understanding of science concepts during the conceptual development stage of teaching. Finally, as students are asked to make sense of new content and connect ideas, science-content music can provide analogies and insights to help students build networks of understanding in the final stage of instruction. When used effectively music can help facilitate the process of conceptual change during several steps in the instructional sequence suggested by Banilower, et al. (2008).

CHAPTER 3: METHODOLOGY

Theoretical Framework

Understanding what happens when science music is implemented as a teaching strategy can best be explored through a constructivist approach to qualitative research. Qualitative inquiry, according to Stake (1995) is constructivist in that it attempts to gain understanding from experience through descriptions and interpretations with which knowledge can be constructed. Constructivism is based on the belief that knowledge is constructed from experience, understood through perceptions, and attempts to understand phenomena "within the context in which they are studied" (Patton, 2002. p100). This study used constructivism as the theoretical framework because the perspectives of both students and teachers in the classrooms where science songs were used as a teaching strategy become important to developing an explanation, description and understanding of the phenomenon. Meaning is constructed by individuals through interaction with their world, and cannot be separated from experience. "When we describe something, we are, in the normal course of events, reporting how something is seen and reacted to, and thereby meaningfully constructed, within a given community or set of communities" (Crotty, 1998. p. 64). This study explored how students constructed new knowledge when music was used as a teaching strategy.

Constructivism is ontologically related to relativism in that reality is individually constructed, and the perspective of all participants in the classroom was important in

understanding a phenomenon, as each informed the study in different ways. Research embedded in a constructivist design recognizes the different ways in which reality is experienced from different perspectives (Patton, 2002). A constructivist approach seeks to understand the meanings of research participants by listening to their stories and describing their experiences (Charmaz, 2000), calling for use of case study methodology. By exploring the different perceptions of students and teachers when science songs were used as a teaching strategy, a description and explanation of the experience was constructed from multiple cases, helping to facilitate an understanding of the phenomenon.

Multiple Case Study Analysis

Multiple case study analysis was selected as the research methodology for this study in order to explore the use of content music when used for teaching and learning in the middle school science classroom. According to Benbasat, Goldstein & Mead (1987), case study research is best suited to exploring the experiences of participants while exploring a phenomenon in its natural setting. The purpose of this type of research is to provide an in-depth understanding of an issue (Creswell, 2007) and is recommended to investigate a phenomenon in depth and in context to describe its most meaningful characteristics (Yin, 2009). Case studies convey experience and offer interpretations of data to gain insight (Stake, 1995). As a form of inquiry case studies investigate “a contemporary phenomenon in depth and within its real-life context” (Yin, 2009, p.18).

Cases are identified in terms of the bounded system in which the phenomenon is experienced and can be investigated with either an individual focus or by using multiple

cases. Because this study explored the experiences of teachers and students in several classrooms, a multiple case study design was used. Yin (2009) describes this type of study as single case design using multiple units of analysis, however, both Creswell (2007) and Stake (2006) define a multiple case study as one that examines a single issue, illustrated by multiple cases, which is the definition that is most consistent with the design of this study.

In designing multiple case studies Stake (2006) describes each case as a separate entity with common conditions and recommends it as being well suited for educational research. Multiple case studies are "a collection of situated case activities in a binding of larger research questions" (p. 90). Stake describes the characteristic that is shared by all individual cases within a study as the "quintain" which is a concept that contextually binds the cases together. The quintain, or common condition, for this study was the use of science-content music for teaching and learning. In multiple case study research, each individual case adds to the understanding of the quintain by examining real situations in which the "activity of the case as it occurs in its context and its particular situation" (Stake, 2006, p. 2). In this study each case was bounded by the middle school science classroom using science-content music for teaching and learning. Creswell (2007) recommends multiple case study research should contain no more than four cases. However, according to Stake (2006), between four and ten cases are considered ideal to better understand experiences of participants and the quintain, leading to the targeted number of six classrooms for the units of analysis in this study.

Case study research relates to my theoretical framework by attempting to construct an understanding of knowledge from participants' experiences related to the phenomena, rather than to discover knowledge or establish causality. This study was designed to contribute to knowledge about teaching and learning through ideas that emerged by exploring the experiences of individuals (Patton, 2002), which is aligned to the theoretical assumptions of Constructivism as the interpretive framework.

Site Selection

In this qualitative, multi-case research study, the research sites selected were six middle school science classrooms in the suburbs of a major southeastern city, chosen based on geographical proximity to my school and home. Public middle schools located in the same school district as mine, closest to and including to my work place, were the targeted research sites, to allow for data collection during working hours. Access was provided with district approval (Appendix A) through inter-district email for all stages of recruitment in this study. The first email was directed at school principals and asked for permission to collect data at their location (Appendix B). Four building level administrators responded with permission to contact their teachers and participate in the study (Appendix C). In the second email, science teachers at these schools were sent an invitation (Appendix D), which was followed up with a personal appeal during a district level professional development session in late August. Although a number of teachers indicated an interest in participation, a total of seven teachers from the three final sites sent email responses volunteering to participate in the study. One school where administrative permission to collect research was obtained did not participate in this study, as teachers there did not respond to the invitation. One of the seven

teachers who initially volunteered changed her/his mind and withdrew from the study before data was collected.

According to Stake (2006) sampling is not considered as an appropriate strategy for case study research. Stake suggested that cases "be selected because they represent the program or phenomenon" (p. 23) and that cases be chosen based on relevance, diversity and opportunities to learn about experiences in context (2006). The cases included in this study were based on relevance and the opportunities they provided to observe the quintain. Teachers who volunteered agreed to implement teaching strategies that use science songs for learning in the middle school science classroom. As part of the initial invitation it was requested that teachers must be willing to implement two or more lessons that use songs and include some of the suggested activities, such as a lesson analyzing the lyrics, so that the quintain could be observed. Once the targeted number of cases for this study was reached, the recruitment phase of the study ended and the three schools where administrative permission was received and teachers volunteered to participate became the research sites.

Demographics & Educational Setting of the Research Sites

School A, my school, reported a school population of just over 800 for the 2010-11 academic year. This school is located in the far northwest corner of the county and the students in this school come from primarily rural and suburban homes. About 84% of the school's population is white, while 13% is Hispanic and the remaining 3% multi-racial, Asian, black or other. Just over 29% of the students at this school are identified as economically disadvantaged based on free and reduced lunch data. School B is located approximately 10 miles southeast of School A and is located in the center of the

county seat. This school has a population of approximately 750 students, and is 67% white, 22% Hispanic, 4% black, 4% multi-racial, 2% Asian and 1% other. Forty-four percent of the students at this school are considered to be economically disadvantaged. School C is 12 miles due east of School A and has a population of fewer than 800 students from mostly suburban homes. White students constitute 84% of this school's student body, Hispanic students compromise 11% with the remaining population identified as multi-racial, black, Asian or other. About 41% of the students at School C are economically disadvantaged (Forsyth County Schools, 2010a).

TABLE 2: Site Demographics

School	Caucasian	Hispanic	Other	Disadvantaged
A	84	13	3	29
B	67	22	11	44
C	84	11	5	41

All three middle schools included as research sites for this study use an instructional model teaching traditional core classes (language arts, math, science and social studies) on a daily basis, along with optional classes for physical education, art, music, band, foreign language and technology. Teachers work in interdisciplinary teams and share common students at each grade level. Advanced courses at these schools serve gifted and able students, while others are inclusion classes that serve regular and low-performing students or children with special needs. As a rapidly growing suburban community, the district has nearly doubled its student population in the past decade resulting in a cross section of students and teachers from diverse

geographic regions immigrating into the district's school system (Forsyth County Schools, 2010b).

Participants

Each of the six classrooms used for this study, including the teachers and students, were a separate unit of analysis, or case, for the purpose of data collection. In order to address the element of diversity, teachers and classes from each middle school grade level (6, 7 & 8) were included in this study. Four of the teachers who participated in this study taught on-level classes. Two were sixth grade earth science teachers, one was a seventh grade life science teacher and one was an eighth grade physical science teacher. These educators included two male and four female teachers with between nine and thirty years of experience. All of these classes included special education or ESOL students using an inclusion model. Two of the teachers taught advanced eighth grade physical science, although both were responsible for teaching other courses in addition to the classes included in the study. One of the teachers who participated in this study had prior experience with using songs for teaching, while all the others implemented the use of science-content music for the first time during the course of this study.

In the initial meeting with each teacher some basic information about using songs for learning was shared based on current research and the outcomes of the pilot study (Appendix E). Each teacher was encouraged to choose songs that would best fit their curriculum and implement the use of songs in the curriculum in whatever ways they saw appropriate. However, all teachers were asked to include a lesson in which students read and analyze the lyrics of the songs selected for instruction as part of the study.

This recommendation was a result of the research and conclusions made in the pilot study about how songs should be used as effective tools for student learning. Other suggestions for implementation were made based on recommendations by Crowther (2006), who recommends that songs be selected which have an easy-to-sing melody and must be heard by students more than once to emphasize key points. He recommends that students be given the lyrics and that music is used selectively as one of several activities in the learning process (Crowther, 2006). Additionally, it was suggested that teachers select songs that contain a bridge, humor, metaphor or other devices for gaining students' attention, and playing the song a minimum of three times to enable musical imagery repetition. Teachers were encouraged to use songs at multiple points in the learning process as the focus of a lesson and to supplement instruction based on practices suggested in the literature (Wallace, 1994; Bennett, 2002; Jenson, 2005; Crowther, 2006).

As an incentive each teacher who participated in the study was provided with a number of resources with which to implement the use of songs for teaching. All teachers were provided with the book, *Top Tunes for Teaching, 977 Song Titles and Practical Tools for Choosing the Right Music Every Time* (Jensen, 2005) and a variety of science songs on CD from various artists. The following audio disks were distributed to these teachers, depending on the grade level and curriculum they taught:

- Banana Slugs, *Slugs at Sea* (1991) – sixth grade earth science teachers
- Jeff Moran, aka Dr. Chordate, *Parts is Parts* (1998) – seventh grade life science teachers
- Michael Offutt, *Physics Songbag* (1995) – eighth grade physical science teachers

- They Might Be Giants – *Here Comes Science* (2009) – all teachers
- Larry Morris, aka Professor Boggs – *Mad Science Factory* (2005) – all teachers
- Larry Morris, aka Professor Boggs – *Round the World With Science* (2010) – all teachers

My husband, Larry Morris, wrote the final CD, *Round the World With Science,* during the summer of 2010 specifically for use in this study. The songs on this audio disk targeted a variety of topics for use at all middle school grade levels based on the researcher's experience and familiarity with the curriculum map used to guide instruction during the part of the academic year that this study took place. Specific elements of effective songs for teaching discovered in the review of the literature and during the pilot study were employed in writing the songs that were included on this CD. The intent was to make sure teachers who participated would have easy access to songs that fit into their curriculum based on the standards they were required to cover during the research period, although they were free to select from songs found on any of the resources provided or use additional references.

In this study student focus groups were used to collect data from students based on their experiences when using songs for learning. These generally consist of seven to ten individual participants, although this number can vary (Marshall and Rossman, 2006). Ideally, the students who participated in these group interviews would have represented a cross section of the students in each teacher's classroom and included a balanced number of students of each gender, socio-economic class and ethnicity. However, the number and composition of students in each focus group for this study was dependent on each teacher obtaining parental consent from students willing to

participate. Once a day and time was determined for classroom visits, each teacher was asked to send home letters to the parents of students in the targeted class advising them of the upcoming visit and inviting students to participate in focus group discussions. Parents were advised that students would only be interviewed with parental consent and that as incentives, students who participated in focus group discussions would receive a copy of the Professor Boggs CD, *Round the World With Science* (Morris, 2010) as an incentive. Participating teachers were given the responsibility of obtaining and collecting permission slips from students and their parents. A copy of the letters and forms sent to parents can be found in Appendix F.

A total of fifty-seven students volunteered to participate in these focus groups, which included thirty-eight girls and nineteen boys. The number of students from each classroom varied from between four and sixteen. Twenty-seven students were sixth graders, five students were in seventh grade and twenty-five were in eighth grade.

Data Collection

Case study designs collect data from multiple sources, including interviews, observations, documents and artifacts (Creswell, 2007, Yin, 2009, Stake 2006). The classroom, including the teachers and students who worked in it while science songs were used as a teaching strategy, were considered a single unit of analysis. Observations, teacher interviews and student focus group discussions were the primary methods involved in data collection for this study and were used to explain, describe and understand the experiences of teachers and students when science songs were used as a teaching strategy in the middle school classroom. Data for this study were

collected over a four-month period during the fall of 2010, beginning in September 2010 and concluding with the final interviews conducted on January 3, 2011.

Interviews:

In this study three interviews were conducted with each of participating teachers before, during and after the completion of a teaching unit in which he/she used science-content music as a part of the curriculum. This interviewing schedule was based on recommended interviewing strategies by Marshall & Rossman (2006). The first of the three interviews was designed to inquire about the background, past experiences and expectations of each teacher participant. These interview questions were based on recommendations by Stake (2006) about understanding each participant's background, and important later in understanding and interpreting data. Subsequent interviews focused on participants' perceptions, impressions and conclusions about their experiences using science songs.

While Marshall and Rossman's recommendations related to the number and timing of the interviews, suggestions by Stake (1995) and Glesne (2006) guided the format of the interview and type of questions to ask. According to Glesne (2006) the type of interview most appropriate when discussing an experience is the topical style with a semi-structured format. In this type of one-on-one interview participants are asked about their opinions, perceptions and attitudes about a particular process; in this case the experience of using science-content music for learning. Stake (1995) suggests that interviews for case study research begin with a brief list of questions and use probes to generate descriptions and explanations. He suggested that interviews provide indirect evidence about a phenomenon and are best used "to obtain the

descriptions and interpretations of others" (p. 64). They are ideal for eliciting descriptions and explanations from different participants to discover multiple perspectives. Teacher interview guides used for this study included basic topics and ideas to focus on with a few open ended questions that were intended to lead to more of an informal conversation. This approach is considered a hybrid interview type (Patton, 2002). Questions for each interview were designed to elicit participants' experience, opinions, knowledge and feelings about the quintain. Protocols for teacher interviews can be found in Appendix G.

In this study the three teacher interviews were used to collect information about how teachers make use of songs for learning and to reveal perceptions about their potential for teaching and learning science. The initial interview occurred between September 9 and September 27, 2010 with each lasting between four and eleven minutes. During the initial interview questions and probes were used to guide the interview, although to facilitate a less structured format, the discussion varied depending on each teacher's background and experience. The questions at this interview were designed to establish the teaching experience and background of each participant, including their prior use of songs for teaching and learning.

The second interview was intended to discover information about the ways teachers were using science songs in their classrooms, and to give them a chance to respond to observation data and information students shared in focus group discussions. Teachers were asked to schedule an observation visit during their use of a second song for teaching and at the same time, a student-focus group interview. This visit was followed up with a second interview about a week afterwards. The timing of

the visit was based solely on each teacher's implementation of songs in the curriculum. The second interviews occurred between November 10 and December 14, 2010 and lasted between nine and forty-two minutes each. The second interview gave participating teachers the opportunity to give an update on the strategies they are using with songs for teaching, and how they perceived their students were responding to the lessons that include science-content music. Teachers were given a summary of the data from class observations and student focus group sessions, then asked to respond based on their experiences.

The third and final teacher interview was designed to allow teachers an opportunity to summarize their experiences and reflect on what they discovered about how songs could be used for teaching and learning. These final interviews were conducted at the end of the study, between December 8, 2010 and January 3, 2011 and lasted between nine and twenty-five minutes each. An interval of at least two weeks occurred between the second and final interviews. Questions and probes used to guide the final interview asked teachers to summarize their experiences, identify the ways in which they believe science-content music could be used for teaching and learning science concepts, how students responded to the experience, and what these teachers thought about the potential for songs to enhance learning. Certain additional questions for each third interview were individually prepared for each teacher, based on information and analysis of the first two interviews, to expand or clarify key ideas.

Focus Groups:

Focus groups, as a form of interviewing, are especially appropriate for interviewing children and adolescents who may feel more comfortable talking with their

peers when interviewed. Focus groups are interviews with multiple participants, which encourage discussion in a supportive environment. Combining focus group interviews with observations in case study research is a strategy recommended by Marshall and Rossman (2006). Although focus groups are often made up of individuals who do not know each other, the groups of participants included in this study were from the same classroom, due to time, permission and scheduling constraints. When ten or more students from a single class had permission to participate in focus group discussions, two groups were unsystematically formed for the group interview to allow all students the opportunity to have their voices heard. In three of the cases there were enough students to hold two separate focus group discussions while each of the other three cases had between four and six students participate in a single interview. Therefore, a total of nine focus group discussions, with between four and nine students in each, took place during this study. These interviews lasted between seven and sixteen minutes each, and took place immediately following classroom observations. They were held in neighboring classrooms that were empty at the time they occurred, or in common areas of the school such as the school mezzanine.

Questions asked during focus group interviews were designed to elicit information about student perspectives and how students see the potential for songs to enhance learning. These group interviews were intended to better understand how the students make use of the songs for learning and discover how songs affected their interest, engagement and understanding of science content and concepts. The interview started with soliciting student impressions about the lesson immediately preceding the interview, then more general questions about using songs for learning

science. For a list of questions and probes that were used to guide the focus group discussion, see Appendix H.

Observations:

According to Hancock & Algozzine (2006) observations are often a part of case study research as they are appropriate methods for collecting objective information about a research topic. Observations can provide insights into, direct evidence about, and lead to greater understanding of the quintain in case study research (Stake, 1995). Marshall & Rossman (2006) describes observation as "the systematic noting and recording of events, behaviors and artifacts (objects) in the social setting chosen for study" (p. 98). The observations included as part of this study were used to generate field notes and included detailed information and descriptions of the actions and interactions of the teacher and students during lessons that include science songs.

Patton (2002) discusses the advantages of including observations as a source of data in qualitative research. The ability to "understand and capture context" (p. 262) aligns with the goal of case study research for understanding a phenomenon within its natural context. Observations often reveal information that isn't captured in interviews. For the purposes of this study observation notes focused on key elements of setting, interactions, language and nonverbal communication while students are engaged in teaching activities using science songs for learning, all included in Patton's list of recommendations for observations (2002). My perspective was as an outside observer using an etic approach, as I visited other teachers' classrooms. The only case where students in any way knew me was in the classroom at my school site. Those students knew of me as a faculty member, but had no prior interactions with me. Classroom

observations occurred during a lesson in which teachers were using science content songs as a teaching strategy and lasted between twenty and thirty minutes each. Primary questions that guided the observations include, “How does the teacher introduce the song?” and “What indications of the students’ level of engagement can be observed?” An observation protocol is included as Appendix I. A summary of the data collection methods employed to address each research questions is included in table 3.

TABLE 3: Data Collection Methods

	Research Questions		
Primary Methods of Data Collection to Address Research Questions	In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?	How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?	What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?
Teacher Interviews	X		X
Classroom Observation	X	X	
Student Focus Groups		X	X

Data Management:

I have stored all data collected during this study electronically. Interviews, field notes and focus group data were recorded digitally and transcribed. Electronic records were kept of all correspondence between the participants and me during the study. Information used to identify specific subjects has been coded and all participants have been identified by pseudonyms to preserve anonymity. Field notes, interview

transcripts and observation records will be kept electronically and all records, including parent consent for minors to participate, will be maintained either on file or disk for a period of five years. Coding and analysis of the data collected in this study was completed using a software program, *HyperResearch* by Researchware (2009), which allows for easier management of the data and cross-case analysis.

Data Analysis

According to Creswell (2007), the unit of analysis includes more than one individual or event as part of an event, program or study. In this multiple case study each unit of analysis included the teachers and students in their middle school science classroom while participating in the activity of using science content songs for learning. The process for cross-case analysis in multiple case studies recommended by Stake (2006) was used to provide insight into the quintain, or use of content music in the middle school science classroom, in this study. In a cross-case analysis the uniqueness of each case is explored while searching for commonalities. Each case provides insight into the quintain, but stands on its own as a unique description of the phenomenon under study. Finding balance between individual cases and the quintain is important in analyzing data. There are three different approaches that can be taken to multiple case analyses, depending on the goals of the study. The first track emphasizes individual case findings; the second on convergent findings and the final option compares findings to explore areas of divergence. In this case study the second variation of cross-case analysis was applied to merge findings and identify patterns of convergence across cases (Stake, 2006).

In this multiple case study analysis, data from each case was first analyzed independently using an inductive, open coding process, which is the main activity in a cross-case analysis (Stake, 2006). Patton (2002) describes the process of case study research whereby the data is condensed, organized and analyzed to produce a record of each case within the study. According to Creswell (2007), case study data should be analyzed holistically based on identifying issues and common themes using constant comparative analysis and a rich, narrative description is constructed from the data. An inductive approach is recommended to allow themes to emerge from the data, which is the method that was used to analyze individual cases in this study.

In this study, transcripts from individual teachers, focus groups and field notes generated during observations for each case were analyzed using the open coding method for first round analysis described by Saldana (2009) and Charmaz (2006). In this process data was reviewed line-by-line to "separate data into categories and to see processes" (Charmaz, 2006, p. 51). Saldana (2009) suggests this method is most "suitable for interview transcripts" (p. 82). Through this open coding method categories and processes were defined and general patterns emerged. Stake (2006) emphasizes the importance of identifying themes in analyzing data from each case independently before conducting a cross-case analysis. Charmaz (2000) provides a detailed technique for data analysis using systematic strategies from a grounded theory approach to data analysis that is applicable to any type of constructivist or interpretive research, including this case study. "Grounded theory provides a systematic analytic approach to qualitative analysis … because it consists of a set of explicit strategies" (Charmaz, 2000. p.522). The methods described for data analysis begin by coding of

transcripts, field notes and memos to define and categorize the data. As data is coded, line-by-line, patterns begin to emerge. A continuous process of negotiating back and forth between the data, the codes and memos refine the emerging themes as a part of the process. Categories are refined and data between cases compared until themes are identified that describe the phenomena. The use of a grounded theory approach to inductive analysis was chosen on the basis of explicit, defined strategies that guide the analytic process and its emphasis on thematic analysis for this study (Charmaz, 2000).

Writing analytic memos is a part of the inductive analysis process to elaborate about the codes and data. In this study memos were written after the initial coding process for each interview and focus group discussion separately to summarize experiences and perceptions (Saldana, 2009). These memos were used in a "member check" process to address validity and as a guide for subsequent interviews in the study. These memos were further reviewed as part of the final round of coding. According to Saldana (2009) this method is appropriate as "analytic memos themselves from the study can be coded and categorized" (p. 41). A focused coding method was implemented on the second round of analysis utilizing observation memos, interview and focus group transcripts to identify common elements and identify emergent themes. These themes, generated during the final analysis, were used to summarize the data about the quintain related to each of the research questions by case (Stake, 2006).

Once individual cases were analyzed, a cross-case analysis was begun by merging the themes developed independently in each case in order to learn more about the phenomenon being studied. In this study a second method suggested by Stake for cross-case analysis was used to make generalized assertions about the quintain by

exploring the uniqueness and commonalities of each case through a synthesis of findings (2006). This track emphasized merging the findings from individual cases using the themes identified in the open coding process to develop generalizations related to each research question. Stake uses the term “generalization” to refer to broad findings, or assertions, that are shared by the cases represented in the study. The findings of the individual cases were synthesized by identifying convergent themes to construct a summary of assertions to develop a deeper understanding of the quintain, in this case the use of content songs for teaching and learning (Stake, 2006). Data from each case contributed to final assertions about the quintain and provided evidence to support them. Areas of divergence in data were also explored to provide additional insights.

Validity:

In this study interview, observation and focus group data was used from six different cases to understand the experience of students and teachers when science-content music is used as a vehicle for learning in the classroom. According to Patton (2002), triangulation of the data provides for a higher quality of data by allowing for correspondence and corroboration. In this case study triangulation was considered both within and across cases. It was first addressed independently in the analysis for each case then across cases to provide a clear and meaningful representation of the quintain. Cross-case analysis is dependent on thoroughness in the development of themes and assertions in the individual case analyses. By considering issues of validity carefully and completely at the individual case analysis phase of research, cross-case analysis validity was addressed (Stake, 2006).

According to Stake (2006), triangulation within cases is considered as a "process of repetitious data gathering and critical review of what is being said (p. 34). Because case study research is constructivist in nature, multiple constructions can occur based on context, understandings and experiences of the observer. Triangulation is an attempt to "assure that the right information and interpretations have been obtained (Stake, 2006, p. 35). Denzin (1978, as cited by Patton) identifies several methods by which qualitative research data can be triangulated. These include the use of more than one type of data, investigators, theories and methods. Data source triangulation was used in this study by collecting multiple types of data: classroom observations, teacher interviews and student focus groups.

Member checks are another way in which validity was addressed in this case study. Stake (1995) recommends this strategy for addressing validity of the researcher's observations and interpretations. In this study each interview, focus group and observation resulted in a summary of interpretations through the inductive analysis process that were presented to the teacher participants for examination at the second interview. A summary of the first two interviews provided some individualized questions for discussion in the third and final interview. Finally, a summary of the case was sent to each teacher who participated in the study for review. Input was sought in terms of adequacy and acceptability. Revisions, additional comments and suggestions for improved accuracy were solicited (Stake, 1995).

Lincoln and Guba (1986) established four criteria for quality data that were applied in this study. These constructs compare to the concepts of validity, reliability and rigor used to assess traditional research and include credibility, transferability,

dependability and confirmability to address the criteria of trustworthiness in the study. Credibility in this study is addressed by selecting multiple, representative cases to study the use of science songs for teaching and triangulation through use of multiple types of data. Transferability was addressed by providing through thick, rich descriptions that included extensive field notes, interview transcripts and analytic memos. Dependability and confirmability were provided through detailed transcripts and records documenting every aspect of the study.

Limitations:

Case study methodology was chosen on its basis to explore the experiences of the participants in context. According to Stake (1995) cases are selected on the basis of maximizing what can be learned from the participants about their experiences in the natural setting. While the cases included in this study inform our understanding of the quintain, any patterns interpreted from the data should not be generalized beyond the experience of those teachers and students who participated in the research. Each case is bounded by its own, unique contextual conditions and filtered through the interpretations of the researcher. The cases included in this study are limited to the number of teachers who were willing to participate in the research, either because of a genuine interest in employing a new strategy for teaching science concepts, or because of an existing professional relationship with the researcher. For some teachers and students, the use of science-content music was new, and others had prior exposure that could have had an impact on their experiences. Because each of the teachers in this study was willing to embrace a new strategy, their experiences may be dissimilar to other potential cases in which the use of science-content songs might be imposed.

Therefore, no generalizations can be implied beyond the experience of the six cases reported in this study.

Subjectivity & Bias

I am a middle-aged, female teacher with more than twenty-five years teaching experience. I began my teaching career with an early childhood focus and spent five years teaching kindergarten. Over the years I migrated to grades second, fourth, fifth and eventually middle school science teaching. I hold bachelors and masters degrees in elementary and early childhood education, an Ed.S. in curriculum and instruction and am currently working toward a doctorate degree in science education. I am certified to teach multiple subjects and grade levels, including K-12 science certification. The diversity in my background, experience and education has helped me approach classroom instruction from an eclectic perspective. I often implement teaching strategies not commonly used by other secondary science teachers. As a secondary science teacher with an early childhood background, I have found using science-content music and songs as a successful teaching strategy that engages my students and helps them integrate and learn science concepts. It is this experience that helped formulate my research question to explore the experiences of other teachers and students who are interested in implementing this instructional strategy, utilizing science-content music in the middle school science classroom. Through this study I explored the data using a lens of having successfully used science-content music as a teaching strategy in my own classroom. This prior experience could present a potential bias in this study in the direction of a generally favorable view of its use.

CHAPTER 4: DATA ANALYSIS

Overview

In this section I highlight each case by first presenting an overview of each case, followed by a thorough narrative of the themes identified during the data analysis. During the introduction of each separate case an overview of the teacher's background, experience and expectations are presented, followed by a summary of the classroom visit from observation notes. Next, each case includes an overview of the experience as reported by each teacher and the students from interview transcripts. This section includes a summary of how the participants felt about the quintain: the use of science-content music for teaching and learning science. Data are presented from the transcripts in this section include general comments and impressions about the experience from both the student and teacher perspective. A data table and overview provide a synopsis of the themes identified during the analysis, which concludes the introduction for each case.

The presentation of the emergent themes and supporting data for each case is organized by research question. The first research question asked, "In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?" The themes identified relating to this question were based on data found in the observation notes and teacher interviews and revolved around how science-content songs were used by these educators for instruction. Additionally, these themes considered how the teachers perceived that the use of

science-content songs helped meet their instructional goals. The second research question, “How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?” and focused on the students’ perspectives in identifying themes. Observation notes and student focus group interview data was used to identify how students perceived the experience and how they felt it impacted their learning. The third and final research question was, “What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?” The inductive analysis process used to explore this question considered both student and teacher experiences as interviews and focus group transcripts were used to consider the potential benefits for including content rich songs in the middle school science curriculum. A summary is included for each separate case that reviews key idea.

The individual case studies are followed by a cross-case analysis that highlights and merges the overarching themes identified separately in each case. A table is provided that summarizes and categorizes the themes followed by a discussion of the areas where the data converges and diverges across cases in order to better understand the quintain through the experiences of both the teachers and students who participated in this study.

Case 1: Derek Martin’s Classroom

Background

Derek Martin is in his twelfth year teaching, and has been at School C for the past four years. He has a master’s degree in science education and is certified to teach both math and science. Mr. Martin has taught in three different counties within the

state, giving him experiences with students from diverse backgrounds. School C where Derek teaches now is located on the northeastern edge of the school district and that is primarily Caucasian and Hispanic with the second highest rate of students from a low socio-economic background. Mr. Martin is currently teaching advanced students in sixth grade for earth science and eighth grade, physical science classes, as well as an engineering class as an enrichment course. His students are primarily gifted and talented and include few minorities or students with special needs, if any. After hearing about the study at a district level professional development session in late August, Mr. Martin volunteered to participate in the study. The use of songs for teaching was a new concept, and his reason for participating in the study was to try "something that would be novel to the students" and to find "new ideas or resources to get the kids involved and motivated."

Implementation

Derek Martin ended up using several science songs during the course of the study. He first began by using a humorous song about electron configurations called "Atom Shack" (Morris, 2005) while teaching about atoms and matter (see Appendix R for lyrics). During the next teaching unit which covered concepts related to forms and transformations of energy, Mr. Martin introduced two songs; first "Some Kind of Energy," (Morris, 2010) a song about forms of energy, and finally "Conduction, Convection, Radiation" (Morris, 2010) about heat transfer with his eighth grade students. During the final interview Mr. Martin reported that he also used the heat transfer song with his sixth grade science class also during their study of convection in Earth's mantle, and

"Tectonics Rocks" (Morris, 2010), a song about plate tectonics as they studied the Earth's lithosphere.

Observation Summary

On the day Mr. Martin's class was observed, students in his eighth grade advanced science class analyzed the lyrics to "Some Kind of Energy" (Morris, 2010), a song about forms of energy (Appendix K), as an introductory activity for a unit on Energy. Students casually entered the classroom and were instructed to pick up a copy of the lyrics from the back table on the way to their seats. Mr. Martin's room, like all of the rooms in this study, was filled with two-person science tables. At the front was the customary demonstration table, with the teacher's desk on one side of the room and a teacher computer table and eyewash station on the other. The perimeter of the room was lines with built-in computer tables, a district standard for all middle schools in the county. The tables were arranged mostly in rows facing forward, with a large table in the back of the room. The room filled up with students as the teacher took attendance and started the song. The students seem to know that the song was meant as a learning activity, and most quietly followed along with the lyrics. One student was highlighting some of the words on the handout as she listened to the song. None of the students in the classroom sung along or moved with the music, but it was their first time to hear the song. When the song ended, Mr. Martin instructed students to divide into groups and draw mini-posters that gave examples and non-examples of each form of energy presented in the verses of the song. Some groups used the lyrics to pull examples from, while others discussed their own ideas related to the different forms of energy included. During the activity all students participated and were on task. All

groups talked amongst themselves while completing the assigned task, and the noise level was relatively low. Mr. Martin's voice could be heard guiding various group discussions among the groups as he rotated around the classroom. As students finished the activity Mr. Martin collected posters for use in a subsequent lesson and instructed students to put the lyrics in their notebooks for later use.

Overview of the Experience

For this teacher, the use of songs for teaching science was a valuable, new resource. In addition to analyzing the lyrics, Mr. Martin used the songs as a springboard for other activities such as classroom discussions and concept drawings, and found them to be engaging for students and felt that they provided a novel way for students to interact with science concepts on multiple levels. Mr. Martin said that he is "always looking for new ideas or resources to get the kids involved and motivated" and feels that he needs to keep bringing new ways to his students to interact with science content. When material is consistently presented in "usual ways, those ways aren't challenging anymore." He says that, "my challenge is to find other ways to engage them with the content." It was this desire that led him to volunteer to participate in this study, and he found that by using songs for teaching, students engaged with the content in new ways. He found that, "it's a different way of engaging; hearing, auditory, the music, the brain, the beat… it's fun at the same time." Derek reports, "it's different than what they are used to, so automatically you're giving them something new" and "it's totally different so they… can't fall into their old patterns." For Mr. Martin, novelty is important in the classroom. "When something is new, something is different, you're really challenging them," and "it gets them out of their little box." It was obvious to Mr.

Martin that the use of science songs did engage his students from a number of different indicators. He reported that his students would sing along with the lyrics when songs were used in direct instruction, and when the science songs were used as background music, “they liked to sing along.” The teacher said that when he played the science songs in class, students would “start singing along to it right away,” and some “would just start singing it on their own.” Not all of his eighth graders were quite as obvious, and while some would sing, “others would just sit in the desk being cool eighth graders and kind of watch and listen.” Sometimes he would “see some of them swaying… moving to the music.”

The students in Mr. Martin’s class generally liked learning with science songs, according to the six students who participated in the focus group interview. With only one exception, these students thought learning science with songs was fun, and agreed that, “If it’s more fun to learn about something, it’s easier to learn.” One student clearly did not like science songs, and said she’d “rather read it in a textbook.” And while it was important to hear her voice, she was the only one in in the nearly sixty students who participated in this study who clearly did not enjoy the activity. Her main reason was that she wanted information presented “straight out,” and that songs “sometimes go too fast you just can’t hear the words.” However, the other students agreed that learning with songs was fun, and anytime learning is fun, it is easier. They said that learning with songs made their science class more fun, and that it was both an interesting and different way to learn.

Synopsis of Themes

During the analysis, several themes emerged related to each of the research questions based on different combinations of data sources, as summarized in Table 4. Songs help students build scientific vocabulary and can cover a large amount of content in a small amount of time. They are also rich in examples and explanations of science concepts. Songs provided students with a level of engagement that enhanced learning. These students found that analyzing the lyrics helped them understand concepts and suggested that to be useful for learning, science songs had to contain certain characteristics. Songs were an easy instructional resource for teachers to use, analysis of lyrics helps students connect ideas, interact with concepts on multiple levels of understanding, and songs have the potential to be used at various places in the instructional process.

In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?

One way in which Derek Martin used songs for instruction was by helping students build scientific vocabulary. Mr. Martin reported, “I think it worked for introducing them; here’s some important words, or key ideas.” This was evident in both the activity that was observed and in the interview data. During the lesson that Mr. Martin taught during the class visit, students were asked to identify terms associated with different forms of energy from the lyrics. The drawing activity was designed to help students take terms from the song and represent them in a different way. Although students could go beyond what was included in the lyrics, he used the terms from the song as a starting place in the discussion. While the group that was assigned to

TABLE 4: Martin Analysis Summary

Research Question	Themes	Sources	Supporting Evidence
In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?	• Songs help students build understanding of scientific terms • Large amount of content covered in short period of time • Songs rich in examples & explanations of concepts	Teacher interviews & observations	Observation notes: • Student behaviors Coding (Teacher): • Student Responses • Key Terms • Songs Stuck • Instructional Time • Content in Lyrics
How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?	• Specific characteristics of science songs make them effective tools for learning • Analyzing songs helps students understand concepts	Student and interviews & observation	Observation notes: • Student behaviors Coding (Student): • Engagement • Good Science Songs • Negative Examples • Picking Apart Lyrics • Learning • Remembering
What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?	• Songs are an easy instructional resource to use • Songs can be used to interact with concepts on multiple levels of understanding • Analysis of lyrics helps students connect ideas	Teacher & student interviews	Coding (Teacher): • Engagement • Analysis of Lyrics • Conceptual Understanding • Teaching Resource • Other Uses Coding (Students): • Picking Apart Lyrics

illustrate chemical energy talked about how best to represent the concept, Mr. Martin told them to refer back to the song, “It says the energy is in chemical bonds.” The use of songs to develop student vocabulary was one of his instructional goals. Derek explained, “The first time, when I played the song with them, I think it introduced key terms, key ideas, key vocabulary.” He added, “The second time around and we would look at it, and try to find what were all the words that really touched on the content.” The use of songs, “did help them with some terminology, some basic definition they could use.”

The second theme that emerged in this case was that when songs are used for teaching, a large amount of content could be covered in a short period of time. Mr. Martin found that the use of songs for learning “worked nicely because the songs are pretty compact.” He elaborated, “It really doesn’t take that much instructional time,” because the lyrics contain a great deal of information that can cover “several concepts all at once and it is something that will engage them in a short time frame.” The science songs Mr. Martin selected to use have “lyrics that are dense… that are useful with the content.” Because the songs cover so much in such a short activity, Derek found them an effective teaching tool. They provided an opportunity to “hit key concepts” as either an introduction or review in “ten, maybe fifteen minutes each time.” One of the benefits of using songs for Mr. Martin was their potential to provide content rich mini-lessons that could be delivered in short time periods using an easy resource that would engage and stick with his students.

The third and final theme that emerged related to this research question related to how the content in the songs provide students with both examples and explanations

of science concepts. Mr. Martin found that science songs "didn't just merely mention content, [they] actually had content in it." When he first began to select songs for teaching, he found that "they had enough information in them; they had enough detail and content in them that they were very useful and I knew that from listening to them I was like, okay, I'll use this." Through the use of a chorus science songs "repeat some of the concepts so that it's not just in one spot in the song, but it keeps reinforcing that concept, and with examples." In class discussions about concepts, student would "refer back to the songs," and "pull from the song, they would give an example from the song." In observing Mr. Martin's class, students did indeed draw examples and explanations from the lyrics. While deciding how to draw their mini-posters related to forms of energy, students working in groups would read and reread the lyrics. In discussing the activity later, one student said the song, "actually tells you about the energies and stuff." Another reported, "For mechanical energy they gave examples of types of that and they all rhymed." A third student said that, "If you have no clue what everything is, it just tells you right off what everything is." The students obviously found the songs useful for explaining concepts. As a follow up activity, students "labeled each of the lines on how it related to the textbook." The effect of science songs on student learning included the ability to provide both explanations and examples of the science content that the teacher wanted students to learn to help them better understand the concepts.

How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?

According to the students in Mr. Martin's room, specific characteristics of science songs make them effective tools for learning. These students enjoyed learning with

songs, but had definite ideas related to characteristics in songs that would best impact learning. Science songs that can be used for learning should be “short and sweet and to the point,” with “still enough catchiness” to help them with recall. They want songs to “be on one topic,” and they should “be in a nice order.” Songs should contain “a lot of examples” and these students found devices such as rhymes and humor helped make concepts easier to remember. They said that songs that are “catchy and easy to remember” would help them learn what they need to know because they “can go back to it and keep it in [their] heads since it’s catchy.” Songs that were not likely to help them learn were those that “change really quick from one thing to another,” or were “too long and drawn out and too in depth,” because they would “just confuse kids more than what they already were.” While they liked the song about energy they learned on the day of the observation because “there were a lot of examples,” they did not feel the previous song “Atom Shack “(Morris, 2005) was as helpful because it didn’t provide much in terms of useful information about atoms. Some of the dialogue in that particular song was confusing, and according to one student, “got muddled around in my brain.” Mr. Martin also shared some ideas of what he thought were the characteristics of songs that would make them effective for learning science. For him the tune should be “catchy and memorable.” He also notes that “the music, the tune, [shouldn’t] take precedence or somehow overshadow the lyrics.” He articulated what students implied about humor, “they also can be maybe silly; fun is always good if they’re a little bit goofy in places.” For songs to be effective learning tools, the characteristics they need most are a catchy and memorable melody, contain content-

rich information, be simple, and contain elements of rhyme and humor to get students' attention.

The final theme that emerged from the data related to the impact of science songs on student engagement and learning relates to the importance of having students analyze songs. This is a necessary activity if songs are to be helpful for students to use as an effective resource for learning. These students said that when they "pick out the parts that mean something," information they needed to know would "get into [their] head." Another student claimed that when Mr. Martin had them analyze song lyrics, they had "to pick apart what can help you and what you don't really need much." It was this activity that seemed to help students interact with concepts at a meaningful and deeper level and helped them better understand the concepts covered in the lesson. For them the effect of using songs for learning wasn't limited to providing explanations and examples; they reported, "it helps with the whole concept," and has the additional benefit of being "easier to remember something when you have it to a tune." This effect is best be summarized by one student, "So, after saying the words we kind of got it more, and we remembered it a little bit better."

What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?

The interview data from both Mr. Martin and his students was used to identify themes related to the potential for songs to be used in teaching and learning science. The first theme that emerged from Mr. Martin was that science songs are an effective and easy instructional resource to use in the classroom. He commented, "it was very easy to use… since I didn't have to come up with the songs," and "it was certainly nice

to have the lyrics already printed up there." Mr. Martin thought that the science songs provided "another resource to hit key concepts" and "gave [his students] one more reference point." For this teacher science songs were a "useful resource" that "rounded out [his] repertoire of things that [he] can do or access" in the classroom. Not only does Mr. Martin fell that science songs are "a good learning tool," but that his students also "get that it's a learning tool." He summarizes, "it was nice that it was so easy to use."

A second theme that emerged related to the potential of using songs for learning was that science songs are useful at varying places in the instructional process. In one activity Mr. Martin used the songs at the beginning of instruction to introduce key terms. During the concept development stage of instruction Mr. Martin suggested that students could use songs as a vehicle to develop their understandings of science concepts by basing skits, videos and multimedia presentations based on them. In his classroom students created mini-posters based on the song lyrics and used the songs as a springboard for a classroom discussion. The songs allowed his students to "engage at a higher level by having a discussion, then maybe even a little bit of an argument where they have to be able to support what they're saying." He also saw science songs as having potential as an assessment instrument as students would have to identify and explain conceptual references used in them. Mr. Martin found that the songs were useful for reinforcing main ideas, "it's not just in one spot in the song, but it keeps reinforcing that concept and with examples," and that they were "great to use for review as well."

Another theme that emerged in analyzing this case is that science songs can be used to interact with concepts on multiple levels of understanding. Mr. Martin

summarized that the use of songs, “worked at different levels,” in “different ways” and “gets beyond the basic understanding.” While songs worked on a fundamental level in defining and explaining terms or giving examples as an introduction or review activity, they also have the potential to facilitate deeper conceptual understanding as students, ”make connections, and that’s a different kind of application.” Because of the complexity of the lyrics, “if they don’t understand the content, they’re not going to see,” or understand references in the songs. So while science songs can help students build vocabulary, to understand the songs students “can’t just know a superficial definition.” Mr. Martin suggests even his students realize that the songs “have deep meaning, deep layers in them and connect to the content.” So while Derek Martin indicates the songs can be useful for developing basic knowledge such as key terms and vocabulary, he believes they have the potential to be used for more meaningful learning as well as students engage with concepts in the songs at a deeper level.

A final theme, and perhaps the most robust one, that emerged related to the potential of science songs for teaching and learning science extends on what was said in the focus group about analyzing lyrics. Mr. Martin believes that this is an important component for students to connect ideas and build understanding of science concepts when science songs are used for instruction. While the student voice is important in understanding the importance of lyric analysis, it is Mr. Martin’s understanding of pedagogy that suggests using songs as a teaching strategy can only reach its potential when students “look at the lyrics and apply what they know, what they may have learned, and to look at the lyrics to understand and see how the lyrics make those connections.” For him, the activity is “critical to using [the songs] as an effective tool or

resource for learning." Mr. Martin described having students analyze lyrics as, "a problem, structured in a different way." When students are making connections during lyric analysis activities, they are required to think at a higher level. The process, "challenges [students] to make some connections right then, or it tests them to apply, hopefully, the connections they've already made." He explained, "They have to be able to make connections to see what the songs about, or to apply the song to the situations, the labs, the activities, the things in real life. And, and the application is going to require more than just the rote memorization of learning."

Mr. Martin compares the process of analyzing songs to the scientific method as the process gets "them to think as a scientist." When students analyze lyrics they must make claims and arguments about references used based on their conceptual understanding. He says, "It touches on the nature of science and how science works… not how bad something is, but are there any holes in something. Is there anything where it might be weak, or not, or how well does it stand up?" In the process students have to judge "how well it matches up with the reality of the content." Mr. Martin gives one example of an incident that occurred when analyzing the lyrics for "Atom Shack" (Morris, 2005). He thought this song was rich with hidden puns and was thrilled when one of his students "made a connection that [he] didn't make." Mr. Martin recalls, "I thought it was neat because with one class we'd gone through and found every possible thing that had to do with something about electron configuration, energy levels [and] orbital levels. But I had a student point out something else that I totally missed [in] the interpretation." In the process of analyzing the lyrics for the song, "Atom Shack" (Morris, 2005), this student found a play-on-words that the teacher had missed. The reference

to Argon as the third energy level filled up (see Appendix R) was recognized by this eighth grader, and demonstrated that “the students have to understand the content to find a play on the words like that and to recognize it.” Mr. Martin summarized the importance of lyric analysis for helping students make learning connections, “If your students don’t understand the content, they’re not going to see all the fun things that fit in the lyrics, all the puns, but when they start to get it, that’s really neat. And when they can find ones you don’t.”

Even though Mr. Martin was asked to include an activity on lyric analysis as part of the study, he said that he would have done the activity anyway. The first time he “heard the songs, played them in my car, I could tell that these were not just songs that mention science words; you know, said science things. They, the lyrics themselves were packed with information and concepts and examples.” Analyzing the lyrics is “critical to using them as an effective tool” and their potential for teaching and learning depends on this activity.

Summary

Mr. Martin’s believes that science songs have been beneficial as a new resource for engaging his students in science concepts. He found that he could cover a great amount of content in a short period of time, as science songs help develop scientific vocabulary and are rich in examples and explanations of the science concepts. The students in Mr. Martin’s class found songs to be engaging for learning, but had definite ideas about the types of songs that they believe will enhance learning. According to their teacher, these students “understand how these songs have deep meaning, deep layers in them and connect to the content.” For Mr. Martin, songs are an easy

instructional resource that have the potential to be used at different places in the instructional process and can be used to interact with concepts on multiple levels. The process of analyzing song lyrics helps students connect ideas and facilitates deeper levels of interacting with concepts when used for teaching and learning science.

Case 2: Sandy Kingston's Classroom

Background

Sandy Kingston is in her tenth year teaching and is currently working in School C in the classroom next door to Derek Martin. She holds a degree in biology with a focus on engineering. She is certified in science for both middle and high school and has experience at both levels. She has taught in several different school districts in the state, and now teaches sixth grade earth science. While Derek Martin's teaches advanced content classes, Sandy's students are on-level, and include students with a wider range of abilities reflecting this school's population of primarily Caucasian and Hispanic students. The day after hearing about this research at a district-wide, professional development session, Ms. Kingston volunteered to participate in the study. This school year has been exceptionally busy for Ms. Kingston, as she has been assigned a student teacher to work with and is taking courses after school as she works on an advanced degree. However, she was interested in bringing a new resource into her teaching, something that would "be a little creative and cement that learning." When she heard about the study she thought songs could be "a great way to just design some different types of things into my lessons." When asked about using songs for teaching before, Ms. Kingston said that she had occasionally used a few songs in the past,

including a rock cycle song and a plate tectonic song, both sung to the tune of, “Row, Row, Row, Your Boat.”

While she was familiar with songs made up to fit existing rhymes, at the time of the initial interview Ms. Kingston seemed unfamiliar with science content songs that were written and produced within their own genre of music for teaching. However, she did have some definite ideas about how the use of science songs could benefit her students. She thought that by bringing science songs into her classroom, it would help students, “to kind of solidify [concepts] in their brains, and I think that they like to act and be able to sing and perform in front of each other. So I think it pairs the content knowledge with them being able to be a little creative and cement that learning.”

Implementation

During the course of this study Ms. Kingston brought several new songs into her classroom from the resources that were provided as incentives in the study. The first, “Conduction, Convection, Radiation” (Morris, 2010) was incorporated into a dance she made up with her student teacher as part of a unit on the Earth’s asthenosphere. Because heat transfer is such an important concept in Earth Systems science, it was important to Ms. Kingston that her students understand how Earth’s mantle moves in convection currents, a concept that would later in the year be revisited during the study of the atmosphere. Another song used for instruction, “The Lonely Fossil” (Morris, 2010) was implemented during the final weeks of the semester. Ms. Kingston also indicated that she had used at least one other song as a review of the rock cycle.

While Ms. Kingston used several songs from Morris’s 2010 CD for teaching during this study, including “The Lonely Fossil,” “Tectonics Rocks,” and “The Rock

Cycle," it was the "Conduction, Convection, Radiation" (Morris, 2010) song that made the biggest impact on Ms. Kingston's classroom. Within a week of our initial interview I heard from this teacher by email, just after lunch. The message was, "We used the heat transfer song today! Kids were dancing, making up motions. We had a ball!" Ms. Kingston had managed to choreograph a few basic dance moves to the song to add a kinesthetic element to her lesson and allowed her students to improvise more. She was both pleased and surprised at how engaged her students were. Later Ms. Kingston explained, "It just really amazed both myself and the student teacher that every student was up. Maybe [it was] the movements and the songs, or the catchiness of that particular song; they all seemed to enjoy it. Not one [student] did not want to do it."

Observation Summary

It was during a review of this lesson that I observed Ms. Kingston's class as few weeks later. This classroom, like all others in the district, included a demonstration table at the front of the room and standard, two-person lab tables for students. The teacher's desk was in the front on the right side, and the eyewash station on the left, with built-in computer tables lining both sides of the room. As the students arrived to class they were handed a lyric sheet for the song and joined Ms. Kingston in singing, "Conduction, Convection, Radiation" (Morris, 2010). After the song finished students were asked to answer a few questions related to the concepts reviewed in the song about heat transfer. Some of the students answered Ms. Kingston's questions using terms from the song. After a short review Ms. Kingston asked students to move the tables to the center of the classroom to make room for a circle. The room immediately filled with excitement as students got up to push the desks together; they smiled and talked while they complied with the request. They didn't take more than a couple

minutes to get the room ready, then quickly responded to Ms. Kingston's announcement that the song was about to begin by forming a circle. The song was choreographed appropriately for the lyrics (see Appendix L), and all students sang and danced as they followed along with the song. They seemed to know what to do and all Ms. Kingston's students were smiling, singing loudly and participating. During the chorus, students reached forward to touch an imaginary object on the word "conduction," raised their hands to represent heat rising on the word "convection," then stretched out their hands and made their fingers dance outward and up when the lyrics cued, "radi-adi-ation." Other hand and body motions appeared to be carefully thought out to represent both the lyrics and the science concepts they were meant to teach. Once the song finished, students were instructed to put the room back together to be ready for the next activity scheduled for the class period.

Overview of the Experience

Ms. Kingston admitted that she entered the study with reservations but was pleasantly surprised at the results she saw with her students. She admitted, "I came into it kind of halfhearted… When I approached it I was thinking to myself, you know, I don't know if they were going to get into this." Ms. Kingston added, "I didn't know how they're going to respond to it, and it just, it really surprised me, and I really enjoyed it." The students in her class reinforced their teacher's opinion that they enjoyed learning with songs. Being sixth graders, they were that they were going to be interviewed and explained how much fun they thought learning with songs were. One student said it was, "a lot more fun than just a teacher coming up to you and saying go through pages," while another reported, "I thought it was totally tubular because it was a lot better than

book work." Ms. Kingston plans to continue using science songs for teaching because she was, "amazed at the response that [she] got out of students."

Synopsis of Themes

Through the data analysis process, several themes emerged using a combination of data sources related to the research questions, as summarized in Table 5. The first was that this teacher held the perception that the use of science songs improved her students' test scores. The second was that using songs for teaching resulted in active learning. Students thought that the songs they were exposed to in this study were catchy "earworms" that helped them engage with science concepts longer and were helpful when used as a study strategy. These songs seemed to be an instructional contagion that spread beyond the classroom and had a universal appeal for students. Finally, this teacher believed science songs have the most potential for instruction when used to reinforce science concepts that have already been taught.

In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?

Ms. Kingston's perception was that by using songs for teaching science, her students' scores on unit tests and quizzes improved. When Ms. Kingston was asked how her students responded to learning science with songs, she replied, "I've seen a greater retention in the material." She elaborated, "The funny thing is we did a pre-test on heat transfer, and then [on] the post-test I used some of the same questions from the pre-test, and the kids, I would say on the pre-test… the class averages were around 35 to 45 percent. At the post-test, the class averages were around 86 to 87 percent. The song I really think was the main component of that, because this is the first test that I've

TABLE 5: Kingston Analysis Summary

Research Question	Themes	Sources	Supporting Evidence
In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?	• Perception that test scores improved • Songs involve active learning	Teacher interviews & observations	Observation notes: • Student Behaviors Coding (Teacher): • Recall on Quiz • Characteristics • Kinesthetics Additional support from Coding (Student): • Like an Experiment • Testing • Explained Concepts
How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?	• Earworms help students engage with concepts longer • Songs are used by students as a study strategy	Student and interviews & observation	Coding (Student): • Earworms • Catchy • Trigger • Study Strategy
What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?	• Songs are an instructional contagion that spreads beyond the classroom • Songs are appropriate for reinforcing concepts • The use of songs has a universal appeal	Teacher & student interviews	Coding (Teacher): • Beyond Classroom • Parent Responses • Retention • Review Tool • Characteristics • Different Learners • Acceptance Coding (Students): • Fun • Teach Others • Remembering • Music Appeal • Engagement • Learn Better

seen that much growth on." Ms. Kingston talked about one student in particular who traditionally has not done well on her previous tests. "I actually had a student that is a 40-50 student and he made a 100… I said, 'what made the difference? Did you take home my study guide and study?' And he said, 'No! It was the song!'" She felt like the increase that she observed on her summative assessment was due to her students being, "able to pull things out of their specific examples because of the song." When asked to compare how this year's students retained the material compare to prior years Ms. Kingston responded, "absolutely different results. It would take a study guide to be able to bring in a couple of days in advance, or a game to be able to bring that back, and I didn't have to bring anything back this time. They were telling me what it meant."

Ms. Kingston believed the songs were primarily responsible for the improvement in test scores for several reasons. She talked about the difference she saw when songs were introduced into her curriculum, "I can ask them something about rocks, that earlier unit where we didn't use the songs, and I don't see quite as much retention as with the songs. Maybe it's just the lyrics and the repetition. They seem to have retained the heat transfer, because of that one particular thing." In the case of the song about heat transfer, she thought the information contained in the song and how it was composed helped her students learn and understand the concepts. "I like the fact that it kept coming back to the chorus again, and the chorus each time summarized the three different types of heat transfer all in one." Ms. Kingston further explained, "And I liked how each verse focused on a different transfer, but then the chorus, again, would summarize the three types each." When students were tested over the materials, "they were able to recall some of the lyrics and the different terminology with that."

Ms. Kingston's students shared her opinion that they performed better on science assessments because of the songs she used for teaching. One student reported, "It helped me remember things for the test because it defined the words really, really well and it just ran over and over and over again in my head." Another student said, "It told me what it meant, and it gave me examples and it like, since it stuck in my head when I was taking the test, I remembered it." A third student commented, "I think I did better, because the song really helped." Each of the eight students in the first focus group reported the same thing; the song provided examples that they could easily recall while taking the test because they could go over the song in their heads during the test. "I just like thought of the song lyrics and just wrote the example because there's a bunch of examples in the song and stuff." Another student said, "It told me what it meant, and it gave me examples and since it stuck in my head when I was taking the test, I remembered it." The students' perceptions, like the teacher's, were that their test scores improved because songs were used for instruction in Ms. Kingston's science class.

The second theme that emerged related to this research question was that science songs used for teaching involve active learning. It was quite evident from the visit to Ms. Kingston's classroom that learning with songs was an active process. During this observation students were involved, active and moving. Every student in Ms. Kingston's class participated fully, with hand and body motions corresponding to the lyrics. Students were given copies of the lyrics as they arrived, but few students seemed to need them; most were observed participating and sung along without referring to the handout. Ms. Kingston also discussed the active element of teaching

with songs, “they absolutely, absolutely loved it; being able to get up and move, being able to sing.” She talked about another day she used the heat transfer song as a review, “Rather than a worksheet to review, I popped the song in a time or two. Just when they think they’ve forgotten about it, they all start smiling and singing, and go, ‘Can we do the motions?’” When asked if the motions were necessary for learning with songs, Ms. Kingston replied, “Not necessarily. I think just the song alone. You know I did the song in advance, before we studied that concept, and then I brought the song back again, so I think that it was the actual song itself.” She gave the example of how students responded when she used the second song, “The Lonely Fossil” (Morris, 2010), “This time I approached it a little differently. I printed out the lyrics. We went over it with a highlighter, and highlighted vocabulary words, and then I’ve just kind of been playing that, like after, if they’re working on independent work, but we didn’t really dance with it, but they still enjoyed it. They think it’s funny, especially when he talks about the ‘fun guy’ and the different stuff in it.” Ms. Kingston later commented, “I noticed they listened, you know, and they were still smiling and making comments on it and they wanted to create motions to that one, too. So they enjoyed it as well.”

Ms. Kingston’s students contributed to support for this theme by talking about the songs. One student said, “I think that the movements helped, but the song did help too, at the same time, but I think the movements just made it even better and easier to remember.” Another student said learning with songs is, “kind of like an experiment… Like you get to get up, and sing, too…. It’s very much like science, if you think about it. If you’re saying a song, or you’re singing a song and you’re dancing around, and you’re experimenting with what you’re doing. And that’s more related to science than it is to

anything else." Clearly, when Ms. Kingston's students learn with songs, learning is an active process.

How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?

The impact of songs for teaching science in Ms. Kingston's class was that the lessons held their interest and engaged students in learning longer. One student reported, "Sometimes it is a really good song and it's just fun to sing and stuff." In this case the songs became powerful "earworms" that helped students understand and remember science concepts; one of the themes that emerged related to the impact of science songs on student interest, engagement and understanding of science. One student said, "It just kind of got stuck in my head and I just kind of remember the parts that went with it." Another commented, "it really did get stuck in my head, because I sat there and sang it throughout lunch." One sixth grader said, "I was singing it for days and my mom was just like, 'I think we should probably take her to a hospital!'" One of the students summarized, "after a while it could get annoying, but you still have it in your brain." When these science songs become earworms, students engaged with the content longer. For example, one student reported, "The first time I learned this song it was stuck in my head all day, and my friends were singing it, too." Another sixth grader explained, "If you have memorized the song, you think about it." In discussing this further one student said, "you think about it and sing in your head and you're like, oh, I knew that." The tendency for these songs to become earworms wasn't seen as an annoyance (although their parents might not agree), but is one way in which science

songs engaged students and kept them thinking about the science concepts they were learning about in class long after they left Ms. Kingston's room.

Another theme that emerged related to this research question was that students found that science songs could be used as a study strategy. Students in this case were clear that beyond being fun, science songs "help you study, too." When asked why, one of Ms. Kingston's students responded, "It's like a different way of studying, because nobody really wants to just like sit there and read out of the book. They usually would just rather just sing a song or something to help them rather than reading out of a book." Probing further, students talked about how that worked. One student said, "It's like it triggers the song back into your mind and stuff," while another reported, "it triggers kind of more about how you've learned about stuff." When used for studying, the songs helped students remember not only the words in the song, but the ideas they were designed to help teach. According to another student, "If you've forgot something, you can always go back to the song that it triggers." These students stated that the songs would help them understand and recall information that was embedded in the lyrics, "I just thought of the song lyrics and just wrote the example because there's a bunch of examples in the song and stuff." One student reported a specific example of how the songs were used for studying while discussing the "Conduction, Convection, Radiation" (Morris, 2010) song, "It helped me remember what conduction and convection and radiation was and how it worked." The students in Ms. Kingston's class found these songs to be helpful for learning when used as a study tool.

What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?

One theme that emerged from the data relevant to this research question is that in this case, the use of songs for teaching science became an instructional contagion that spread beyond the classroom. When the "Conduction, Convection, Radiation" (Morris, 2010) song was first introduced, Ms. Kingston reported that one of her colleagues came to her room to find out what was happening, "She came to me and said, 'What's going on? What are they doing and singing and they're all standing up?' I said, you've got to use this. They're going to love it. And even she was amazed." She further explained, "It spread… because kids were talking about it and singing it at lunch, and showing what they had learned. And then my class actually took a day where we went to another room and taught all of her classes that day, and to be able to teach something, to me, shows mastery. Not only did they know it, but they could actually teach it, and they were even explaining to each other the reason we do this motion is because conduction is like when heat moves through a spoon." Apparently Ms. Kingston's students' enthusiasm for the songs spread not only beyond the classroom but also into the community, "I've had parents e-mails about it, [students] doing this on the soccer field." The school principal, whose daughter is in this class told Ms. Kingston that, "one of her daughters had tried for cheerleading, and was up at a restaurant doing the cheer dance, and then her younger daughter that's in my class, said, 'Well, let me show what we learned.' And she did the song and the dance." Apparently this student had been singing the song enough that, "the principal actually knew the words to the song herself!" Because Ms. Kingston's students responded so positively about learning

science with science-content music, other teachers showed an interest in teaching with songs. One parent contacted Ms. Kingston because he “is an earth science teacher in [another] county, and he actually was telling me that he wanted to learn the song and start using more music with his classes in a different county.” She further reported that, “Even our math teacher started using a Pi song right after that because the kids responded to [songs] so well.”

The students in Ms. Kingston’s room and their parents reported the same thing. One student shared, “This morning my Mom, I had to show her the song and stuff… I had to show her the whole thing, and she’s like, ‘Okay.’ She wanted me to teach her.” Another student commented about sharing the song with one of her friends, “And my other friends are in different science classes, they always go, ‘What are you singing?’ And we always say, ‘you should be in Ms. Kingston’s class. It’s a lot of fun, and that’s where the song came from!’” It was obvious from parent emails and comments that the songs had spread to students’ home and beyond. Ms. Kingston reported, “I had three [emails] in a day that came in, and I probably still have those, if you’d like… and [the parents] just said this, specifically, this song, this dance that they’re doing, on the soccer field, you know, they really enjoy learning, and you’ve made it fun. And thank you for using this.” These songs seemed to be a learning contagion that spread well beyond Ms. Kingston’s classroom.

A second theme that emerged related to the potential that songs have for teaching and learning is that Ms. Kingston believes that songs are most appropriate for reinforcing science concepts she has already taught. At the time of the final interview she was planning “to do the Rock Cycle song to review with them.” Ms. Kingston

explains, “It’s just kind of reinforcing what they have learned.” In this case, the teacher feels that, “if they maybe didn’t get it when I was up presenting it, or if they’re having trouble with the worksheet, they may hear something.” She added, “it’s been a great review tool, and a great way to just design some different types of things into my lesson.” The students supported this idea by stating, “It was really fun to sing and the lyrics helped you because it would give you a definition, but in kid version.” Other support for this theme is found in the frequent statements in which Ms. Kingston describes using science songs for reinforcing concepts due to her perception that the use of songs helped improve test scores. However, to be a useful tool in reinforcing science concepts she feels that, “I would definitely say that the lyrics would have to be on target with our concepts and our content.”

Finally, the last theme related to the potential of using science songs for teaching and learning is that they have a universal appeal. Ms. Kingston stated, “I think different kids have different interests and some may like the computers, and some may like doing the hands on activities. But it just really amazed both myself and the student teacher, that every student was up and… they all seemed to enjoy it.” She further stated, “It’s ones that I can’t get into anything, it’s like I looked around and they were watching and once everyone started doing it, and they thought, ‘hey, I’ll be a part of this too.’ So it was really, really great.” Ms. Kingston thought that the use of science songs has the potential to reach “students that I have not been able to reach through other methods.” Every student interviewed from Ms. Kingston’s sixth grade science class reported the same thing, “It was fun!” Some said, “It’s funner than just reading out of a book,” and others reported it was, “a lot more fun than just a teacher coming up to you

and saying go through pages." And because it was more fun they said, "you remember more by doing something that's fun." These students recommended that other teachers should use songs for teaching science because, "I think maybe [students] would pay more attention." When Ms. Kingston was asked about why she thought the songs were engaging for all of her students she responded, "I've tried different things like computer games, group based activities, and a lot of things [like] that. I think that so many people are doing things with our technology-based world that we live in. And I think that sometimes the kids are actually burned out on that. This was just an old… kind of an old school way to bring music into it." Ms. Kingston summarizes by saying, "There was not, I mean out of all the students, there wasn't one student that did not want to do this. Not one. And that's what… I kept waiting for every period. There's going to be somebody that's going say, 'I don't want to do this!' or, 'This is stupid.' And it never happened. They were all like, 'Wow!' They had a great time." She believes, because of her experience, that the use of songs for learning science has universal appeal for all her students.

Summary

In this case, it was the teacher's perception that the use of science songs for teaching and learning science improved students test scores. While no hard data was collected, Ms. Kingston cited examples of students who did better than on prior assessments and believed the difference is due to the use of science-content music. It was her opinion that overall test scores showed greater gains than prior years' classes and contributes the difference to the songs she used for teaching. The use of science songs, she indicated, involved her students in active learning. Student interest,

engagement and understanding of science concepts were influenced by the tendency of these songs to become earworms and were used by students as a study strategy. In terms of identifying their potential for teaching and learning science, Ms. Kingston and her students described how these science songs became an instructional contagion that spread to the students' homes, other classrooms and the community. After using several science songs for teaching, Ms. Kingston believes that they are most appropriately implemented in reinforcing concepts she has already taught. She said that, "it's been a great review tool," and that the use of songs for teaching, "didn't require a lot of resources." Finally, in this case, the teacher believed the use of science songs as a teaching strategy had universal appeal for her students. Ms. Kingston summarized, "I try to engage them, in a lot of different ways… I try to do something different every day, but this was the one thing that I feel like that I've done that they were all into."

Case 3: Martha Russell's Classroom

Background

Mrs. Russell started teaching in New Jersey in the 1970's after earning a degree in science education with a concentration in chemistry. She accepted her first teaching position at a Junior High school in New Jersey teaching seventh grade earth science and discovered that she really enjoyed the content. When she returned to school to earn a master's degree, she specialized in earth science. A few years later Mrs. Russell was given the opportunity to move to chemistry, her first love, but decided she enjoyed the earth science too much, and stayed where she was. She taught eight years in New Jersey, before leaving education to raise a family. Mrs. Russell returned to the classroom six years ago, teaching sixth grade earth science at School A. The

students at this site are the least diverse and have the lowest percentage qualifying for free and reduced lunch. They are also the most rural of the three populations. Working in the same school as the researcher, Mrs. Russell had expressed an interest to participate in the study long before it was formalized. When Morris was composing the songs for "Round the World With Science" (2010), one of the CDs provided to all the participants in the study, she provided input on concepts that should be included in one of the songs that she later used as part of the study. Having taught in the same school with the researcher for the past five years, Mrs. Russell was familiar with the use of science songs for teaching, but had not used them in her own classroom. The one exception was the use of the song, "The Age of Aquarius" for teaching astronomy in her first years in the classroom. She did, however, use various forms of mnemonics to help students remember science terms and key ideas as a regular teaching strategy and saw the use of science songs having similar potential as an instructional tool.

When discussing her interest in the study Mrs. Russell said, "I use mnemonics. I use any kind of catchy phrase I can. I think the next logical step… is if the music is in there, I think that will help them to remember even better. And that's what I'm interested in, especially with my lower learners, where it's so difficult." She shared specific concerns about her struggling students, " I have a lot of students that find science difficult. Sixth graders don't have experience with a lot of science in elementary school. They don't know how to handle the vocabulary heavy subject that we have." Martha hoped that by introducing songs for teaching, their potential would go beyond vocabulary development and help them understand science concepts and processes. She stated, "If they're sitting there trying to figure out how to illustrate the process, they

might be able to use the music to help do that." Her goal was to provide students with "any tool they possibly could use to help them learn better."

Implementation

During this study Mrs. Russell used both "Rock Cycle" and "Tectonics Rocks" (Morris, 2010) with her students during their study of Earth's lithosphere. She mentioned introducing "Conduction, Convection, Radiation" (Morris, 2010), although did not indicate to what extent this song was used for instruction. Both the rock cycle and plate tectonics songs were used to both introduce and review concepts in Mrs. Russell's class. She developed Power Point presentations that cued the lyrics and included images and graphics that illustrated each verse and chorus of these. These presentations were between ten and fifteen slides each, and helped students follow along with the songs. A sample is provided in Appendix M. Initial lessons were conducted in which students analyzed and discussed the lyrics. The slideshows and songs were regularly revisited during the unit for review of the concepts they included.

Within a few weeks of starting the study Mrs. Russell presented her initial lesson using science songs with "Rock Cycle" (Morris, 2010) (Appendix N). A few days after introducing the first sing she came to me in the lunchroom and indicated that her students were thoroughly enjoying the experience. She invited me to come down and see her students' response. Later that day, during my planning period, I walked into her room and found her students engaged in an activity reviewing the lyrics and singing along with the song. Every student seemed to be engaged and participating. The volume at which they were singing easily overshadowed the recording that played through the classroom's sound system. I stayed long enough to see Mrs. Russell review the lyrics and discuss what they meant with her students. Although this was not

the formal observation set up for the study, it did demonstrate the success this teacher was experiencing using songs for teaching early in the study.

Observation Summary

The formal observation occurred with this same class while using the second song, “Tectonics Rocks” by Morris (2010) about six weeks later. Mrs. Russell’s classroom was constructed like all the other science classrooms in the district, with the only variance being that her desk was positioned at the back of the room, rather than the front. Student lab tables were arranged facing the front, and a single window was located behind Mrs. Russell’s desk. Due to fire code regulations only a minimal number of posters can be displayed on classroom walls in the district, and Mrs. Russell had a couple of geology posters included on hers. I arrived about 10 minutes after class began while Mrs. Russell was reviewing plate tectonics concepts on her white board. She was leading a class discussion of key ideas related to plate tectonics that included content about subduction zones and plate boundaries where earthquakes and volcanoes are located. While the teacher had already introduced this song earlier in the unit, this lesson was an in depth analysis of the song lyrics (Appendix O). When Mrs. Russell announced for the day’s lesson they would revisit the song, “Tectonics Rocks” (Morris 2010), several students responded in unison with a loud, “Yeah!” She passed out the lyrics then started the slide show presentation that was prepared for the lesson. When the song began several students asked if they could sing along and Mrs. Russell responded, “Okay, but not too loud.” In this class of twenty-two students, about six started singing right away, and a dozen or more joined in on the chorus. All the other students, except one, followed along with the lyrics as the song played. That single student, a girl sitting halfway back on the right side of the room, seemed disinterested;

she did not sing along or follow along with the song. When the music ended one boy in the front called out, “Let’s sing it again.” Another boy in the back echoed the comment. The boy in the front would later be referred to by his peers in the interview as normally being a behavior problem in the class who always focused and enthusiastically participated in lessons that included science songs. Mrs. Russell told her students they would sing the song again after the activity.

For the activity Mrs. Russell divided the students into teams and assigned each group a different stanza of the lyrics to analyze. She instructed them to talk to each other and decide what the words meant, then write their interpretation in the box beside each verse on the handout. After a few minutes Mrs. Russell began calling on each group to share what they talked about in their groups as part of a class discussion. She asked questions about specific terms used in each verse of the song. Some groups gave a verbal interpretation of the lyrics while others went to the board and drew a picture related to the concept and explained it. For example, on the verse related to divergent plate boundaries the boys leading the discussion drew a rough map of Africa and South American that showed the approximate location of the Mid-Atlantic Ridge and arrows that indicated sea-floor spreading. As the activity progressed approximately half of the students filled in their handouts based on what all the groups shared, while others only completed their assigned section. A few students were off-task and inattentive during the discussion. Two boys in the back of the classroom were wrestling during the discussion. After the lyric review was over Mrs. Russell asked the students if they want to sing the song again. Several students respond with “yes, yes, yes,” and most of the class joined in singing along with the slideshow. During the chorus the

students who sang the loudest were the two boys in the back of the room had been wrestling a few minutes earlier during the class discussion.

Overview of the Experience

Mrs. Russell had hoped that by participating in this study she would give her students a new tool to help them learn the science content and concepts she teaches. When asked if the use of science songs for teaching worked she responded, “It exceeded what I expected.” She said her students really enjoyed learning with songs. The comments Mrs. Russell made included, “They really got into the songs,” “They loved the beat,” and “My students asked to have the songs… they kept asking me for one thing, when are we going to do another song? Can we hear it again?” She added, “I think it helped them learn… much better.” Mrs. Russell’s students also expressed the same sentiments, “You’re having fun and listening to it.” One student commented, “I didn’t think they would be as cool as they are.” They also felt that the songs helped them learn the concepts Mrs. Russell was teaching. One student reported, “I think it helps understand the ideas,” and another said, “It helps you understand a little better.” They felt that the song, “explains, and then you can remember.” Mrs. Russell plans to find new songs and continue using science-content music throughout the school year. The songs already introduced will be used to review, “I intend to use the songs as a jumping board for our Friday Flashbacks to try to keep them on track.” Her students have asked about other songs she plans to bring into her lessons for other concepts during the course of the school year. She said they asked her, “’Mrs. Russell, how many songs do you have for the spring?’ And I’m sitting there going, I have to think about that and see what we’ve got.”

Synopsis of Themes

During this case analysis, different sources of data were used to identify several themes related to each of the research questions, which are summarized in Table 6. They included this teacher's use of science songs to help students visualize concepts and enhance development of scientific vocabulary. Active participation and use of songs as a mnemonic device for helping students to remember key ideas were two ways in which they enhanced student engagement and understanding of science concepts. The potential for songs to enhance teaching and learning science included using repetition to build ownership of concepts for some learners and presenting scientific content to students in a way that they care about.

In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?

For Mrs. Russell, the use of content rich songs helped her students with visualization of science concepts. The slideshows she prepared and used with both songs provided her students with a visual aid that corresponded with the lyrics and helped illustrate concepts. The pictures came from online resources and included graphics that illustrated different geologic processes that form different types of rock, pictures that correspond to each rock type, and diagrams that emphasize different stages in the rock cycle. Mrs. Russell explained, "When we went through the lyrics, we talked about it [and] we looked at pictures on the white board." Students also created their own illustrations that matched the lyrics," so that they could take what the words were and visualize it and then try to put it all together." The slideshows and student drawings helped provide students with mental images related to the content. But in this case, the use of the songs goes further in helping students visualize the concepts.

TABLE 6: Russell Analysis Summary

Research Question	Themes	Sources	Supporting Evidence
In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?	• Visualization of concepts • Enhances development of scientific vocabulary	Teacher interviews & observations	Observation notes: • Activity notes Coding (Teacher): • Visualization • Big Picture • Construct Meaning • Key Concepts & Phrases
How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?	• Active participation in learning • Mnemonic device for helping students remember concepts	Student and interviews & observation	Observation: • Student behaviors Coding (Student): • Participation • Movement • Catchy • Earworms • Remembering
What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?	• Repetition builds ownership of content for some learners • Presents scientific content to students in a way that they care about	Teacher & student interviews	Coding (Teacher): • Repetition • Recall • Learning Differences • Reference Song • Student Responses • Engagement Coding (Students): • Repetition • Learning Styles • Alternative Resource • Understanding

Mrs. Russell explains, “I think they were able to visualize in their brains what was going on a little bit better.” Once they learned the song, “they were able to take that and when they heard the phrases they were able to visualize, think about what happened a little bit better.” She provided an example of how students would visualize the content in the song, “The one that kept popping back up was we were talking about high up, low to high to low. Changes in tectonics, changes in mountain formations, changes in what used to be the ocean and then became the mountain. It was ocean, now it’s mountain. Oh! The forces caused there to be a change!” It was the combination of the lyrics with the images students created that Mrs. Russell believed would help students better understand concepts, “It was kind of like taking the songs, taking those pieces and trying to put it into a puzzle to make a whole idea.” She added, “That’s how they can piece it together and get the whole conceptual idea together.” Mrs. Russell believes that the use of songs for instruction “helped them to visualize” the concepts she was trying to teach.

Another theme that emerged in this case was that the use of science-content music enhanced development of scientific vocabulary. Mrs. Russell felt that for sixth graders one of the greatest challenges in learning is understanding the language of science and said, “with all of the vocabulary, [it’s] very hard.” In her class the songs were used in lessons to help students develop an understanding of key terms. During the activity observed for this study Mrs. Russell pulled out important terms and key ideas from the lyrics and asked her students to elaborate on them. For example, when students presented the third verse of “Tectonics Rocks” (Morris, 2010) during the analysis activity, the teacher asked her students what kind of mountains form when

magma rises through the surface. A couple students responded before one correctly replied, “volcanoes.” Another example comes from the third verse of the lyrics which stated, “Subduction is when one plate goes below, and melts into the flow, The denser plate goes low while the light one rises high, And on the continents new mountains reach up to the sky” (Morris, 2010). Mrs. Russell discussed what the term “subduction” meant in the lyrics and how it was used with her students. She explained to them it referred to how, “the light plates rise when two continental plates converge to ‘crinkle’ and form folded mountains.” This example was designed to help them better comprehend the term, which is necessary to understanding the processes that change Earth’s surface. She explained that, “by choosing those key words, I was able to point things out.”

Learning the language of science is one of the most difficult challenges Mrs. Russell faces when teaching concepts to her students. She reports, “With all of the vocabulary, that’s very hard… especially for some of the lower learners to be able to take that information and apply it.” For Martha, the songs helped her students develop their comprehension of the scientific vocabulary needed to understand the concepts. “The lyrics from the song, they were able to take that and use that to help them,” Mrs. Russell explained. She added, “By using the key phrases from the songs, they were able to take that information, actually apply it a little bit better than they would have when it was just reading from a book or whatever.” The fact that the song repeated key ideas in the chorus and was played multiple times also helped students integrate key terms into their own vocabulary, “the vocabulary… the more they hear it, the better they do with it.” When she delivered subsequent lessons Mrs. Russell would often refer back

to the songs she had introduced to remind her students what terms meant, “when there was a question that came up that we needed to think back… I’d say what about that third verse of the song?” She said that, “All I would have to do is say the key words, and [they’d] say, ‘Oh yeah! I get it now!’”

Mrs. Russell’s students provided additional support for this theme. When asked, “How does the song help you understand it?” One student responded, “It has like a bunch of key words.” When asked how the song helped them understand science concepts another student said, “There are big words in there that means so many things about tectonic plates.” Another student said, “It tells what all of them mean,” and another added, “and it doesn’t use all those big words like the book does.” I asked these students how the songs helped them understand the vocabulary and one student explained, “Well, sometimes it just kind of confuses me if I can’t remember a lot of things. Like, if it’s just words, then I get them all jumbled in my head, because there are a lot of words every single day. [Sigh] So, I guess it’s just better to hear it in a song because I like music.” Another student responded, “I just take the other words off, and remember the main word, and then I know.” Mrs. Russell summarized how songs helped enhance her students’ development of scientific terms, “They took the vocabulary. I think that was a big factor right there.”

How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?

Student interest and engagement are impacted by the use of science songs in the curriculum by providing an opportunity for active participation in learning. While observing Mrs. Russell’s classroom, it was easy to identify different levels of student

engagement during the lesson. Some students followed the slideshow silently; some sang along for the entire song and one girl was observed making hand motions to go with the lyrics. More than half of the students in Mrs. Russell's class sang along during the chorus and several students were moving their bodies to the beat. Only one student seemed disinterested and chose not to participate. The boys in the back who were wrestling during the discussion part of the lesson stopped when Mrs. Russell started the song and joined in singing, quite loudly. The students in this case were active, not passive learners, during the use of science songs for learning. The students explained, "You get to participate more than reading the book," and "If it's a song that can go to a tune, you can move, then you [are] more likely to know it." Mrs. Russell gave the students some gestures to go along with the lyrics to "Tectonics Rocks" (Morris, 2010), which can be found in Appendix O. The students thought that helped. One student discussed how the song and motions helped her remember the answer to a question on an assignment, "I can't remember what one of my questions was, I was thinking of subduction, I was moving my hands and going, okay this one goes under." The children in the focus group discussed the boy who sat in the front of the class and called out, "Let's sing it again" during the observation. They indicated he is often in trouble in class, and "he doesn't like reading in books." But when the songs are used in class, "he's always singing because he likes participating more." All the students in the focus group agreed that learning science with songs is, "kind of fun, because you can just sing along, and you get to learn more things." They said that they "like singing and they're always moving and grooving." These children see the use of songs as an opportunity to become active participants in learning.

The second theme that emerged from the data in this case related to student engagement and learning is that these students thought that the songs were useful mnemonic devices for helping them remember science concepts. These students felt that “with the song you can kind of remember the words, since it’s so catchy.” They talked a lot about the songs being ‘catchy,’ and described it as, “the tune of it” and, “it all rhymes.” The tune was important for some students, “it helps me because the songs have a catchy tune.” For others, the rhymes in the lyrics seem to be more helpful, “If you like remember one line, then you can remember the next and the next.” Whether it’s the tune or the rhythm, these songs are earworms that serve as mnemonic devices. One student said that when songs are ‘catchy,’ “they get stuck in my head for a really long time.” The students in Mrs. Russell’s class said that, "when songs get stuck in your head, it’s easy to remember the stuff.” Another reported when a “song gets stuck in your head, then you know the definition and then you’re able to do well on your test.” For these students, these songs were compelling. According to one student, “even if you tried to ignore it, you can’t.” Another added, “and people in the hallways are always singing it.”

Remembering key terms and ideas for some concepts can be challenging for a sixth grader, and science songs seemed to help students in this case. One sixth-grader reported, “I really, really could not remember anything, and then, when we learned that song, that was like, I’ve got all of it!” Mrs. Russell’s students gave several examples of how these songs helped them understand and remember concepts. “Like for example, the rock song, I couldn’t remember the different kinds, then like after I listened to that song, I know all them, like, really good,” one student explained. Another told me, “I

learned about subduction, and I didn't really remember it when I first heard it, and now, since I've started hearing the song, I remember." These students used the mnemonic power of songs to help them recall information for different reasons. They talked about using songs to help them on their homework, "They can help, like, on homework sometimes. I get stuck on some questions, and I think about the songs, and it helped me do my homework a lot." Sometimes they used the songs to help them with important assessments. A number of the students in Mrs. Russell's class said how the songs helped them on their tests. One student said, "I remember I was taking my last test, and I couldn't remember, and then my song came up in my head and I'm, like, oh, okay!" Another told me, "I was just doing every answer because we learned the song." A different student said, "Because then, if you sing it a lot… you can remember it. And then, like when you're taking tests, you just like sing it." Yet another reported, "I can actually think of the song in my head and I can get the answer right." According to the experience of these students, science songs are a powerful mnemonic device that, "helps you remember whatever you're trying to remember."

What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?

Hearing science songs over and over again became a regular occurrence in this classroom during the course of the unit. Mrs. Russell found that this repetition built ownership of content for some learners. She reported, "I think the repetition really helped. And they enjoyed the repetition." The songs were played almost daily in her room, partly by design but also because her students wanted to have the songs repeated. Mrs. Russell reported, "My students asked to have the songs… They asked

me constantly, ‘Can we hear it? Can we hear it?’” As a planned strategy, repetition was intended to help her students learn and retain science content. The songs were introduced early in the unit then referred back to as concepts were explored, “We used it to learn what the song was about and then we kept tying back to it. So it wasn’t like we were just doing the same old thing over and over again.” She talked a lot about the positive learning outcomes exhibited by her lowest students, “A lot of the lower learners got very excited with the songs.” Mrs. Russell elaborated, “I think the low learners began to feel a sense of true accomplishment when they were able to take those phrases, or remember what the song said and actually applied [it] to what we were doing.” She compared her experience this year using songs for teaching to prior years, “There were some lower students, and they were actually getting things, that students I did not see getting last year.” When asked how effective she thought the songs were for learners who were not as low Mrs. Russell responded, “I think it was probably effective in a different way.” She explained, “I think probably the higher-level students saw the value in it, but I didn’t see them wanting to have the repetition; whereas the lower level students were eager for that repetition because it seemed to help them.” Later she added, “I actually had some of my higher students, are, like, ‘Again?’ But they kind of got it, maybe, faster, and didn’t feel the need for it.”

Mrs. Russell’s students didn’t mind the repetition at all. When the students in the focus group were asked, “Do you get tired of listening to it?” there was a collective and definitive group response, “No!” When asked why one student responded, “Because it’s entertaining.” These students seemed to understand the purpose of repetition; “If you just go over it once and then not go over it multiple times then you really don’t

understand what they're saying." Another student commented how repetition was important for developing her understanding of the concepts, "the first time you hear it you don't really understand it. But she lets us hear it like multiple times and then you're like, oh! And then she explains it, and then you're like, Oh yeah, okay. Now I understand!" All of Mrs. Russell's students seemed to enjoy the repetition, and for some students, repetition helped them understand and remember the concepts they were trying to learn.

Another theme that emerged in this case was that when songs are used in instruction, scientific content is presented to students in a way that they care about. Students in Mrs. Russell's class like songs. One sixth-grader reported, "I've liked music since I was little." These students reported they are more likely to pay attention in class and to remember what they learn from songs. They agreed that, "When the teacher just talks it really doesn't stick to your head, you just get tired," and "It's not like reading a book, because if you read a book you just forget everything." But when songs were used to present science content, "There are a lot of good things about it… it's like you can learn from it, because it's more better than a book, a teacher and study guides and all that." They said that, "it was more fun," and "we always go with the fun one, and that always works. We learn more stuff from that."

Mrs. Russell agreed, "First of all, I think the engagement makes all the difference." Because they were more interested she thought it helped them learn, "not only [with] memory and recall, I think they got so excited about it. That this helped them to get into it." Mrs. Russell found that music speaks to her students in a way that they care about, "Kids love music. And it's like the ideas are there, but with the rhyming of

the lyrics, and just the catchy phrases, they liked it." She added, "It was something to look forward to; it was something they could relate to, because of the music. It is cool. It was cool to them, and therefore it's cool to me, because we're getting the ideas across." When content was presented in a way students care about, "they remembered it. I had students I could point to them. I could say words, and they could fill me in. I could start the phrase and they could finish it; and if they could do that, that's remembering. That's pulling it out of their brain, whereas otherwise they weren't interested remembering it." For Mrs. Russell, student engagement "makes a difference in their learning. It helps, I think. It meets some of their learning styles. It's something they enjoy doing, and anything that can help them along that's fun," has the potential to improve student learning. The students in Mrs. Russell's class enjoyed learning with songs so much that she said, "I kind of used it as a motivational tool. They would say, okay can we sing this song again? We'd done it the day before, I'd say, okay, we'll go back and do that at the end of class." Mrs. Russell believes that because the use of songs for learning presents science content to students in a way they care about, "they're learning it without it being such a task."

Summary

In this case the use of science-content music helped students in Mrs. Russell's class visualize the concepts she was teaching and enhanced the development of the scientific vocabulary they needed to understand those concepts. In order for students to grasp scientific concepts they need to know Martha said songs helped by stressing, "key ideas, towards key concepts, the vocabulary. Those are big things that I think would help with what we have to teach with concepts." The use of songs also engaged

Mrs. Russell's students, as active participants in learning while they sang and moved along with the songs; something that was observed in her classroom and emphasized by her students. These students indicated that the songs were helpful mnemonic devices and that the "songs helped [them] remember" key terms and concepts in science. Finally, the data analysis for this case revealed two important ways in which content rich songs can potentially impact science teaching and learning. First, for some students repetition builds ownership of science content. Mrs. Russell thought her lowest students gained the most from repetition, "A lot of the lower learners got very excited with the songs." For these students, "more repetition makes the vocabulary easier for them." While she thought that repetition was more beneficial to one type of learner, she saw most of her students enjoying the experience, "From what I could tell, the majority of them really enjoyed it. But some of them were just a lot more reserved about it than others." Second, the use of songs for teaching and learning presents scientific content in a way that most students care about. Mrs. Russell's students enjoyed the experience so much she is now challenged with finding more songs for teaching concepts she will present the second semester. She said, "they kept asking me for one thing, when are we going to do another song?" Her final comment in the last interview summed up the experience, "keep the songs coming, we love them!"

Case 4: Betty Taylor's Classroom

Background

Betty Taylor is a veteran teacher with nearly thirty years in the classroom. Her background includes a variety of teaching experiences, encompassing middle and high school science, social studies, math and science, in eight or nine different public and private schools. She has a master's degree in middle grades education and is certified

in math, science and social studies for middle school. This is Mrs. Taylor's first year at School B, which is the most diverse of the three schools participating in this study. The student population at this site is 67% Caucasian and 33% Hispanic with 44% identified as disadvantaged. Her students, however, are primarily gifted and talented as she teaches advanced science and math courses at this school. While most of her experience has been in eighth grade, Mrs. Taylor enjoys teaching sixth-grade the most because, "They're still eager to learn; they really enjoy school; they're easier to manage." She admitted that her current eighth grade students are special, "I have eighth graders walking in the class going, 'Oh this is so cool, I love this class,' and they do. So, that means something to me, because I've rarely heard that from eighth graders." Mrs. Taylor is not only experienced, but has been recognized as an exceptional teacher. In 2005 she was a state finalist for the Presidential Award for Excellence in Science Education. When notified that she was a finalist for this award she described herself as, ""a real hands-on teacher. I think I am a very traditional teacher because I want the children to understand the world and think of solutions to problems." She added, "Some of my assignments are very routine strategies to build a knowledge base. Other activities are more engaging because students have to use that information to play a game or activity" (HometownGwinnett.com, 2006). In the past Mrs. Taylor has used some music in her teaching. Years ago she included Gustov's symphony, "The Planets" as part of her astronomy curriculum, which focused in on how the tempo and instrumentation of each movement represented what was known about those worlds at the time the music was composed. She has used some "Schoolhouse Rock" songs with students but few lessons utilizing content-rich songs.

When Mrs. Taylor was first interviewed, she said she was interested in participating in this study because she wanted to find "something more creative for the right-brain" student. She discussed her students in terms of left and right-brain learners, "Knowing what I know about right-brain, left-brain, the creative side and the linear side, I know that science just really doesn't grab those kids, and I was hoping that something like this would do that." Mrs. Taylor also expected that using songs for teaching science would reach some of her more active learners; "Some of them are going to be moving around with it. Some of them are going to be singing the song while they're trying to take the test, or they're thinking about the song while they're trying to take the test. So I think it kind of helps those kids that you miss." Another important outcome for participation in this study was that Mrs. Taylor hoped that "some of the words that they learn in science, they'll have to know in the songs [to] kind of help connect a little of the vocabulary." She stressed the importance of students being able to participate in the discourse of science, "I always talk about, 'do you speak science?'" For students to participate in science, it is important they understand the language.

Another reason Betty Taylor volunteered to participate in the study was that she values research. She stated that by participating in the study, "I can be contributing to the professional learning that goes on." She emphasized this commitment to her students when she explained to them the reason for my observation and interviews, "I think children should participate in the research and recognize that what we do with them… it's not off the cuff, it's not off the top of our head or, it's not, let's see if this happens. I think they need to understand that most of what they do has background stuff going with it."

Implementation

The songs Mrs. Taylor used during this study included, “Conduction, Convection, Radiation,” about heat transfer, and “Some Kind of Energy,” about types of energy, both by Larry Morris (2010). These same songs were used by other eighth grade teachers in the study due to a common curriculum map guiding instruction in the district. Her plan was to introduce the songs, “after I’ve done the teaching. I found that the children understand it better as reinforcement.” She actually used the heat transfer song at the beginning of the unit and the energy song at the end. When introducing the “Conduction, Convection, Radiation” song (Morris, 2010) Mrs. Taylor had her students, “talk to me about some of the different words that we were using and what other science words could be used for some of the words in the lyrics.” When she introduced “Some Kind of Energy” (Morris, 2010) students, “had to tell me how the lyrics reflected the ideas of the science.” In implementation of these lessons Mrs. Taylor said, “my only challenge was just finding time” to fit them into her curriculum.”

Observation Summary

Betty Taylor’s classroom was the last one that was visited for the observation during the data collection phase of the study. She apologized, “I wasn’t as prepared as I would have liked to have been.” Her classroom looked nearly identical to all the other science rooms in the district, right down to the placement and location of the demonstration table, eyewash station and window. The only variance was the location of the teacher’s desk, and Mrs. Taylor’s is in the front on the left. The single window was in the back, on the right. A similar number of two-person lab tables faced the front, and when her students walk into the room Mrs. Taylor had instructions written on the whiteboard, “Jumpstart: Listen to the song. Write down the action words you hear in

the song." The students began to take their seats while Mrs. Taylor started the song, "Conduction, Convection, Radiation" (Morris, 2010) through the classroom's sound system. They talked quietly to each other for a few minutes then started writing in their journals. When the song ended someone asked, "Will you restart it again?" She instructed them to listen again and to write ten action words from the song in their science journal. During the second time the song was played Mrs. Taylor circulated through the classroom and asked her students to share their action words. The students shared the words they had written while Mrs. Taylor probed for deeper meaning and led a discussion about the song. All the students were on task and participated in the activity. After the song played the second time Mrs. Taylor gave students a handout with the lyrics to the song (Appendix L). She told her students their instructions were to write notes on the left side margin about the meaning of the song lyrics while they listened to it a third time. At the end of the each verse Mrs. Taylor stopped the song and led a class discussion about the lyrics and what they meant. Every student participated fully in the activity and contributed to the discussion. To conclude the group activity Mrs. Taylor explained to her students that they needed to read what the textbook said and compare it to the song lyrics, taking additional notes in the right margin of the lyrics handout.

Overview of the Experience

The response Mrs. Taylor had to the use of science content songs was one of total surprise. She said, "That surprised me because we have such a hard time getting middle school kids to sing" adding, "I never dreamed the kids would be singing the song. Mrs. Taylor explained, "I really did not expect this response from them. We use music so often when they're young to teach learning and stuff. Most of these songs the

children sing they learned when they were little. And to see them at this age still enjoying that very elementary type strategy…. I've been surprised." Not only do her students sing along with the songs in class, but they also ask to have them repeated, "I've got kids actually singing the song.… They come around singing it and, and sometimes they'll say, 'If we're really nice will you play this one, or would you play that one?' or, 'Can we hear this one?' So they're, they're buying into it more than I thought they would." The strategy has been so successful that she has been looking for songs not only for teaching science, but to bring them into her math classes as well; "I'm going ahead and looking at what I can do the next time with them, because they liked it. In fact, I also found another website for some math ones too."

The students in Mrs. Taylor's classroom agreed, they all enjoyed learning science with songs. Their comments included, "It spices up the lesson," and it, "makes learning a lot more fun." One student said, "you may not realize that you're learning until you go out of the classroom and then you come back for a test the next day, and you're like, oh yeah, and you start singing the song and you remember." As a way to learn, this strategy seemed effortless to these students, "Plus all you have to do is sit back and let it sink in, instead of taking notes, reading something, and then answering questions off of the reading." For Mrs. Taylor's students, the use of songs was more familiar for them than it was for their teacher. Their science teacher the previous year had used other songs for teaching that they still remembered. For this, this was not an unusual way to learn, and definitely "better than bookwork."

Synopsis of Themes

During the analysis, a number of themes emerged related to each of the research questions, using different data sources, as summarized in Table 7. When

considering how teachers used science content songs on teaching and learning, the data from this case suggested that it promoted discourse in the language of science and provided teachers with an opportunity to address student misconceptions. Student interest and understanding of science is impacted as they become engaged in active learning and utilize the mnemonic nature of songs to make it easier to remember concepts. The potential that science-content music has for teaching and learning science is related to the socio-cultural appeal of music to these students, how they were used to connect ideas and organize knowledge, and that science songs reached different types of learners in different ways.

In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?

The first theme that emerged from the data related to this question is that the use of science songs for teaching and learning science promoted discourse in language of science. Mrs. Taylor talked about the importance of what she called, "speaking science." "The main problem children have," she said, is "the language in science." She added, "It's 'speaking science' because I think it's the vocabulary that brings them down…. They know what they experience, they know what they witnessed in the lab and activity, but attaching the language to that is where they [fail]." The use of science songs gave the students in this case practice in learning to "speak science." In describing the lesson that was observed Mrs. Taylor said that her students, "had to talk to me about some of the different words that we were using and what other science words could be used for some of the words in the lyrics." She added that it gave her an opportunity to, "see if they know the vocabulary. Seeing how they put that together

TABLE 7: Betty Taylor Analysis Summary

Research Question	Themes	Sources	Supporting Evidence
In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?	• Promotes discourse in language of science • Provides opportunity to address misconceptions	Teacher interviews & observations	Observation notes: • Activity Notes Coding (Teacher): • Vocabulary • Analysis - Language • Misconceptions • Content in Songs
How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?	• Students engaged in active learning • Mnemonic nature of songs make it easier to remember concepts	Student and interviews & observation	Observation notes: • Student behaviors Coding (Student): • Active Learning • Natural Learning • Earworms • Easy to Remember • Trigger More • Study Strategy
What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?	• Songs have socio-cultural appeal to these students • Reaches different learners in different ways • Connect ideas and organizes knowledge	Teacher & student interviews	Coding (Teacher): • Interest in songs • Familiarity • Different Learners • Cognitive Pathways • Analysis – Sense Making • Review Activity • Cement Learning • Depth of Knowledge Coding (Students): • Value of Music • Purpose for Learning • Lyrics

might help me see a lit bit about their use and the comprehension." Mrs. Taylor had additional ideas for the using the songs to develop the language of science, "Instead of giving kids a really hard core study guide for a test… I [could] use the song and tell the kids to tell me what we've learned and what vocabulary connects to this word, I meant to this phrase, or to these lyrics."

The opportunity to use science content songs to practice "speaking science" was evident in the interactions that were noted during the observed lesson. In response to the teacher's request for ten action words from the lyrics, one student called out, "conduction." Mrs. Taylor responded, "Is conduction an action word?" Another student chimed in, "I put conduct," which was answered with, "When did he say that?" Another student responded, "in the last verse, metals conduct.'" Later Mrs. Taylor asked her students to share their interpretation of the lyrics. Responses included, "Substances that flow, like water," and, "hot and cold mixing." She then asked about how convection mixes and asked students to compare it with conduction, using information from the song. As the students responded she made sure that they understood the terms and guided them through a discourse about the concepts, as they practiced "speaking science." The use of science songs for learning provided students an opportunity to practice the discourse of science as they used learned songs and analyzed the lyrics.

Mrs. Taylor talked quite a bit about misconceptions in science and the opportunities that were provided when teaching with science songs to address them; a second theme that appeared in the data. She provided details about the misconceptions held by her students related to heat transfer. When matter is heated her students, "all think the molecules are getting bigger... because they all tell me that

the molecules were expanding, and they're not. They're moving faster. The matter's expanding." Mrs. Taylor added in her discussion about this misconception, "The song doesn't address that… or create it." This explanation isn't uncommon, she stressed. "There are adults that don't know that." She added, "I've had it before, with sixth grade, now I've got to address it again with these kids before they move on." Another problem she identified was, "they talk about the hot air rising and cooling. But then they don't talk about that it reheats and moves around. They don't finish the cycle; finish the current." Again, Mrs. Taylor is clear, "The song doesn't create that misconception." But the song did provide her with an opportunity talk to her students and address those misconceptions, "they're beginning to see more that there's those ideas of the radiation moving through, and particles moving, and it's helping them to see that." By engaging students in a discussion of ideas presented in science content songs, Mrs. Taylor found, "it's helping me clear up misconceptions for them."

How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?

Data provided in the classroom observation and focus group interviews supported the theme that in Mrs. Taylor's classroom the use of science content songs engaged students in active learning. One of the students stated, "It's active learning. Like music, it sticks in your brain. You're not going to forget it." Students said they listen better when they are actively engaged in learning. "When people are talking… and they're like lecturing or something, I just zone out, and then I miss half the lesson. But then with a song it wraps it up and makes it easier to listen to." These students were engaged and having fun. One student said, "We were having fun over there, we

were dancing." Another eighth-grader commented, "Some people could take it bad; that you were listening to songs in class instead of learning, but you really are learning." Learning with songs seems more natural to these students, "It doesn't really seem like you're learning anything, but the third chorus, or, by the third time you're listening to the song, you're like, 'Oh yeah, I am remembering this stuff!'"

Students' active participation in learning was also evident during the classroom observation. When the song was played the first time two girls were moving to the beat before the chorus was sung the second time. Students were tapping their feet in time with the rhythm, and singing with the chorus. The longer the song played, the more students were seen "bopping" to the beat. Students listened and remained engaged during the activity, something that they admit is a problem during many traditional classroom lessons. One of Mrs. Taylor's students said, "You don't have to listen to the teacher talk about it and zone out." Another reported, "You don't tune out or go to sleep." The students said that as a teaching strategy, "It makes sense," and "It was an easier way to learn." According to these students. "It's more fun, and you remember it more." One student summarized the experience learning with science songs, "It's kind of like active learning."

Another theme that emerged related to this research question is that the mnemonic nature of songs made it easier for these students to remember concepts. According to these students, science content songs became "stuck in your head and then it goes through your head all day and so you memorize it." When asked what made these songs memorable they said, "It was catchy," and "they have a tune and it's kind of upbeat, and stuff." Sometimes songs stayed with students because they were

“annoying, [and] you cannot get it out of your head so you remember it really well.” Other times it was, “just a really good song, and you just want to remember it.” Another student echoed this statement, “sometimes you just want to… remember it. You want to keep it in your head.” The fact that these science songs “get stuck in your head” means that it easier to recall the content. “If you remember the tune of a song, it helps you remember the words,” one of Mrs. Taylor’s students reported. And these songs could be recalled easily. One of these eighth-grade students explained, “if someone is talking about something and they say the word that’s in the song, it will remind you of the song, and you can just sing the whole thing. Even if it was a long time ago, you still remember it.” However, one of the worst things about the mnemonic nature of these songs was that, “you’ll get in trouble sometimes for singing it randomly.”

The tendency for these science songs become “earworms” made them ideal for studying, and Mrs. Taylor’s students said that they used them, “to help me review for a test.” They reported that while studying, “I’d be hearing the song… listening to the different things, and then I’d be studying about conduction, or convection.” Using the songs for studying was, “easier to remember because you remember the beats with the words.” Sometimes they were focused entirely on studying for science and “would be listening to the song and studying at the same time,” and other times they found they “could be multi-tasking, doing homework for another subject, while having that in the background, helping you.” Mrs. Taylor’s students felt that because songs are mnemonic devices, “you wouldn’t forget it,” and “it would stay in your head for the test.”

What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?

The potential for science-content songs for teaching and learning is explained by identifying themes from both student and teacher interviews. The first of these is that for the students in this class, music has socio-cultural appeal. During the student focus group one student talked about the importance of music, "Music is, well, with most people it's a good thing. It's something, you know. We go on iTunes and buy music. It's worth something." This statement expressed the value these students put on songs and their level of engagement when songs were used to teach science; "If you associate learning with something that's worth something, then people will want to learn." Another student said, "It kind of gives you a reason to remember something, instead of just… spouting off the facts."

Mrs. Taylor discussed the role of music in these students' daily lives. She said, "There's always been people [that] aspire to it, there's always been the garage bands and everything else." But for these students, music has social-cultural connections, unlike previous generations. Although Mrs. Taylor isn't sure about why, she indicated a number of factors that might contribute to their connection with songs. Accessibility was mentioned as one possibility, "and the ease of getting just the sound track, or whatever. Because in the past you had to find somebody to play the piano, you had to find somebody you know. You couldn't get just the soundtrack. Because it wasn't like it is now," she explained. Mrs. Taylor also talked other cultural factors that influenced her students; "It's more media," and "I think it's just general over exposure." She talked about specific influences from society, including the movie, "High School Musical" and

the television show, “America’s Got Talent” as having had a social effect on her students. A current television series, “Glee” has had a major socio-cultural impact on Mrs. Taylor’s students. She said, “These kids talk about ‘Glee.’ The boys and the girls, they all talk about ‘Glee’ in those two classes.” Mrs. Taylor added,

> “For whatever reason, this generation, or this group of kids, and these two science classes I have… even come and ask, ‘did you watch ‘Glee’ last night?’ because they want to talk about it when they get to school. I mean, we’ve got teachers here that watch ‘Glee’ just to have a conversation with the kids.”

Music is available through multiple resources and formats for this generation and she added, “I just think it has to do with the accessibility.” These students are “part of the digital generation [which] makes sense.” The socio-cultural aspect of music to the students in this case added to the potential of using content songs for teaching and learning science.

The use of songs for teaching reached different learners in different ways, which was another theme that emerged from the data. At various times in the interviews Mrs. Taylor indicated that the use of songs benefited different types of students in special ways. She reported, “I noticed different comments from different kids. Sometimes when I’m doing activities and labs I hear certain kids go, ‘Oh that’s cool; Oh that’s great!’ or they’ll ask a lot of questions. But on this, I was hearing a different group of kids respond to it.” When Mrs. Taylor talked about groups of students, she first talked in terms of students based on brain-dominance. She stated, “Music would come in different parts of the brain.” The creative, right brain student was discussed first, “I know it would help right brain kids. I know it would help the musically talented kids.” Mrs. Taylor indicated that it would speak to their creative side, but songs would also

"help the right brain child be more linear." Later she mentioned, "I think it helps left-brain kids… because music's linear and mathematical." The use of science-content music would potentially benefit students with different learning modalities as well. Mrs. Taylor explained, "It would also help tactile kids… I think it's very clever how you can connect the music in things to that…. Especially with the tactile, moving kind of kid." She not only thought gifted students responded positively to the use of songs for teaching science, but discussed another teacher's use of the songs with students who were considered low learners; "One of his kids had learned the verses to the songs… and she was one of the students that was being served in the collaborative class, but she learned, she was singing the song." She thought the use of songs was effective, "especially [with] some of his special needs kids." In general, Mrs. Taylor believed that the use of science songs with students for instruction "helped all of them."

A final theme that emerged from the data was that the use of content-rich songs for learning has the potential to help students connect ideas and organize knowledge in science. Mrs. Taylor thought that using science songs for a review activity was the best time in the instructional process for maximizing their teaching potential, "it's the same way I use all my media and videos. I want them have knowledge before they go and watch it." She added, "It also helped that I did the song when they had some knowledge to bring to the lyrics." Later she offered an alternative strategy, that the songs could be introduced earlier in a unit and used throughout instruction to tie ideas together. "I think now if I start with the lyric and then went back to it later, they'll get it. Or some of them will probably go, 'Oh, right, that was in the song!'" Regardless of where a song is used in the unit, it was important that they engaged in an activity comparing the

song lyrics to what they learned, so that "they had to kind of make a connection between the two." Mrs. Taylor explained, "I'm just thinking it's helping it connect, cement [learning]." As students engaged with the songs in the analysis activity, they had to, "have an understanding of the idea, of the science behind what the lyric's trying to say." A specific example came from the lesson observed where students analyzed the "Conduction, Convection, Radiation" song (Morris, 2010). "Their motivation came from what they already knew about heat. They already had some idea about it. And by the third time, it was kind of fun to see how they matched a song and lyrics to what they knew about the science." Mrs. Taylor noticed that during the analysis activity students critiqued the lyrics and, "some of them were kind of like, 'I would have said it this way,' or 'I would have done it this way.'" She added, "they would laugh, and they would get some of the stuff so, they loved some of that." When students participated in this activity, they had to bring "an understanding of the idea, of the science behind what the lyric's trying to say," to the activity. Mrs. Taylor said, "it helped the kids put the detail and the depth" to their understanding of the concepts. She elaborated on how the songs helped students make learning connections:

> "Some of the kids were picking up more… they were moving their hands in waves to radiation, and they were moving their hands around in convection… It didn't talk about that. The song didn't put that in there. But they brought [what] they had learned from here, and what the song was doing, with [what] they knew about waves, and they knew about it moving… the conduction part they got the idea about touching, but the convection they were trying to put motions to the song, and their motions weren't coming from specific parts of the lyric. It was coming from what they knew from the science. And so that's where I'm seeing some depth come into what was going."

Based on the data from these interviews, the use of science-content songs has the potential to help students organize knowledge and connect ideas.

Summary

During the data analysis several themes emerged. For Mrs. Taylor, it was important that her students learn to "speak science," and she found that the use of science-content music helped towards that goal as her students critiqued the lyrics and what they meant. This activity also allowed Mrs. Taylor the opportunity to address misconceptions students had about science concepts covered during this activity. The students were engaged in learning with songs in a way they described as "active learning." Mrs. Taylor's students talked about the mnemonic nature of songs, and how content was, "easier to remember," because, "if the tune is catchy then it's really easy to remember." The themes revealed in the data about the potential for science-content music to be used in teaching and learning science included the fact that songs have a socio-cultural appeal for these students. The students talked about the "value" of music, and Mrs. Taylor discussed the ways in which her students are immersed in a culture of music that includes "general over exposure" to songs in the media and the, "accessibility and the ease" of obtaining music. The data also suggested that the use of science songs seems to reach different learners in different way. Linear, left-brain students would appreciate the "linear and mathematical" nature of songs, while creative right-brain students would be drawn to "how it was composed" and, "take something creative like music and then say, okay what are they really saying here?" Additionally, Mrs. Taylor discussed both the kinesthetic-tactile learner and how songs reach low learners in other classes. Finally, the use of science songs helped Mrs. Taylor's students, "connect science to some of their experiences," while they analyzed "lyrics and [tried] to see why somebody writes something." The lyric analysis activity,

according to this teacher, “helped the kids put the detail and the depth… to it.” Mrs. Taylor thought the experience of teaching science with content-rich songs was more successful than she had initially hoped. She reported, “I was not expecting this… I just wasn’t expecting this.” When asked if she would continue to use songs for teaching science Mrs. Taylor responded, “Yeah. Because I like it.”

Case 5: Anna Darcy’s Classroom

Background

This year was Anna Darcy’s eighteenth year in the classroom. She is certified in biology and general science for grades six through twelve, and for middle school math and language arts. In college Anna’s major was biology. Most of her teaching experience has been in science, although she did teach language arts one year and has some experience teaching in on an interdisciplinary team, which she loved. This is Mrs. Darcy’s third year at School B where she teaches seventh grade life science. Her on-level students represent the cultural and economic diversity of this school, which includes more than one in five children of Hispanic ethnicity and nearly half the students on free and reduced lunch. Prior to her current position she taught in a neighboring county that has a student population five times larger than her current school district. Mrs. Darcy has some experience teaching with songs. While teaching language arts she used the “Schoolhouse Rock” series to teach grammar. When Anna started at her current school she found some of her colleagues had already been using science songs to teach for a number of years. During her first year at School B Mrs. Darcy co-taught with Larry Morris at the same grade level, who wrote many of the songs used in this study. She has played his songs in class before, but not used them for “an in-depth study. Just played the songs.” “Cell Castle” (Morris, 2010) was one that she has used

with students in the past; “We would put the lyrics up on the screen and say hey, let’s listen to the song. But it wasn’t a study of the lyrics.” She also used a version of the “Mitosis Dance” (Morris, 2010) in the past, but “it was more physical than it was listening to music…. it was more to learn the movements.”

One of Mrs. Darcy’s reasons for participating in this study was that she wished she “had more of a background with it.” She cited the importance of reaching different types of learners as one of her primary reasons for wanting to incorporate science songs in her curriculum. She wants to “become better at it, because I know how important it is. You know… different types of learners.” Mrs. Darcy said that she hopes using science-content music can “help me open an avenue to help other students.” Another expectation that she had was that she wanted the use of science-content music to “hook them, to get them interested…. because I think that’s where I struggle the most, is keeping them engaged.” Mrs. Darcy has used science songs before and feels that they have the potential for learning, but wanted to learn more strategies for implementation of songs for teaching and be exposed to more resources. She summarized, “That’s what I’m looking for; ideas.”

Implementation

During the course of the study Mrs. Darcy used a number of songs. As part of her unit on cells she used “Cell Castle” (Morris, 2005), then while studying genetics she included the song, “Mendel the Mighty Monk” (Morris, 2005). During her unit on biological evolution she used two songs; “Evolution” by Larry Morris (2005) and “Evolution Revolution” by Dr. Chordate (Moran, 1995). Mrs. Darcy also included the song, “The Lonely Fossil” (Morris, 2010) while covering the standard related to understanding the fossil record’s role in biological evolution. Late in the semester she

taught a lesson using, “Kingdom, Phylum, Class & Order” (Morris, 2010) for the study of biological classification. “Cell Castle” (Morris, 2005) was introduced before the study started, as she has done in the past. After the first interview Anna went back to the song and used it as a review by analyzing the lyrics “and we just, we kept singing the song, and going back over it and talking about what the different cell parts were.” For the song about genetics Mrs. Darcy reported that to develop vocabulary she had her students, “circle any words and then they had to kind of write down what they thought that meant.” When Morris’s “Evolution” song was introduced to the class it included a lyric analysis activity. The song was then replayed in class several times “to reinforce all the science.” The “Evolution Revolution” (Moran, 1995) was introduced at the same time as Morris’s song, but was not replayed or repeated although Mrs. Darcy commented, “it might be good after the unit, as like a culmination.” She indicated that she thought the information included in the song was more appropriate for older students, rather than middle school learners. Towards the end of the study Mrs. Darcy introduced the classification song to her students to help them learn the levels of classic biological taxonomy.

Observation Summary

On the day Mrs. Darcy’s class was observed, students had just started their unit on Evolution prior to the visit with a pretest and introduction. As the class “warm up” for the day the teacher had posted on the board, “What is Evolution?” and “What does ‘survival of the fittest’ mean?” The instructions were for students to write the answers to these questions on page seventy-seven of their class journals. Twenty-three students were in this class, with both a student teacher and a paraprofessional. After taking attendance Mrs. Darcy led a class discussion, reviewing answers her students had

written to the warm-up questions. While students shared their responses the student teacher passed out lyrics to the song. Mrs. Darcy then directed her students' attention to the lyrics for "Evolution" (Morris, 2005, see Appendix P) saying, "Look at page that says, "Evolution is Not So Scary,'" and asked them to label the verse numbers. She then posed the question, "What do they mean by the chorus?" Students were told that when they listened to the song, every time the word "Evolution" was sung they were to put their hands together, then move them outward to represent small changes over a long time. Everyone was asked to make the hand motions, and was told if they didn't, the next time they would have to lead the class during the song. Students were asked to find the word "Evolution" in the lyrics the underline it everywhere it appeared, and reminded to make the hand motions every time they hear the word. Mrs. Darcy added that they would listen to the song twice; the first time they were to listen, and the second time they were to sing along. She reinforced the meaning of the hand motions they were to make as showing "small changes over a long time."

Students followed along as instructed the first time the song was played. Most, but not all, of the students made the desired hand motions. A few participated by singing along but many showed no sign of engagement. After the song was played Mrs. Darcy led a class discussion of the lyrics, asking them to elaborate and interpret the concepts covered in the lyrics. She told the students she would play the song again and asked that this time they sing along and make the specified hand motion every time they heard the word, "evolution." This time some of the students sang, others just listened and watched. One boy laughed to the lyrics and another sang as he tied his shoe. Some of the students, mostly the Hispanic boys, were off task and inattentive. It

seemed that there were about equal number of students singing and those that did not. Most of the students that did participate were doing so fairly quietly. A student who was sitting isolated in the back of the class was singing the loudest. After the song ended a student mentioned that this song got "stuck in the head," to which Mrs. Darcy responded, "That's the point, it gets stuck in your head and you remember it." A discussion followed in which the teacher brought up the idea that evolution is a problem for some people, but if students understood what the song explains then it really isn't a scary concept, as emphasized in the lyrics. Next, students were directed to turn to the next page in their journals and write the chorus of the second song, "Evolution Revolution" by Dr. Chordate (Moran, 1995). Mrs. Darcy posted the words to the chorus on the board, "If you've got the genes, then you've got the means, to mutate and change your traits" (see Appendix Q). This song was quite different from the first one in that it is in rap format. The students listened to this sing, and at one point a girl sitting close to the front caught one of the lines in the song and laughed out loud. When the song ended one student said that he liked the first song better, while another indicated he thought the second one was better. Mrs. Darcy wraps up the lesson by telling students she planned to have them return to the song again throughout the unit.

Overview of the Experience

Mrs. Darcy believed that the use of science-content music has been a positive experience for her students. She said, "I know it's made them more excited about science." When asked how she thinks the songs helped her students learn science, she responded, "I think it motivates them…. It helps them remember things." She talked about the class that was observed and reported that they were the only class that wasn't engaged during the lesson. Mrs. Darcy explained, "That was funny, because

that one class you came in… they were just not excited of all the classes that day. I couldn't believe it by the end of the day, I'm thinking, [if] she would have come to this class, because every class… they perk up when they hear the music." Other classes, Mrs. Darcy reported, enjoy the songs so much that some of her students have asked for the songs to be repeated and "some of them saw it as a reward." Generally, she added, her experience has been that her students, "like science, but they… love the music."

In this case the students reported a different level of engagement than what was observed in the classroom visit. The students in Mrs. Darcy's class agreed; they liked learning with science songs. They explained, "It is a lot funner to remember a song," and "I think it's a lot easier to do the song because… you want to learn it." They also understood that the songs were intended to be learning tools, "to help you understand," and were designed "so we can understand the stuff." For these students the power of songs for teaching comes from the role that music plays in their everyday world; "I think it's easier for kids to understand music better, because music is part of their everyday lives." One student added, "Sometimes kids even express their…moods through music," while another commented that "a lot of kids like music." The students from Mrs. Darcy's class agreed, "They like to have a fun way to do things." And for them, learning with songs filled that need.

Synopsis of Themes

During the analysis several themes emerged from a combination of data sources related to each of the research questions, as summarized in Table 8. Related to how teachers use songs for teaching and learning, one theme was that songs tell stories that promoted sense making of science concepts with content-rich lyrics. Another was that key concepts were emphasized through repetition. Student engagement and learning

was impacted as songs provided a change of pace in the learning environment and specific characteristics of science songs made them effective tools for engaging students and helping them learn. The potential for songs to enhance teaching and learning in science were related to socio-cultural aspects of learning that could conceal engagement, and lyric analysis was a necessary activity to connect content-rich lyrics to the curriculum.

In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?

One of the themes that emerged from the data was that songs tell stories, which promoted sense making of science concepts. Mrs. Darcy talked a lot about songs being a form of stories and how that helped her students understand the concepts she was teaching; "I think they understand, because there's adaptation in there. There's selection. There's mutation. I think the concepts make sense because it's telling a story. You know, I mean, I think it makes more sense." Initially, as a way of presenting science concepts, Mrs. Darcy thought, "the music threw them a little bit. But I said that's okay. Just listen, and… that to me, told a story." She provided some examples of how the songs brought together concepts in a way similar to telling a story, "the kids like that beginning, middle, end piece and I'm trying to think which other songs, I think it was that Lonely Fossil, maybe. They were like, 'Oh, the fossils, that's the fossils we've been talking about.' I'm like, 'Yeah!' Like, it just made sense to them. It took this random piece that I'm teaching and [they]… could just kind of see like the stories."

The story-like nature of songs was demonstrated through interactions observed during the classroom visit. During the classroom discussion of the evolution song

TABLE 8: Anna Darcy Analysis Summary

Research Question	Themes	Sources	Supporting Evidence
In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?	• Songs tell stories that promote sense making of science concepts • Key concepts emphasized through repetition	Teacher interviews & observations	Observation notes: • Activity Notes Coding (Teacher): • Story • Synthesize Information • Resources • Repetition • Catchy
How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?	• Provides a change of pace in the learning environment • Specific characteristics of science songs make them effective tools for engagement and learning	Student and interviews & observation	Observation notes: • Activity Notes Coding (Student): • Listening • Not boring • Rhyming • Humor • Catchy • Easier Supported by Coding (Teacher): • Change of Pace
What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?	• Socio-cultural aspects of learning can conceal engagement • Analysis is necessary to connect content-rich lyrics to the curriculum	Teacher & student interviews	Coding (Teacher): • Reluctance • Coolness • Engagement • Lyric Analysis • Curriculum Match • Learning Connections Coding (Students): • Embarrassment • Movements • Explains Terms

Mrs. Darcy asked the students to review verse four and find the phrase that says evolution “is like a puzzle, with missing pieces.” She then asked her students, “What do you think happened to them? Did everything become a fossil?” She led a class discussion about the how the fossil record supports evolution, but has gaps that can’t be explained. Next Mrs. Darcy directed students to look at the line, “we never see the changes that led to rejection,” and discussed what that meant with her students. During this activity Mrs. Darcy tied together content they learned in class with references in the song to help students make sense of important concepts. Mrs. Darcy believes that when songs are used her students can “follow along and they can put the pieces together, and they’re saying, ‘Oh I get it,’ because… I teach in little pieces, and so it helps me kind of go back and put them together.” She added, “I think the songs fit it together.”

A second idea that appeared in the interview data is that key concepts in science were emphasized through repetition when songs were used for teaching. Important ideas were repeated in two ways. First, songs were played multiple times in class to reinforce concepts, often at students’ request. Mrs. Darcy believed that, “there [are] some things that I feel are so important we need to be repetitive.” She said that students did not seem to get tired of hearing the songs and even asked to hear them multiple times; sometimes after they had moved on in the curriculum. “They keep asking to go back to ‘Cell Castle,’” she reported, “today we played Evolution song, and one boy said, ‘Can’t you just do Cell Castle one more time?’ So I mean it; they ask, they ask for it.” Mrs. Darcy added, “There were several songs that… that they begged for.”

The second way in which key ideas were emphasized in songs is that the choruses frequently included the most important concepts related to the topic and generally were repeated several times in the lyrics. Mrs. Darcy explained, "What they love the most are the choruses, because that's what has been repeated over and over again." According to this teacher, the repetition of key ideas helped students to remember and understand science concepts, "they couldn't help but learn it. That's what I like about it… You may not even have been trying to learn it, and you know it." Mrs. Darcy discussed the song about biological classification, "I think it's helped because of that repetition and that fun… it's helping them remember things." She hoped that the repetition would help her students remember key concepts on assessments, too. "I'm hoping when they're taking the test… they're saying the words over in their heads." Mrs. Darcy explained that when her students were tested over evolution concepts she said, "I would tell them [to] remember the song… I think that made a difference." She added, "I think it did make a difference. And I know I'll see a difference with the Kingdom, Phylum, Class and Order… That was huge."

How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?

Student interviews and the class observation provided the data used to identify themes related to the impact that using content-rich songs had on student engagement and understanding of content and concepts in science. The first theme that emerged in this case was that songs provide students a change of pace in the learning environment. During the observed class lesson students were involved in several different activities in a short period of time centered on the song. In the twenty-plus

minutes they were observed Mrs. Darcy included a writing activity, a class discussion, a singing activity and movement. This variety provided a change in the learning environment that the students enjoyed. For them, classroom lectures are the least engaging learning activity a teacher can use, “When the teacher is talking it’s so boring, it goes in one ear and out the other,” one student reported. However, when songs are used for teaching another student explained, “when I listen to music I don’t really picture anything, I just sit there and listen to it and like it goes in my ear and stops.” When asked what made the difference one student responded, “when we’re listening [to] songs sometimes they put it where it’s a funny voice, but the teacher talk is dull and her voice gets annoying sometimes.” They talked more specifically about the songs that were observed in the evolution lesson, “both of them made you want to stick around and listen for the rest of the song.” One student said, “It’s not boring like doing work,” while another said, “I liked it; I just like listening.” Mrs. Darcy also added some insight, “I think they like it because it means a little break.” She elaborated, “Every class, they perk up when they hear the music. And it’s just kind of like today, they were doing bookwork and we needed a little, just a break, so I put the song on.” And when science songs are played in class, “the music makes them more excited to pay attention.”

According to these students, specific characteristics of science songs made them effective tools for engagement and helping them learn. Without a doubt, these students think that with science, “you can just learn it from a song.” One student said that with the songs, “it’s easier than doing work on paper,” and “after you listen to a song, normally it gets stuck in your head.” As far as these students are concerned, they are engaged when learning with songs because, “it’s pretty much just like a game for students.” One

student reported that, “some people try to get competitive… and seeing who can learn the song better.” During the course of the interview students defined the characteristics of songs that made them more engaging and helped them learn; these included humor and a catchy beat.

When songs contain elements of humor students are more engaged. One student reported, “It was easy to understand because… when you’re laughing you pay attention more.” Another student agreed, “It says all this stuff… you learn stuff and then you laugh because it’s funny.” Songs also helped these students remember concepts. According to one seventh-grader, “it’s a lot easier to remember them, because they’re funny. Some of them are funny and they have funny words.” In some cases the humor comes from the lyrics. One student talked about how one of the songs said, “something about the family, like how something was wrong with them, like… your nose [is] where your eyes are supposed to be, stuff like that, and it was funny.” Another way in which these songs included elements of humor was by use of rhymes. When asked what made the song funny one student said, “The way he was like rhyming everything together.” Students are much more likely to pay attention to songs because, “teachers are up there… they just talk. But in the song, they are rhyming; it makes it funny.” A third way in which humor was included in the songs was by use of sound variations. One student commented about the “Evolution Revolution” song by Dr. Chordate (Moran, 1995), “it was like the guy had a weird accent.” Another student added, “the beat’s really fun, and it makes you want to get up and move around… just the way he says it, it’s just really funny.” The ‘catchy’ character of science-content music also added to student engagement and retention of science content. One student reported, “if it has a

catchy beat, and you like listening to it, then it's easy to memorize it… and [we] can recite the song and that could be stuff on a test." They liked songs that have "a tune and a beat that's catchy." The use of humor and a catchy beat in these songs were characteristics that engaged Mrs. Darcy's students and helped them learn.

What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?

The first of two themes that emerged from the data related to the potential of songs for teaching and learning science is that the socio-cultural aspects of learning can conceal evidence of engagement. When asked about the lack of engagement observed in the class that was visited, Mrs. Darcy responded, "in that class everybody just seemed kind of…'he's not doing it, I'm not going to do it.' It was… very odd." She compared that class with her others, "you know, in the other classes, it's interesting, because I had some pretty popular boys be like, 'I want to stand up and sing it!' And that kind of led the whole class, you know; all of a sudden it was cool." She said, "It's almost as if they were a little embarrassed." The students in the observed class agreed, "I get embarrassed easily." Mrs. Darcy discussed the dynamics of the class that was visited. She described one of the students that participated in the interview as a potential leader, however, "she rolls her eyes at everything we do." The class in general, she says, is "difficult to engage with anything." She added, "They were… negative… from the get go. You know, from the beginning of the year." She also compared their progress on a recent assessment, "their average was a 65%. The other ones were, I mean here this one was a seventy-five, [another] had a seventy-nine; so, almost ten points." When asked what percent of her students seemed reluctant to

engage in songs for learning she responded, “I mean, I would say small; like ten percent, maybe.” She recognized that students engage in different ways, “There’s those who want to dance, sing, stand up… then there’s those who are okay with listening. Then there are those who roll their eyes.” She added, “There were always those who thought, ‘who cares about the song?’ But those are the ones that didn’t care about anything.” When asked what Mrs. Darcy experienced with that class and using songs for teaching since the observation, she responded, “still kind of… hesitant.” She added, “They like to listen to it, but they’re not going to sing to it.”

All the students interviewed from this class said that they enjoyed the use of songs for learning, which wasn’t evident in many of their observed behaviors. However, students said that they didn’t necessarily feel comfortable with being seen participating. For example, the one girl that had rolled her eyes during the lesson insisted during the focus group interview that she liked learning science with songs but was embarrassed to sing in front of her peers. Apparently there were differences in what these students were willing to demonstrate, based on the perceptions of the motions used with the song and the degree to which they observed their peers interacting with the song. To explain why singing was embarrassing one student reported, “I don’t like singing either, because I sing really bad.” Mrs. Darcy’s students thought that not only was singing embarrassing they added, “it’s embarrassing that I have to do this,” while making the hand motions they were asked to do with the evolution song. Mrs. Darcy’s students said they liked learning with songs but added, “The only part I don’t like about songs when she makes you dance with it.” When asked, “You don’t like the dance moves?” the group responded, “No!” Later in the conversation while they discussed learning with

the song, the “Mitosis Dance” (Morris, 2010) they contradicted themselves. They reported, “It was fun,” and added, “it actually helped me a lot… because the way we were doing it and like going through the cycle and stuff, and actually a lot easier to actually visualize it, because like we watched another class do it, and then we did it ourselves.”

To clarify why there was a difference in their perceptions about moment with songs, these students said that they “actually like moving around, not just moving your hands.” They explained, “When you’re doing the hand motions, we’re just sitting in our desk… it’s a lot better up dancing, moving around and we’re all doing it.” The reference to it being okay to participate when “when we’re ALL doing it” seems to support Mrs. Darcy’s theory that signs of engagement might not be evident, due to socio-cultural factors. She explained, “I probably have more leaders in other classes that will stand up and tap their foot and its cooler in the other classes to do it.” Mrs. Darcy added, “I think it does engage them. I’ve just got to pick the right song to get the most of the kids.”

The second and final theme to emerge related to the potential for science songs to enhance teaching and learning was that analysis is necessary to connect content-rich lyrics to the concepts being covered in the curriculum. For Mrs. Darcy the lyric analysis activity was important, “it makes a huge difference to analyze the lyrics.” She added, “it’s a way to help them remember the important things.” When asked how important this activity was for songs to be used in meaningful learning she responded, “I think it is critical. I think it definitely is, if I want it to be more than just background music.” Later she emphasized this point, “I think it makes a huge difference to analyze the lyrics.” This activity allowed Mrs. Darcy’s students, “to be able to connect it to things.” Mrs.

Darcy gave some examples of how she structured the lyric analysis activity, “I liked using the lyric sheet with the empty [column], and then say, write this down, or highlight it… We highlighted all the vocab words. And then, [for] some of them we defined the vocab words. But because they could go back and look, it was kind of like a little cheat sheet. I mean, go back to the song and see how they use it in the song.”

Mrs. Darcy described how lyric analysis helped her students make sense of the concepts she was trying to teach, “I think, so they’re processing it… I want them to have it, I guess in their mind. Not only that little jingle, but what it meant. Why would he choose to put that in a song?… And then it makes a connection and then they’re like, ‘Oh!’” Without the lyric analysis activity, Mrs. Darcy explained, “We’re just singing words. It’s kind of like my daughter at home. She just sings words, and I’m saying do you really know what that means, what you’re saying. ‘No, I just like the beat.’ But I want it to be more than that. I want it to go to a deeper level.” The analysis of science song lyrics delivered on this instructional goal for Mrs. Darcy as,“ they had to think about what the lyrics were.” Because lyric analysis is a critical activity Mrs. Darcy says that it is important that when using science-content music for teaching to, “actually pick songs that are meaningful to the curriculum.” When she selects a new song, she says, “the first place I look are the words, just to make sure … it’s worth my time investing the time in it that it’s going to meet my curriculum.”

Students in Mrs. Darcy’s room also described how through the process of analyzing lyrics they were able to make better sense of the concepts. One student reported, “This is pretty interesting, so you get into it and really it’s talking about what we’ve been learning.” They said that using the songs was different from other activities

in that, “every word it sort of gives some meaning,” and, “it gives you an explanation about it.” When science-content songs were used for instruction students felt it helped them, “picture in your head instead of like just writing down the definition and not understanding it.” Another seventh-grader added, “It gives you a big picture too, like not just looking at the little parts of the song, but like looking at the whole song, it’s like a big picture. It’s not just like small little ideas locked in the middle of the song.” The data suggests that both Mrs. Darcy and her students seemed to think that the lyric analysis activity helped them connect content-rich lyrics to the curriculum for deeper understanding of science concepts.

Summary

During the data analysis of Anna Darcy’s case, several themes became apparent related to the research questions. In this classroom, science songs were useful as a teaching tool because they told stories that promoted sense making of science concepts. Mrs. Darcy thought that “because it’s telling a story… I think it makes more sense.” She also believed that through repetition key concepts were emphasized. Another theme that emerged was that science songs were engaging for students by providing a change of pace in the learning environment. Mrs. Darcy noticed that, “I just love… how happy they looked when I turned the music on.” She and the students said basically the same thing, that when science songs are used for teaching, students were “doing something other than sitting there, looking like they’re in a fog and fall asleep.” The students in this class had specific ideas about how important characteristics of humor and “catchiness” had to be included in songs if they were to be effective tools for engagement and learning. Probably one of the most interesting themes that emerged

was related to the socio-cultural aspects of learning. The class that was observed did not demonstrate evidence of engagement, which was the only group of students that Mrs. Darcy reported that did not seem to enjoy learning with science songs. However, based on what the students said in the group interview, they liked learning with songs but were embarrassed to have their peers see them engaged with the activity. Mrs. Darcy reported that in other classes when certain students who were seen as leaders outwardly engaged with the activity, other students followed suit and also participated. Her conclusion was that an element of "coolness" was required before students were willing to be seen engaging in the song; otherwise evidence of engaged tended to be concealed. The final theme that emerged was that the lyric analysis activity was critical for students to connect content-rich lyrics from science songs with the concepts covered in the curriculum.

Mrs. Darcy and her students indicated that learning science with songs is fun, although they recognized that it may not speak to all students in the same way. For some students, the use of songs resonate; "I see kids who like just the songs. I mean that, that's kind of their moment." When asked which students don't benefit from the use of science songs in the curriculum Mrs. Darcy responded, "those who… choose not to participate." The use of songs has made a difference, according to this teacher. Citing what she observed during the evolution unit Mrs. Darcy said, "every kid in this class can tell you what Evolution is and it stuck. I've never had that many kids get it that quickly." Using songs for science has been a positive experience for Mrs. Darcy. She explained, "I think sometimes the other teachers are like, they probably just like science; But I think the music has made it even that more exciting."

Case 6: Max Cantor's Classroom

Background

Max Cantor has spent the last nine years teaching eighth grade science at School B. The first six of those years the curriculum was earth science, but a shift in state standards in 2007 resulted in change to physical science. Teaching is Max's second career, as he was an environmental engineer for six years before going into education where he initially hoped to teach math. However, Mr. Cantor has found that he enjoys teaching science because it has, "lots of really cool things you can do; experiments and stuff." He found that with science, "it's very easy to tie it to the real world." Max is currently teaching on-level eighth grade physical science to students who reflect the school's 67% Caucasian and 22% minority population. Forty-four of these students are considered to be from low socio-economic homes determined by qualifying for free and reduced lunches. School B is the only school where Mr. Cantor has taught.

Although Max didn't respond to an initial email invitation to join the study, when asked at a district-level professional development session if he would be willing to participate, he agreed. While Mr. Cantor had not used songs for teaching prior to this study, other teachers in School B had used science songs for years, and he had, "heard good things about it. Other teachers have said that they used some of the songs… and they said that it worked well in their classroom and especially in seventh grade because of some of the biology type songs. So, I got good recommendations from other people that it's helpful." He added, "Their kids learn well with it, so I figured, hey, why not try it?" Mr. Cantor hoped that by bringing science-content music to his students, "the songs will kind of make [students] think in a different way and might tie the music in with them."

After hearing the recommendation that a lyric analysis activity be included when using songs for teaching, Max responded, “I liked the fact that you said we need to analyze lyrics because I think getting down to what it’s saying and seeing how they can tie that in to what we’re learning. I think it will be cool, because it ties in creative thinking.” He planned to use science songs to, “get them to draw some pictures of what they’re getting out of the music and see how it ties with what we’re doing in class with the concepts.”

Implementation

During the course of the study Mr. Cantor only introduced one song, “Conduction, Convection, Radiation” by Larry Morris (2010) during the final weeks of the data collection period. “We introduced it one day and then we came back to it the next day,” he reported. On the initial day the class listened to the song and discussed some of the key concepts included in the lyrics. Then students were given the option of illustrating the lyrics or writing additional verses for homework. On the second day, Max said, “We just went more into analysis.” For the drawing assignment, “some of them did really, really well, and some did okay; they only… drew a picture of part of the stanza.” For the students who wrote additional verses Max said, “some of them had some really creative thing because then they had to build in their own examples, or… put other facts in there.” Mr. Cantor only employed one song for teaching and delayed implementation until the end of the study because of uncertainty about how to fit it into his curriculum. He explained, “It was just it’s one more thing to fit in, you know, and that’s the way I looked at it at first.” However, after completion of the activity he reported that he was much more comfortable with the strategy and was planning on using the song, “Position, Velocity, Acceleration” (Morris, 2010) in his next unit, “I know how to do it

now… and so now that I've done one, it makes it easier for me to implement other ones."

Observation Summary

Max Cantor's classroom visit occurred during last period on the first day that the song was introduced. The room arrangement was nearly identical to all the other classrooms included in this study, with Mr. Cantor's desk at the front and student lab tables facing the front. When the students arrived they were told to get out their journals and listen to the song. The volume was down low and students were both writing and talking, but did not appear to be listening to the song. After Mr. Cantor asked students for their permission slips to participate in the focus group he began the lesson and the noise level reduced noticeably. He walked to the front of the room where three pictures were projected on the white board, representing three types of heat transfer. He stressed key phrases during the introduction, "radiation moves in 'rays', "convection is 'movement," and "conduction is touching.'" After concluding a class discussion Mr. Cantor moved to his demonstration table where he turned on a pot of boiling water with seeds in it to demonstrate convection. Students were allowed to move out of their seats to see the seeds move in the current. Afterwards, Mr. Cantor asked his students to return to their seats and complete the journal warm up activity while he passed out song lyrics. Their task was to listen to the words to see what the words said about heat transfer. While the song played students listened and followed along with the lyrics printed on the handout. When the song ended several students asked to have it played again, but Mr. Cantor advised them they needed to move along in the lesson so that they would understand their homework but would hear the song again later.

The directions for the lyric analysis activity were posted on the white board and included having students underline examples and key words, add key facts that are specific to the heat transfer method mentioned in each verse, make notes about information that was left out or difficult to understand, and add lines to the song to make the song better or provide more information. Mr. Cantor reviewed the instructions then led a class discussion of the lyrics, drawing student attention to these concerns. During the class discussion that followed Mr. Cantor marked up the lyrics projected on the white board, directing student attention to the points that he thought merited emphasis. He drew boxes, circled terms and asked students to rewrite key facts from the lyrics on their handouts. After the discussion of the chorus and first verse concluded, Mr. Cantor explained to students that their homework was to illustrate the song or write an additional verse.

Overview of the Experience

Although Max Cantor had procrastinated implementing a lesson using science songs during the study due to what he indicated was uncertainty about how to work it into the curriculum, he found that it was a much better experience than he had anticipated. After the class visit he reported, “I have to say… I was a little overwhelmed by the prospect, and then it went really well, and I enjoyed it.” He said he thought his eighth grade students would not enjoy the experience, but that their response “surprised me. I actually didn’t think they’d be cool with it.” He added, “They loved it. They really did enjoy it. The cool thing was they enjoyed singing it. I didn’t think they were going to enjoy singing it, but they did.” Max felt like his students were genuinely engaged during the lesson. His evidence for student engagement came from the behaviors he observed with his students. “They were totally tied into it,” Mr. Cantor reported. “You

can tell because they're singing the song, and they're asking questions [and] they're underlining things. So they're involved with it." Max added, "When kids are engaged they're going to learn more." Engagement, Mr. Cantor believes, has an impact on learning; "Any time you have a high level of engagement with your students, you're going to have a high level of learning." According to Mr. Cantor, his students benefited from the use of science-content music for learning, "I definitely believe that it had an impact on, kind of, stretching them." Mr. Cantor said that he "didn't do any in-depth analysis on it, but it did feel like there was a deeper understanding after the songs based on the grades from [their] quiz." His assessment was based on a perceived "improvement from previous years."

Generally, the eighth grade students in Mr. Cantor's class confirmed what their teacher saw; they enjoyed learning science with songs. There were four students who participated in the focus group, one boy and three girls. However, one of the girls did not contribute to the discussion beyond responding to a question early in the interview, "I don't know. I just wanted to get out of class." At no time did she give an opinion or offer any input to the conversation. The other three students carried the discussion. Those students indicated that they did have fun learning with songs, and that it was a familiar strategy, used by their science teachers in seventh grade. When asked what they thought about learning with songs they responded, "science class is actually fun, if you listen to the songs, and stuff." They were also asked if they thought the songs helped them learn the concepts Mr. Cantor was teaching. They responded that they thought so because they did well on the test and that the "Conduction, Convection, Radiation" song (Morris, 2010) had something to do with their success. When asked if

they would like their high school science teachers to use songs for learning one student responded, “I think it would be great actually, because it will be easier for us to learn, and [we’d] actually know what’s going on, because they’re playing songs.”

Synopsis of Themes

While analyzing the data from this case, several themes emerged related to each of the research questions, based on a variety of data sources, as summarized in Table 9. Teaching and learning science was enhanced when songs were used as they provided students with alternative explanations of science concepts while content-rich lyrics explained key ideas and gave examples of concepts. Student engagement and learning were impacted by the novelty of using songs for teaching science while students interacted with the content longer. Themes that emerged related to the potential for science-content music in teaching and learning were that music had a special appeal for these students and lyric analysis helped students connect ideas and organize new knowledge

In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?

The first theme that emerged from the data related to this question is that songs provided students with alternative explanations of science concepts. Mr. Cantor explained how this worked in his classroom, “The songs presented the material in [a] slightly different way… I taught it in one way, and gave certain examples, and then the songs that we used kind of gave some other examples and used some other vocabulary. And it just kind of reinforced what they had already learned. So it kind of expanded a little bit what they had heard from me.” He added, “Instead of it just being me instructing, it was kind of like I had another, kind of, instructor; the person who wrote

TABLE 9: Max Cantor Analysis Summary

Research Question	Themes	Sources	Supporting Evidence
In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?	• Songs provide students with alternative explanations of science concepts • Content-rich lyrics explain key ideas and give examples of concepts	Teacher interviews & observations	Observation notes: • Activity notes Coding (Teacher): • Different Insights • Examples • Scaffold • Content in Lyrics • Facts in Lyrics • Key Words
How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?	• Novelty of strategy engages students • Students engage with content longer	Student and interviews & observation	Observation notes: • Student Behaviors Coding (Student): • Novelty • Voice • Lyrics • Learning • Earworms
What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?	• Music has a special appeal to students • Lyric analysis helps students connect ideas and organize new knowledge	Teacher & student interviews	Coding (Teacher): • Music Generation • Kids Like Music • Connect Ideas • Deeper Level • Interpretation • Lyric Analysis • Visualization Coding (Students): • Key Ideas • Learning

this song… They kind of gave another slant on the same information that was [the] same facts, but it kind of gave it a different view on it." During the classroom observation Mr. Cantor used the song, "Conduction, Convection, Radiation" (Morris, 2010) to teach concepts of how heat is transferred (see Appendix L). One reference that Max pointed out to his students during the observed lesson came from a section in the lyrics that referred to the different ways that a hot potato can be cooled. He talked about how this particular song explained science concepts to his students in an alternative way, "You know we're still talking about conduction, but you can [find] some different examples and, and look at it in a slightly different way, but we're still talking about conduction as heat transfer through touching." Mr. Cantor explained how the use of the song to explain concepts in a different way helped his students because, "it gave it to them, a lot of times, in a non-scientific way so that they could see that it wasn't just the definitions and facts that I give them, but they could understand it with some kind of street words, almost…. it kind of took it to a deeper level for them." Having a different explanation is important, Mr. Cantor added, because students need to understand and recognize concepts beyond the classroom. "That helps them because there's going to be somebody that writes a test that's not me, or somebody that has examples, or has them apply at a higher level… that's not me." The use of science songs to reinforce concepts gave Mr. Cantor's students additional experience applying concepts using alternative explanations and definitions.

The data analyzed in this case revealed a second theme related to the first research question; content-rich lyrics explained key ideas and gave examples of concepts. After conducting the lesson using the song, "Conduction, Convection,

Radiation" (Morris, 2010), Cantor reported, "The cool thing was the song was content rich." When asked to explain what he meant by "content rich" he responded, "It doesn't have to say definitions… but it has got to be based on fact." He talked about how the song used for the lesson was "content rich" and provided his students with more information about the concepts they were studying, "We pulled out examples. We pulled out key words." He added,

> We focus a lot of times on key words, like convection, we talk about hot air rising, cold air sinking; well the song didn't say that all the time. It talked a little bit more like circulation, or used other synonyms and analogies, that they had to look a little bit deeper than the surface level [for] key terms.

Mr. Cantor further explained, "There were just so many visual things in the song, like all songs do that, typically. They bring to mind a picture, one that really enhances learning in science, because if it's something they can see, and, you know, in their mind there; it's going to be kind of deeper for them." He added, "I think it gave them a lot more examples… than I can typically give them."

During the classroom visit indicators were observed that showed how the content-rich nature of science songs helped Mr. Cantor's students build a broader understanding of the concepts he was teaching. During the lesson Max helped his students, "pull out the images… pull out examples… pull out facts" from the lyrics of the science song he used for instruction. Starting with the chorus, Mr. Cantor asked his students, "What are three key facts?" They identified the first one in the lyrics "Heat will flow from hot to cold." A second key idea from the chorus was identified by the students, "Molecules are moving." Mr. Cantor responded that this was not a key fact and asked them, "Why?" During the discussion he explained that as the temperature

goes up, the molecules start to move faster. The next student said that heat can move, and the teacher asked, “Delve into it more, how?” They decided that the lyrics summarized how heat moves in three ways from hot to cold. The classroom discussion continued as Mr. Cantor helped his students identify other key words in the song; “feel,” “touch,” “bump”. While students identified important terms from the lyrics, he circled the words on the white board and added side notes; pointing out what he considered to be important. In this way Max helped his students identify the key terms and examples used in what he defined as “content rich” lyrics.

The requirement that lyrics be content rich is necessary when selecting a science song for instructional purposes. Mr. Cantor said, “You really have to look for song that has good factual science information in it. You know, that you can use.” He explained, “I feel like it’s got to be a content rich song to make it worthwhile” for learning and added, “I think definitely finding the right song is key, like I was saying. It’s got to have the science behind it. And it’s got to introduce it in a way that… kids this age can pull it out of it.” For him, “when [students] can make those connections, that’s what I think makes it rich in content.” He summarized, “I just keep going back to how rich is the writing.”

How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?

For the students in Max Cantor’s class, it was the novelty of the strategy that engaged them most. In the class period observed, Mr. Cantor’s students demonstrated behaviors that suggested engagement. While the music played, most of the students sang along. Some of these eighth graders sang loudly, a few stood up, and every one

followed along with the lyrics printed on the handout. These students explained why they thought the lesson was engaging; “It’s something out of the ordinary,” they said, and added, “the way you’re learning is more interesting.” These eighth graders talked about how the songs presented science content to them using a different “voice.” One student said, “You’re so used to everyone’s voice.” Another elaborated, “I wanted a lot more, because… I hear Mr. Cantor’s voice, like, every day, you know, so… it’s just different when he… played the song.” They compared learning science with songs to their other courses, “in other classes they don’t do songs or anything, and it’s just boring all the time.” These students agreed that the novelty of the experience engaged them, “it’s better than just doing anything ordinary.”

A second theme that emerged from student interviews was that the science songs engaged them with the content longer. These songs become earworms that “help me remember sometimes… because it gets stuck in my head.” The eighth graders in Mr. Cantor’s class said that science songs, “just get stuck in your head… it’s just simple; so simple, that it just gets stuck in your head.” One student said, “for a test it’s a good thing, but after class it’s just really annoying.” The fact that these students thought science songs were “annoying” wasn’t necessarily a bad thing. They were asked specifically about the heat transfer song that they heard in the observed lesson, “What makes that song most memorable?” They responded with smiles, “How annoying it was!” These eighth graders explained how they thought this characteristics of science songs helped them learn, “I think it helps you better learn and keeps it stuck in your brain and [you] don’t forget about it, like, over the weekend or something.” And because the song is ‘stuck in their heads,’ they are engaging with the content longer.

One student explained “I just sing the song and then after a minute or so, after the song’s done, I try to look at the lines on the sheet… and we look at a few of the lines, and then I start thinking about it.”

What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?

The first theme to emerge from the data related to the potential for science songs to be used for teaching and learning science was that music has a special appeal to students. Mr. Cantor explained, “The cool thing about songs is that all kids are into music.” He elaborated, “These kids, they love music. And even though it wasn’t kind of their genre, they love beats… rhymes, and all that kind of stuff.” Before the study began Mr. Cantor didn’t fully realize the potential songs had for teaching science in his class, “The first time I heard the songs, I was like, ‘Oh, my kids are going to make fun of this song!’ But they loved it, and I was shocked… so, there’s got to be some catchy stuff to it, but that’s not for me. They’re going to enjoy the music anyway.” Max reflected on how important music is for today’s students, “a lot of times they need to have music on, because that’s how they study, and so… they need that going.” The way music speaks to this generation of students is an important realization for teachers, and one reason why teaching science with songs has such potential. Mr. Cantor explained:

> We have to apply our learning to them, and make it real for them, and with songs… they all have their iPods, they all want to listen to music, and it kind of makes them feel like, ‘Okay, you know something about me. You know that I like music. You know so you’re trying to teach in a way that you think I might enjoy.’ And so… that raises the level of engagement. And so then you’re going to have them more tied into what you’re doing. And, they even enjoyed singing the songs.

A final theme that appeared in the data was that for these students, lyric analysis helped them connect ideas and organize new knowledge. For Mr. Cantor, the true potential for songs to be effective in helping students learn science concepts lies in this activity, “They’ve got to see the lyrics to make some connections with what the science is and what they’re currently learning. They can see some of the pictures and examples, but to get to that really deeper factual stuff, they’ve really got to see the lyrics.” In this activity students were required to, “show the connections between the information” contained in the lyrics and what they were taught by Mr. Cantor. He described the activity as, “One of those higher-level skills; one of those analysis skills.” Students made those connections when Mr. Cantor asked them to, “Pull out some facts and tie that in with the other information that I’d already given them, and show how it’s all related. I think the synthesis part, it’s got to have them think … how does what I know attach to this new information they’re giving me?”

Mr. Cantor explained how analyzing the song in the observed lesson helped his students make those learning connections. “With ‘Conduction, Convection, Radiation,’ it was like they had to understand that the reason a certain line was in the song was because heat transferred in this way. You know, so it’s kind of like it was a synthesis and analysis process, so it just required some higher level thinking skills.” He talked about how he implemented the lyric analysis activity, “We introduced the song as they were reviewing, having some questions, like a journal activity where they were trying to access knowledge from a previous lesson, and the song was playing.” Later, he explained:

> We played it three times before we got into analyzing the lyrics. And then we looked at the lyrics and just went through and did some of the easy

> stuff; like, 'What are some examples you see in here of each different type of heat transfer?' And then we went back and dug deeper into it, 'Where are some facts that you see? What are some facts that you can learn from these lyrics? Either facts you already know, or new facts that you didn't know already?"

This step, Mr. Cantor found, was the most challenging for his students, "We pulled out facts, and that, the facts part, was hard for them, because they just wanted to copy." Instead, he wanted his students to think deeper; he wanted them to think about, "This is what it says, but what [is] the real fact that's hidden in the song?" In order to make those connections, Mr. Cantor wanted his students to consider, "Why is he saying this?" and, "Why does this apply in this situation?" He added, "It wasn't just hearing the facts … [they] had to kind of make a leap to get to those facts." When engaged in the analysis activity, Max said, "You really look at the lyrics and if you, as a class or individually, kind of dive down into it, you can really get some good… facts and some real, good content out of that." Mr. Cantor summarized, "Trying to interpret what the song says into a fact of, that we know, it was good. It was very… very good. It was kind of in-depth for them."

Summary

The data from this case revealed several themes related to the research questions that guided the study. First, science-content songs were useful for teaching by providing students in this case with alternative explanations of science concepts. This teacher said that when his students were learning with songs they might have thought, "[He] really wouldn't have given us that example, or use the terms in that way. But based on what I know that he taught us, I can see how this relates." A second theme related to how Mr. Cantor used science songs for learning was that he found

science songs have “content-rich lyrics” that explained key ideas and gave examples of concepts to his students. The novelty of using songs for a teaching strategy was what students found most engaging, and they interacted with the science concepts longer. Mr. Cantor supported what his students said, “I think it really does engage all your learners… I think every learner’s going to get something out of it new that they didn’t get out of the other teaching styles that I was using.” The data analyzed also suggested that the special appeal music has for today’s students was one way in which science songs have a potential impact on teaching and learning science. Additionally, for songs to have instructional potential, students must be involved in a lyric analysis activity to help them connect ideas and organize new knowledge. When asked, “Are you going to keep using songs?” Mr. Cantor responded, “Yeah…. because I think it added [a] different dimension to how and what I teach… definitely to how I teach. Not really to what; it doesn’t really change what I teach, but it changes how I teach.”

CHAPTER 5: CROSS-CASE ANALYSIS

The purpose of this study was to learn more about the experiences of teachers and students when content music was used for teaching and learning in the middle school science classroom. A multiple case study design was used to explain, describe and understand what happens when content-based songs are used as an instructional strategy to help students understand science concepts. In this study six teachers and their students shared experiences and insights about the use of science songs for teaching and learning, which were used to better understand the quintain; a term suggested by Stake (2006) to represent the common condition or experience across cases that binds cases together. Synthesizing the data, that is, exploring the similarities and differences in the themes identified for all six individual case studies provided a deeper understanding of the quintain; and the use of science-content music in the middle school science classroom for teaching and learning. What follows is a discussion of the cases in context and a synthesis of the findings in the study.

Cases in Context

The six cases included in this study were "selected because they represent the program or phenomenon" (Stake, 2006, p. 23) being studied. As indicated by Stake, the opportunity to learn about the quintain is the most important criteria for selecting cases for multiple case study research. The participating middle school teachers included in this research were those both accessible, and willing to implement the use of science-content music as a teaching strategy during the data collection phase of the

study. They taught in schools from the same district the researcher works in, were geographically close, and where both the administration and teachers were willing to participate; thus providing an opportunity to observe the quintain. Once the targeted number of six cases was met, based on recommendations by Stake (2006), the recruitment phase of the study ended and data collection began.

Common Characteristics

These cases were contextually bound in that they all occurred in middle schools located in the same school district. All of the teachers were experienced, rather than novice educators, with no less than nine years' experience. All the classrooms were in buildings constructed using similar plans, each one laid out with a nearly identical arrangement of student lab tables with slight variations in the placement of the teacher desk. A common framework for state standards in science was used by all teachers according to grade level that resulted in many of the same songs being used across cases, while teachers covered the same concepts. All six teachers received the same introduction to the study with instructions to use two songs in upcoming units and include a lyric analysis activity as part of the study. Other suggestions were made for implementation strategies and an identical list of important points and guidelines were reviewed with each teacher at the beginning of the study, as shown on Appendix E.

Each teacher was provided with four CDs from which to select songs and additional resources for science-content music were suggested to explore additional songs for teaching science concepts. One of the recordings provided to each teacher was content specific and varied by grade level. A second CD that was provided to all participants in the study was the 2009 release of *Here Comes Science* by They Might

Be Giants, which included Flash animation videos for all the songs. My husband, Larry Morris, recording science-content songs under the alias of Professor Boggs, produced two of the CDs provided to these teachers. The second of those CDs, *Round the World With Science* (Morris, 2010) was produced specifically for this study in that the songs were written to purposely address content standards covered in the participating school district during the data collection period. The concepts covered in these songs spanned the curriculum for all three grade levels and were written according to research-based suggestions as described in the research review in Chapter 2 and discovered during the pilot study about songs for learning. It was this final CD that provided the content-based science songs for most of the study, although different songs were used based on grade level.

Commonalities in Implementation

Across the six cases, there were a number of commonalities in terms of how teachers implemented science songs. Sixth grade teachers used songs about heat transfer during their study of the Earth's mantle, and the songs about plate tectonics and the rock cycle from this CD. Eighth grade teachers at both schools used "Conduction, Convection, Radiation" and "Some Kind of Energy" from the same recording (Morris, 2010). The seventh grade teacher used a number of songs from both of Morris's CDs, as well as one by Dr. Chordate.

There are a number of possible explanations for Morris's songs being chosen by these teachers during implementation of this study. One possibility is that these songs were intentionally tied to the content standards being addressed during the study. Sandy Kingston emphasized the importance of having easy access to songs that fit the

curriculum. For songs to be chosen as a useful teaching tool, she said, “the lyrics would have to be on target with our concepts and our content.” Derek Martin explained why he selected the songs he did, “They had enough information in them. They had enough detail and content in them that they were very useful and I knew that from listening to them. I was like, ‘Okay, I’ll use this.’” Derek compared these songs to others that were provided, “You gave me another CD by They Might Be Giants; is that right?” he asked. Then added, “I think I remember a song, or two on there that I’m like, ‘Well, I might be able to use this.’ But I don’t remember the tune.” Anna Darcy explained her preference for selecting songs from Morris’s CDs, “I know that [Morris] knows the words we’re using in science. So I know he’s familiar with what I’m doing.” During the interviews several of teachers said that content emphasis tied to the curriculum was the most important criteria in selecting songs for teaching science as well as being able to find songs to fit the concepts they were teaching.

Variations in Implementation

Even though all teachers were given the same instructions and resources, they chose to begin implementation of the study at different times in the semester. The teachers at School C were the first ones to bring science-content music into their curriculum. Within days Sandy Kingston reported her students were learning about heat transfer in Earth’s mantle with “Conduction, Convection, Radiation” (Morris, 2010). Derek Martin’s classroom was the first visited in early November using his second song, “Some Kind of Energy” to teach about energy forms and transformations. Two of the teachers at School B were the last to use songs for teaching with both Max Cantor and Betty Taylor’s observations having occurred in early December, near the end of the data

collection period. Both those teachers waited until well into the semester and cited finding time to learn and implement a new teaching strategy as a major obstacle in implementation. Max Cantor reported it was, “one more thing to fit in, you know, and that’s the way I looked at it, at first.” He added, “By doing it once, now I’m like okay, I know how to do it now. And so now that I’ve done one, it makes it easier for me to implement other ones.”

While initial instructions for all participants asked them to include a lyric analysis activity during the study, there were interesting variations in how each teacher interpreted what it meant and how they implemented this strategy. A comparison of implementation strategies is summarized in Table 10. All the teachers in this study provided students with lyrics on a handout for the analysis activity but what they had students do with the lyrics differed. Two teachers, Derek Martin and Martha Russell asked students to work in groups to interpret lyrics, then shared their thoughts with the class. The other teachers included a whole-class approach to the activity. Max Cantor and Betty Taylor both followed up by assigning students an independent activity; Cantor’s students had to write illustrate or add verses, while Taylor’s eighth-graders were asked to do a comparison to the textbook.

All the teachers except Sandy Kingston asked their students to interpret lyrics in a paper and pencil task. Betty Taylor emphasized the use of action words in the song, while both Martha Russell and Anna Darcy stressed identification of ‘key words’ and terms used in the songs. Max Cantor provided the broadest explanation of what lyric analysis meant with his students and included instructions about differentiating between

vocabulary words and facts, and further encouraged students to identify places where the lyrics were confusing and to add questions about the content presented in the lyrics.

TABLE 10: Implementation Comparisons

Teacher	Lyric Presentation	Activity
Martin	Lyric handout	Groups interpret and make mini-posters showing examples & non-examples to share with class
Kingston	Lyric handout	Class dance
Russell	Lyric handout includes empty boxes and Power Point	Groups identify vocabulary and interpret verses to share with class; some wrote words, others used pictures
Taylor	Lyric handout	Find “action words” then interpret and discuss as a class; compare with textbook independently
Darcy	Lyric handout includes empty boxes	Listen with hand motions and underline key words, then class discussion
Cantor	Lyric handout and projected on White Board	Find key terms, add facts, questions and notes as a class; compose new verses or illustrate independently

The two sixth grade teachers demonstrated the most unusual ways of engaging students in lyric analysis activities. Martha Russell developed a complex multi-media presentation for both the songs she used, complete with graphics and timed with the lyrics. Sandy Kingston developed a kinesthetic activity, involving a choreographed dance. Both of these groups of students were highly enthusiastic about learning science with songs in the focus group discussions, a factor which could easily be contributed to their age as easily as to the activity involved. A seventh-grade teacher, Anna Darcy, used hand motions to emphasize key ideas related to evolution in a whole-group activity but with less student enthusiasm. Regardless of how the lyric analysis activity was implemented, all teachers who participated in the study reported that this was a positive

learning experience that helped their students engage with and understand the science concepts they were teaching.

Synthesis of Case Findings

The final outcome of the cross-case analysis resulted in a number of assertions for each research question based on a merging of the themes from individual case findings that provided insight into the quintain. According to Stake (2006), this process should be a synthesis of ideas found in individual cases, rather than a further analysis of data. Consequently, areas of divergence in the data for this multi-case study are presented separately. The cross-case analysis produced six assertions, each with a single focus that resulted from a process of comparing similarities and differences across cases, as identified in Table 11. Supporting evidence is provided in the discussion related to each assertion. In attempting to understand how science-content music was used for teaching and learning middle school science in these cases, two assertions resulted from a synthesis of findings: first, that science-content music helped students develop scientific vocabulary, and second, that songs provided students with an additional resource to construct meaning of science concepts. In reviewing how student interest, engagement and understanding of science concepts were impacted by using science-content music, merged findings suggest the students thought that songs provided novelty and variety in the learning environment and were considered to be a mnemonic device that aided learning. The final assertions suggested in the cross-case analysis are related to the potential use of science-content music for teaching and learning science based on the experiences of both teachers and students. They included how the socio-cultural appeal of music can be utilized when using science-

TABLE 11: Assertions from merging cases during Cross-Case Analysis

Research Question 1: In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?						
Assertion: Songs help students develop scientific vocabulary.	**DM**	**SK**	**MR**	**BT**	**AD**	**MC**
• Build understanding of scientific terms	X					
• Build vocabulary base			X			
• Develops language of science				X		
Assertion: Songs provide students with an additional resource to construct meaning of science concepts.	**DM**	**SK**	**MR**	**BT**	**AD**	**MC**
• Providing alternative examples	X					X
• Explaining key ideas						X
• Visualization of concepts			X			
• Telling stories					X	
Research Question 2: How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?						
Assertion: Songs provide novelty and variety in the learning environment.	**DM**	**SK**	**MR**	**BT**	**AD**	**MC**
• With novelty or change in environment	X				X	X
• With active learning		X	X	X		
Assertion: Songs are mnemonic devices that aid students in learning	**DM**	**SK**	**MR**	**BT**	**AD**	**MC**
• As a mnemonic device			X	X		
• As a part of a study strategy		X				
Research Question 3: What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?						
Assertion: Music has a socio-cultural appeal for students that can be utilized in science instruction.	**DM**	**SK**	**MR**	**BT**	**AD**	**MC**
• Instructional contagion		X				
• Music has a universal appeal		X				X
• Students care about			X			
• Songs have socio-cultural appeal				X		
Assertion: Lyric analysis can help students connect ideas and build conceptual understanding.	**DM**	**SK**	**MR**	**BT**	**AD**	**MC**
• Lyric analysis helps students connect ideas and organize knowledge	X			X	X	X

content music for instruction; and finally, that lyric analysis can help students connect ideas and build conceptual understanding. As is the implication with all case study research, these findings are limited to these cases and cannot necessarily be generalized beyond the bounds of this study.

Assertion 1: The use of science-content songs impacts learning by helping students develop scientific vocabulary.

During the individual case analyses themes related to the use of content-based songs to develop scientific vocabulary appeared in the data for Derek Martin, Betty Taylor and Martha Russell. While the data collected from these teachers emphasized the use of songs for developing scientific vocabulary, all the other teachers included in the study, and some of the students, provided support for this assertion, as summarized in Table 12. In the case of Derek Martin, he reported that the songs were used to help students build "a working definition" of science terms. He said that they "were not simply a song that happened to mention the word 'bird' or something, or happened to mention the word 'atom,'" but went beyond in developing the language of science. Derek explained, "It worked at different levels. I think it worked for introducing them to some important words, or key ideas." Mr. Martin added, "I think it's deeper than just vocabulary. It's deeper than just spit back out, recognizing examples on the worksheet." Mrs. Russell talked about one of the greatest challenges she faces with teaching her students; "Sixth graders don't have experience with a lot of science in elementary school. They don't know how to handle the vocabulary-heavy subject that we have." She added, "With all of the vocabulary, it's very hard." In her experience the songs helped her students because "by choosing those key words, I was able to point

things out." For Mrs. Taylor, it is important that her students learn to "speak science." She explained, "A lot of times they don't think they know things and they do know it, and they do have it. They just don't have the language with it." The use of science-content music as a teaching strategy helped her students develop the language of science.

Most of the activities observed during the classroom visit included some component of vocabulary development as well. Sandy Kingston's students made kinesthetic motions when key words were mentioned, such as making circles with their hands in front of them when the word "convection" was sung. Anna Darcy said that during the lyric analysis activity she asked students to, "underline the vocab-words" that they discussed in class, and Max Cantor had students "pull out key words." One of Mrs. Darcy's students elaborated how the song helped her build an understanding of science vocabulary, "every word it sort of gives meaning; it gives you an explanation about it." Another student said, "It defined the words… it actually defined the meaning of them." Finally, while the data from Sandy Kingston to support this assertion wasn't extensive, she did provide an example of how the songs helped her students build scientific vocabulary. At her third interview she talked about using "The Lonely Fossil" (Morris, 2010) in a lesson she covered earlier in the day;

> There was one class that I did not play the Lonely Fossil for, because our schedule got cut short. When we were doing the questions that class could not get the answer, 'trilobite.' And the other classes had gotten it. And I thought, why did they not know? And then I said, y'all know, you remember it's in the song. And they said, "What song?" So it was almost like that song even introduced that key [term], 'index fossil' to them.

Although the data were only significant enough to support an emergent theme in half of the six cases, every teacher involved in the study, and many of the students, discussed how the use of science-content music helped build scientific vocabulary.

TABLE 12: Supporting data for "Developing scientific vocabulary"

Assertion 1: Songs impact learning by helping students develop scientific vocabulary.	
Martin	*I think it worked for introducing them to you know, here's some important words, or key ideas.*
Kingston	*They were just picking out different words, and talking about, "We've seen that one before." Or, "I already knew what that one meant."*
Russell	*And then the vocabulary; a lot of that was there too, and the more they hear it, the better they do with it.*
Darcy	*I would say underline the vocab-words you remember learning about.*
Taylor	*Some of the words that they learn in science they'll have to know in the songs, [to] kind of help connect a little of the vocabulary.*
Student 1	*It defined the words… it actually defined the meaning of them.*
Student 2	*It has like a bunch of key words.*

Assertion 2: Science content songs impact learning by providing students with an additional resource to construct understanding of science concepts.

Most of the teachers in this study talked extensively about how the use of content-rich songs impacted teaching and learning by providing students with an additional resource to build understanding of science concepts, although each of them provided a different insight to how this worked. Themes from five of the six cases contributed to this assertion by emphasizing different approaches, however every teacher included in this study made statements that contributed to this finding. Table 13 provides an overview of supporting data from all of the teachers and several of the students recognizing the potential for these songs to provide an alternative resource for students in building understanding of science concepts.

To support this assertion both Max Cantor and Derek Martin discussed how the songs provided students with alternative examples and explanations of the concepts they were studying. Mr. Martin talked about how the songs "gave them something else

to refer to," then added how important it is that, "students get a chance to pull from something other than the all-mighty textbook as their base reference." These songs, he said, "would have examples in them, for the students to recognize" and "it keeps reinforcing that concept, and with examples." Max explained how the songs worked as an additional resource for his students, "The songs presented the material in a slightly different way; I taught it in one way, and gave certain examples, and then the songs that we used, it kind of gave some other examples and used some other vocabulary." Martha Russell discussed the use of songs as an additional resource for students to build understanding of science concepts, but explained this in terms of a visualization process. She reported, "They were able to take that and when they heard the phrases they were able to visualize, think about what happened a little bit better."

Anna Darcy talked more about how songs were more like stories that could be used as an alternative resource for building understanding. She described the song lyrics as fitting together to tell a story. For her, this provides something that she feels is missing from her day-to-day teaching, "I think it just was a different way because sometimes I get into a bad habit of teaching pieces and never looking at fitting it together. And I think the songs fit it together." Once again, even though the data from Sandy Kingston didn't significantly add to this assertion, she did provide an example of how the songs provided an additional resource for her students to draw from. While sharing a conversation she had with a student about his results on an assessment, she explained:

> He said, "I could remember that conduction was heat movement through a spoon, stir a cup of coffee." He said that for convection, "I remembered warmer currents rise, cooler currents sink." So he remembered direct things and examples from the song.

Students in most of these cases confirmed that these content-rich songs provided an additional resource for them to build understanding. One of Mr. Martin's students talked about the energy song from the lesson on the day his class was observed, "I like this one because it told you what it was and then gave you a couple of examples." Mrs. Kingston's sixth-graders said that, "there's a bunch of examples in the song," while another student in her class added, it "summarizes the main ideas and stuff." Mr. Cantor's students had the most to say about science songs as an additional resource for explaining concepts. One of his students said, "If you look in the book it says the same things. It's just in song form." Another added, "It makes little words, instead of those huge words in the books that keep you all confused." Mrs. Darcy's students said, "It has like all these describing words and it describes everything for you."

TABLE 13: Supporting data for "Additional Resource to Construct Meaning"

Assertion 2: Songs impact learning by providing students with an additional resource to construct understanding of science concepts.	
Martin	*The songs would have examples in them, for the students to recognize, "Oh that's an example of… you know, whatever this concept might be, so, you know, conduction and the particles touching, or whatever."*
Kingston	*He said, "I could remember that conduction was heat movement through a spoon, stir a cup of coffee." He said that for convection, "I remembered warmer currents rise, cooler currents sink." So he remembered direct things and examples from the song."*
Darcy	*I think [the song] just was a different way because sometimes I get into a bad habit of teaching pieces and never looking at fitting it together. And I think the songs fit [concepts] together.*
Cantor	*The songs presented the material in slightly different way. I taught it in one way, and gave certain examples, and then the songs that we used. It kind of gave some other examples and used some other vocabulary. And it just kind of reinforced what they had already learned.*
Student 1	*There's a bunch of examples in the song and stuff.*
Student 2	*They gave us so many specific details more than your teacher tells you.*
Student 3	*When it's a song, it kind of like summarizes the main ideas and stuff.*

Assertion 3: Songs provide novelty and variety in the learning environment.

The data from student focus group interviews and classroom observation were used to better understand the quintain in terms of how content-based songs impacted student interest, engagement and understanding of science concepts. One assertion that appeared consistently in the themes across all cases was related to engagement through novelty and variety. Supporting data for this assertion is provided in Table 14.

Students from all cases talked about how much they enjoyed learning science with content-based songs. Some students, like those in Anna Darcy's, Derek Martin's and Max Cantor's classes, talked more about the novelty of learning science with songs, while students in the other classes explained engagement more in terms of "active learning." The active nature of learning with songs was most obvious in Sandy Kingston's class as all of her students got up and danced with the song. In every classroom observation at least a few students were observed singing and moving in their seats to the beat every time science-content music was played. Some made unsolicited hand motions, such as one girl in Mrs. Russell's class during the chorus of "Tectonics Rocks" (Morris, 2010). A student from Mrs. Taylor's class summarized, "It's active learning. Music, it sticks in your brain."

Students described novelty in a variety of ways. One student said that learning with songs was, "something out of the ordinary." A sixth-grader in Martha Russell's class said, "You can learn from it, because it's more better than a book, a teacher and study guides and all that." Another student elaborated on her level of engagement, "It doesn't seem like its work. It just seems you're in the middle of class, and you're listening to a song." The most common comments made by students addressed how

difficult it is to pay attention to 'teacher-talk.' However, songs presented content in a way that kept them listening, as explained by one student, "When people are talking and they're lecturing or something, I just zone out, and then I miss half the lesson. But then, with a song, it wraps it up and makes it easier to listen to." One of Max's students explained, "I wanted a lot more, because I hear Mr. Cantor's voice every day, so it's just different when he played the song." Anna Darcy's students reported, "When the teacher's talking it's so boring, it goes in one ear and out the other." She added, "When I listen to music I don't really picture anything, I just sit there and listen to it and it goes in my ear and stops." Regardless of how engagement was explained, students across cases reported that they enjoyed learning with songs and most were more likely to pay attention in class than when traditional teaching methods were used.

All six teachers also recognized how songs engaged their students through novelty and variety. Derek Martin explained, "The engagement level, I think, is definitely higher with something like this, with the music, because it's just a different mode of delivering it to them." Max Cantor reported, "It's also new to them. It's like people don't do that all the time." Anna Darcy also offered her support; "I think they're more actively involved rather than passive, just listening to me say it. All of a sudden they're tapping their foot and clapping their hands." Some of the teachers reported that their students asked to hear the songs repeated frequently. Martha Russell said, "They kept asking me for one thing, when are we going to do another song? Can we hear it again?" Sandy Kingston reported that even when she tried to have students listen to popular music, they asked to hear the science songs again instead; "Sometimes I play something off my iTunes… and they'll say, "Put on the 'Conduction, Convection,

Radiation' song." I'm like, are y'all serious? Yeah, we want to hear that! And we'll play it again." Ms. Kingston said that her students' engagement level was so great that they continued singing and dancing about heat transfer beyond the classroom. She reported receiving feedback from parents, "I had three emails that came in in one day and just said this, specifically, this song, this dance that they're doing on the soccer field, they really enjoy learning, and you've made it fun." Betty Taylor talked about how her students' responses to learning science with songs exceeded her expectations, "I was surprised at how much they really wanted to sing it. Because usually trying to get kids to sing in class has just been not going to happen." She added it was, "easier to engage them with this than with the lab." Max Cantor also found the level of engagement he observed with his students impressive, "I was a little surprised by that; sixth or seventh, they might like it, but no, the eighth graders, they loved it!" Teachers, as well as students, claimed that the novelty and variety of learning with content-rich songs enhanced student interest and engagement in the middle school science classroom.

TABLE 14: Supporting data for "Songs provide novelty and variety"

Assertion 3: Songs provide novelty and variety in the learning environment.	
Kingston	*I had three emails that came in in one day and just said this, specifically, this song, this dance that they're doing on the soccer field, they really enjoy learning, and you've made it fun.*
Russell	*Well they kept asking me for one thing, when are we going to do another song? Can we hear it again?*
Darcy	*I just think the music makes them more excited to pay attention.*
Student 1	*If it's more fun than it is to learn about something, it's easier to learn.*
Student 2	*You can't learn as much if you don't have something fun to remember it by.*
Student 3	*It doesn't seem like its work. It just seems you're in the middle of class, and you're listening to a song*.

Assertion 4: Songs are mnemonic devices that aid students in learning

One assertion that was suggested from the themes identified in three cases was that students thought science-content songs provided mnemonic devices that helped them learn and remember science concepts. Mnemonic devices are learning techniques that aid memory. Themes that emerged from the data in Martha Russell's and Betty Taylor's cases indicate that students used science-content songs as mnemonic devices to remember concepts, while Sandy Kingston's students went farther in using them to study for tests. However, students from most of the other classes, and all of the teachers, provided additional statements to support this finding, as shown in Table 15.

Students in Martha Russell's and Betty Taylors classrooms talked extensively about how the song became earworms and got "stuck in their heads" and helped them remember important ideas in science. One eighth-grader in Mrs. Taylor's class stated, "Music sticks in your brain. You're not going to forget it." A student in Mr. Martin's class talked about one of the songs they learned in this teacher's class:

> We listened to it all the time in science. And then this guy on my bus, he was singing it on the bus, the whole bus ride home. So it obviously got stuck in his head and it got stuck in mine, too.

One girl from Sandy Kingston's class offered, "It just gets stuck in your head; it's just simple. So simple, that it just gets stuck in your head." In Sandy Kingston's case, the theme that supported this assertion suggested that these students used songs to help them as a study strategy. One student explained, "the song gets stuck in your head, and then you know the definition and then you're able to do well on your test."

Across all cases students described these songs as “catchy” and talked about how the use of rhymes and humor made them easy to remember. Mrs. Russell’s students said, “You can kind of remember the words since it’s so catchy,” while another said, “It all rhymes, so you can remember it better.” One of Mrs. Darcy’s students offered, “it’s got a tune and a beat that’s catchy and then it says all this stuff; you learn stuff and then you laugh because it’s funny.” The fact that the songs seemed to become earworms for many students was one of the things they appreciated most about them. “I think the best part is you can go back to it and you can keep it in your head since it’s catchy,” one of Mr. Martin’s students explained.

Even the teachers recognized the potential for science songs to act as mnemonic devices to help students remember science concepts. Derek Martin said, “We can’t help, but sometimes, have lyrics stick with us. So even just as an academic learning device, it’s great.” Anna Darcy said that for her students the songs were compelling, “They couldn’t help but learn it. That’s what I like about it. You may not even have been trying to learn it, and you know it.” Mrs. Russell she saw specific students that the songs seemed to help the most, “Even during the test last week, I had some of them sitting there with their hand motions. And I could actually tell that some of them were kind of trying to sing it along as we were going with the test.” Mrs. Taylor also noted a similar tendency, “I noticed sometimes they would be working a question, and it [would] trigger, and they would start singing.” These songs were powerful mnemonic devices that had value in helping students remember important concepts in science.

TABLE 15: Supporting data for "Songs are Mnemonic Devices"

Assertion 4: Songs are mnemonic devices that aid students in learning	
Martin	*We can't help, but sometimes, have lyrics stick with us. So even just as an academic learning device, it's great.*
Kingston	*He said, "No, it was that song. It got stuck in my head and I actually learned it."*
Russell	*It's a good recall method for them.*
Darcy	*They couldn't help but learn it. That's what I like about it. You may not even have been trying to learn it, and you know it.*
Taylor	*I noticed sometimes they would be working a question, and it [would] trigger, and they would start singing.*
Student 1	*I think the best part is you can go back to it and you can keep it in your head since it's catchy.*
Student 2	*You think about it and sing in your head and you're like, "Oh, I knew that."*
Student 3	*It doesn't really seem like you're learning anything, but the third chorus, or, by the third time you're listening to the song, you're like…Oh yeah, I am remembering this stuff!*
Student 4	*With the song you can kind of remember the words since it's so catchy.*
Student 5	*I really, really could not remember anything, and then we learned that song, I got all of it.*

Assertion 5: Music has a socio-cultural appeal for students that can be utilized in science instruction.

The third and final research question related to the potential of songs for use in science teaching based on the experiences of teachers and students in these cases. The common focus for the themes identified in addressing this question related to why the use of science-content music should be considered as an instructional strategy. In analyzing the data for all individual cases, themes appeared to support the assertion that music has a socio-cultural appeal that can be used for instruction in four of the six

cases. The themes related to the socio-cultural appeal of music varied in how they were expressed, but the binding concept for these ideas relates to the socio-cultural aspect of learning with songs. The socio-cultural appeal of music is a synthesis of the ideas related to the importance of music in the culture of middle school age students. The themes identified in each case represent a different dimension to understanding the role music plays in the lives of these students. For Sandy Kingston, she found that songs had a broad appeal, and that they spread like an instructional contagion far beyond the walls of her classroom. The universal appeal of music was a theme that emerged in Max Cantor's case as he realized the impact using songs for teaching had on his students and that by bringing it into his lessons had reached students in a new way. Martha Russell described the nature of songs as something students care about as she talked about the media influences that depended on music, while the experiences of Betty Taylor and her students more directly resulted in identification of the theme that songs have a socio-cultural appeal. Data supporting this assertion across all cases is summarized in Table 16.

For most of the teachers and students in these cases, the power of music had an appeal to students that was universal. Virtually every teacher in the study discussed how his or her students connected with music. Martha Russell acknowledged the appeal of music for her students, "Kids love music. And it's like the ideas are there, but with the rhyming of the lyrics, and just the catchy phrases, they liked it." Betty Taylor talked a lot about how much music resonated with her students, and how it infiltrated every aspect of their lives. She related the phenomenon she observed with a school-wide interest she saw students had with the television series, "Glee;" and the special

meaning songs had for them. "Glee" is a currently airing, musical-drama series that is targeted towards teenagers. She explained, "They all talk about 'Glee', so I'm thinking that with all the competitions, with songs and stuff on there, I think they're more receptive to songs and music." She talked about other socio-cultural aspects of music and how it infiltrated the media from movies like "High School Musical," a Disney made-for-television film aimed at a teen-age audience, to social karaoke events and easy access of digital music downloads. Max Cantor also talked about the appeal of music, "They may not like this music, this not be their style, but they still like music."

Although the data wasn't sufficient enough in Derek Martin's case to generate a theme, he recognized that students "identify with music" and further supported this assertion; "Simply the power of the music sticking with you, and the lyrics sticking with you, there's nothing else. I mean there are other ways that you can engage with material. Although I think this is one of that gets the students interest. So that gives it a little extra, you know, compared to other activities that also helped them engage with the material." Students across cases talked about how music resonated with them. As reported in the case study for Mrs. Taylor's class, one young man summarized it best:

> Music is, well, with most people it's a good thing. It's something. We go on iTunes and buy music. It's worth something. If you associate learning with something that's worth something, then people will want to learn.

Using science-content songs to teach has the potential to affect teaching and learning because it tells students, according to Max Cantor, "You know something about me. You know that I like music. You know so you're trying to teach in a way that you think I might enjoy."

TABLE 16: Data supporting the "Socio-cultural Appeal of Music"

Assertion 5: Music has a socio-cultural appeal for students that can be utilized in science instruction.	
Martin	*Simply the power of the music sticking with you, and the lyrics sticking with you, there's nothing else. I mean there are other ways that you can engage with material. Although I think this is one of that gets the students interest. So that gives it a little extra, you know, compared to other activities that also helped them engage with the material.*
Kingston	*Students right now need some kind of creative outlet and they seem to like music.*
Russell	*Kids love music…. And it's like the ideas are there, but with the rhyming of the lyrics, and just the catchy phrases, they liked it.*
Darcy	*You can't listen to the songs and not be happy. You know, I mean they're positive.*
Taylor	*I think they're more receptive to songs and music.*
Cantor	*They all have their iPods, they all want to listen to music, and it kind of makes them feel like, okay, you know something about me. You know that I like music. You know so you're trying to teach in a way that you think I might enjoy.*
Student	*Music is, well, with most people it's a good thing. It's something we go on iTunes and buy music. It's worth something… If you associate learning with something that's worth something, then people will want to learn.*

Assertion 6: Lyric analysis can help students connect ideas and build conceptual understanding.

The final assertion that resulted from a synthesis of the case findings is that when songs are used as an instructional strategy for teaching science, the process of analyzing lyrics can help students connect ideas and build conceptual understanding. This theme appeared in four of the six cases fairly consistently and with nearly the same terminology. Derek Martin, Betty Taylor, Anna Darcy and Max Cantor all extensively explained how having students dissect and analyze the lyrics of content rich songs

helped them connect ideas and build understanding of science concepts. Table 17 summarizes some of the data to support this assertion.

Derek Martin's response to the use of science songs was reflected in what he saw happen with his students: "When they start looking at the lyrics, and they're like, Oh! There's some meaning to this! Oh! This stands for something else!" When he gave them a new song to analyze Mr. Martin said, "They've got to look at the lyrics and apply what they know. They have to look at the lyrics and understand and see how the lyrics make those connections." Anna Darcy also stressed the importance of analyzing the lyrics for the songs as a meaningful learning experience: "I want them to be able to connect it to things; otherwise we're just singing words. But I want it to be more than that. I want it to go to a deeper level." She said that when her students analyzed song lyrics she asked them, "Why would he choose to put that in a song? It's because… and then it makes a connection and then they're like, 'Oh!'" Mr. Cantor said that when his students analyzed the lyrics, "they had to look a little bit deeper than the surface level." For him, "It's not about definitions, but how does this illustrate the concepts?" Max added, "They have to be able to make that connection with the example that they read or hear from the song, or read in the lyrics, or hear from the lyrics. So, there's that aspect of it. And, I think that's one of the strongest aspects, obviously." Betty Taylor thought it was important to analyze lyrics after concepts were introduced to maximize their potential and suggested that was because students needed something "to bring to" the activity. She explained it, "helped that I did the song when they had some knowledge to bring to the lyrics." She added, "It helps us transfer that information, that whole experience. I think that this is one of those elements that helps with that."

Martha Russell also talked about how analyzing lyrics helped her students make connections, “When songs are used for teaching, students can “take what the words or action, what the meaning of the words actually is. They can take it and say, ‘Oh! Yes! This means such and such.’” She added, “That’s how they can piece it together and get the whole conceptual idea together.”

Although the students didn’t articulate well how analyzing lyrics helped them make learning connections, they explained what they thought was gained from the activity and gave some examples of how it worked to help them. One student from Mrs. Russell’s class said, “It helps me understand… how they work, and stuff like that,” referring to how the lyric analysis activity helped her understand concepts included in plate tectonics. Another of her students said she thought the song helped her learn because after one of the songs was introduced and analyzed, “The next day we were doing stuff in class and I was just doing every answer because we learned the song.”

One student in Sandy Kingston’s class gave this example, “When I hear convection, or conduction, or radiation, those words, or see them written in anything, I think of the song and then I know what it was talking about.” A student from Anna Darcy’s class tried to explain how the evolution song helped him connect ideas:

> You’re like hey, this is pretty interesting, so you get into it and it’s talking about what we’ve been learning. It was saying about the ancestors were hairy part. It was just saying it doesn’t matter what they were, it matters that you could’ve had a mutation in your cells and it doesn’t matter what they had.

Another of Mrs. Darcy’s students provided her insights into how lyric analysis helped connect ideas, “It gives you a big picture too, not just looking at the little parts of the song, but like looking at the whole song, it’s like a big picture. It’s not just like small little

ideas locked in the middle of the song." While the data collected from students didn't emphasize how science songs helped them connect ideas to develop understanding of science concepts, they did provide some additional evidence to support this assertion.

TABLE 17: Data supporting "Lyric Analysis Helps Connect Ideas and Builds Understanding"

Assertion: Lyric analysis can help students connect ideas and build conceptual understanding.	
Martin	*To see my students pick out, pick apart the lyrics and to see some of them even find connections that I missed, going over it with the class. To me shows that the lyrics are complex. There's, there's a deeper level of understanding you have to get to be able to do that.*
Kingston	*That helped him make the difference, you know, and the connections there.*
Russell	*That's how they can piece it together and get the whole conceptual idea together.*
Darcy	*Why would he choose to put that in a song? It's because… and then it makes a connection and then they're like, "oh!"*
Taylor	*It helps them connect science to some of their experiences because a lot of times they don't think they know things and they do know it.*
Cantor	*They've got to see the lyrics to make some connections with what the science is and what they're currently learning. They can see some of the pictures and examples, but to get to that really deeper factual stuff, they really got to see the lyrics.*

Divergence Across Cases

In conducting the cross-case analysis emphasis was placed on synthesizing themes from the individual cases to better understand the use of science-content music in the middle school classroom. However, there were some anomalies, or areas of divergence, in the data that warrant further discussion.

Not all students like learning science with songs.

While the vast majority of students enjoyed learning science with songs, there was one student among the fifty-seven participants who rejected this idea and clearly did not enjoy learning with songs. For one eighth-grade girl in Derek Martin's class, songs interfered with learning. She reported, "I don't like learning with songs, because they don't necessarily come out and tell you what it is, straight out, but sometimes they go too fast and you just can't hear." For her, this strategy is neither engaging, nor novel. She would "rather read it in a textbook." In her focus group interview she had little else to contribute to the conversation about why her experience was so different from her peers, but her classmates did support her in explaining that not all songs are good for learning.

While the other students in her class didn't concur with her opinion, they suggested that some songs that were too complicated, confusing, or included irrelevant information might hinder learning. One of her classmates reported that the song, "Atom Shack" (Morris, 2010) presented problems for him:

> During the test I actually thought it was a little confusing if I went back to try to 'listen' to the song. I couldn't remember how in the song where everything went in order. So then I got kind of confused and I stopped trying to refer to the song. Since that song was kind of like repetition with slight changes, it got muddled around in my brain.

Another student suggested, "If the song is too long and not catchy, and it's just words, it may confuse them more and not help them as much." For songs to be helpful, this student continued, they should have "some sort of order and relation." He explained this meant lyrics needed to present information in logical order, give examples and rhyme. Another student summarized that songs should be, "simple and catchy."

As these students discussed their experiences they offered their opinions on characteristics of songs that they thought were helpful for learning. One of the boys in the group compared a song he thought was good for learning to one that wasn't, "it just tells you right off what everything is. But in the other one, the electrons, you have to know a little about it to understand what it's talking about." When asked what made a good science song, one student in this focus group responded, "short and sweet and to the point." And while this group continued to offer criticism of certain songs, every student in the group, except this girl, reported that they did enjoy learning with songs, consistent with all of the other students in the remaining cases. For students, the use of science songs engaged them in learning and provided mnemonic devices for remembering information, as indicated by the assertions suggested relating to student interest, engagement and understanding of science concepts.

From the teacher's perspective, a song with lyrics that required his or her students to apply information was more desirable than one that simply could be used to aid recall of information. The merged findings of the individual cases that relied primarily on the teachers' data suggested that they wanted songs that would help students build scientific vocabulary and provide alternative examples and explanations of science concepts. Additionally, teachers thought that the lyric analysis activity had the potential to help students connect learning and build understanding of science concepts. While the dissenting student and her classmates discussed a preference for songs that were "catchy and short" for remembering, these teachers wanted songs that were more in depth to build conceptual understanding. Derek Martin explained, "We're

trying to boost it up here, and get to higher levels of engagement, higher levels of thinking." For him, the lyric analysis activity required students to, "have to understand a deeper meaning… They [have to] define where the connections are with the content." The students recognized the potential for songs to build deeper understanding, as suggested by one of Mr. Martin's students, "I think that really helped, because then you're picking it apart." But at the same time, they expressed a desire for simpler songs, "If it's too in depth, the song wouldn't really help much." Teachers wanted songs that would foster deeper understanding, but students wanted them as mnemonic aids for easy recall of information. The difference in the teachers and students' perspectives for the use of science songs in learning science were divergent enough that they could explain this student's objection to the strategy. Regardless of the reason, however, this student's opinion serves as a reminder that no teaching strategy will appeal to or work for all students.

Divergent Themes

While most of the themes identified while analyzing data from each case reflected the use of science-content music had a positive impact on students, there were a number of themes that did not have enough support to be further developed during the cross-case analysis. Some ideas, for example, Sandy Kingston's perception that test scores improved, or Martha Russell's suggestion that repetition builds ownership of content, were mentioned briefly by at least one other teacher in the study. Most of these themes, while not having adequate support to develop into a cross-case assertion, also did not appear to conflict with other findings. There was one theme, however, that does seem to diverge from the other results and merits further discussion.

One of the themes identified in the analysis of the data from Anna Darcy's case was that the socio-cultural aspects of learning could conceal engagement when learning science with songs. This emerged from observations that students in the visited class did not seem to be engaged in the song, while they reported during the focus group interview that they liked learning science with songs. What was observed in this class included students who seemed uninterested and non-participatory in the lesson. During the interview they explained that they were self-conscious about singing and making motions in class and in front of their peers. Mrs. Darcy said she observed that in other classes students seemed to engage more when those who were considered strong leaders participated; which suggested that socio-cultural factors could prevent students from exhibiting indicators of engagement. So while the socio-cultural appeal of music to these middle school students suggests that content-based songs can be helpful in science instruction, other socio-cultural factors can hinder the appearance of engagement, such as anxiety over not standing out in front of one's peers by participating in the activity. The finding that socio-cultural factors can conceal engagement diverged from the assertion that music has a socio-cultural appeal for students that can be utilized in science instruction, based on data from almost every other case.

The experience of Anna Darcy and her students was not entirely unique. Even in Mrs. Kingston's classroom where the engagement level appeared highest, a similar concern appeared. During one of Sandy's interviews she reported, "You know at first, there were some that were hesitant to do the motions, but once they saw that it was accepted, and that people were enjoying it, they all did it." Betty Taylor also reported a

similar experience, “Some of them are afraid to just kind of get involved in it, but I think, from what I could tell, the majority of them really enjoyed it. But some of them were just a lot more reserved about it than others.” She added, “I think some students are hesitant to let you know how they feel about the music.” Even Max Cantor talked about this socio-cultural phenomenon, “They all enjoyed doing it. Some of them were like kind of embarrassed, or whatever. But because I modeled it, and I sang it, they did fine.” So while students overwhelmingly reported a high level of engagement, and both teachers and students recognized the appeal of music for learning, and that some socio-cultural factors could result in students appearing to be more reserved in lessons that included science-content music, or responding with more enthusiasm when participation seems to be more socially acceptable with their peers.

Summary

The purpose of a multiple case study is to examine the how cases are connected or bound together to gain a better understanding of the quintain (Stake, 2006). By first exploring the six individual cases for this study in depth, then synthesizing the findings, a number of assertions were made about the experience of teachers and students using content based songs for teaching and learning in the middle school science classroom.

These assertions were constructed based on data from multiple sources, including classroom observations, teacher interviews and student focus group discussions. They represent binding ideas reached by examining correspondences and correlations between cases. The most strongly supported of these assertions came from students who found that science songs provided novelty and variety in the learning environment, but also appreciated them as mnemonic devices. The value of using

songs to teach science was appreciated by teachers for their use in developing scientific vocabulary and presenting concepts to students in alternative ways. Both these students and their teachers emphasized the socio-cultural appeal of music as a potential advantage for using science-content songs for teaching, and found that analyzing lyrics can help students connect ideas and construct understanding of scientific concepts. These assertions, while limited to the cases from which they originated, can lead to better understand the experience of educators and students when science-content music is used for teaching and learning.

CHAPTER 6: DISCUSSION, IMPLICATIONS & CONCLUSION

This study was designed to explore and interpret the experiences of both students and teachers when science content songs were used in the middle school science classroom. A review of the literature supported the use of science music in the curriculum based on limited findings from neuroscience and musicology about the power of songs in aiding recall. However, no studies could be found related to the use of content-rich songs as a teaching strategy in the secondary science classroom. Based on an understanding of constructivism as a learning theory proposed by Fox (2001), it was suggested that the use of science-content music could provide students with additional experiences to construct knowledge through the interpretation of and interaction with songs presented during teaching. This chapter presents a summary of the study, discussion related to the final assertions presented in the cross-case analysis, implications of those findings in terms of teaching and learning science with content-based music, and suggestions for further research.

Summary of the Study

This study was designed using multiple case study methodology. In exploring how science content songs could be utilized in the classroom for teaching and learning the following research questions were asked and used to guide this study:

- In what ways do teachers use science-content music in the curriculum to enhance instruction in the middle school science classroom?

- How can the use of science-content music as a teaching strategy impact student interest, engagement and understanding of science content and concepts?
- What does the experience of students and teachers using science-content music suggest about its potential for teaching and learning science?

This study used constructivism as the theoretical framework because the experiences of both students and teachers in the classrooms where science songs were used as a teaching strategy were important in developing an explanation, description and understanding of the quintain; a term used to refer to the common experience being studied. A total of six middle school teachers and the students in their classrooms participated in this study. Data were collected from teacher interviews that occurred prior to, during, and after implementation of lessons in which science-content music was used as a teaching strategy. A critical component of teaching science with content-rich music was that these teachers included a lesson in which students had to analyze the lyrics for each song as a learning activity. Each class was observed during a lesson in which science songs were used, followed by student focus group interviews in which fifty-seven students participated in groups of varying size. During the data analysis a number of themes were developed for each case to summarize data about the quintain related to the research questions. A cross-case analysis was conducted by merging the themes from each case into a set of assertions that developed a deeper understanding of the use of science content songs for teaching and learning.

Discussion of Assertions and Related Research

The cross-case analysis from this study resulted in a synthesis of findings from each of the six separate cases to better understand the use of content music when

implemented for teaching and learning in the middle school science classroom. The findings are represented by a set of assertions based on the research questions that guided this study. The first research question was directed at how science content songs were used by the teachers who participated in the study for instruction, and their instructional goals when implementing these lessons. The second research question focused on the students' perspectives and how they felt the inclusion of science-content music in the curriculum impacted their learning. The final research question considered both student and teacher experiences to suggest potential benefits for including content-rich songs in the middle school science curriculum. The assertions in this study resulted from a synthesis of the findings in the individual cases and are discussed in terms of their relevance to understanding how and when science content songs can be used to engage students and help them construct an understanding of science concepts. While many of these findings have implications from a constructivist approach to learning in how students construct meaning from experience, some resonate more closely with either cognitivist or social learning theory in their implications. Table 18 presents a summary of assertions based on the learning theory they most align with. By exploring each of these assertions and how they connect to the literature, it is possible to develop an understanding of the practical applications for using content rich songs in the middle school science classroom. What follows is a discussion of each of the findings and how they connect to research in the field of science education.

TABLE 18: Alignment of Findings with Learning Theories

Learning Theory	Premise	Alignment with Assertions
Cognitive or Brain Based Learning Theory	Describes how mental structures, or schema, are built through interactions of experience with memory and cognition.	Songs are mnemonic devices that aid students in learning. Lyric analysis can help students connect ideas and build conceptual understanding.
Constructivism	Based on the understanding that learning occurs through experience to construct meaning and make sense of the world.	Songs help students develop scientific vocabulary. Songs provide students with an additional resource to construct meaning of science concepts.
Social Learning Theory	Learning is a social process through active engagement with others to understand new ideas and experiences	Songs provide novelty and variety in the learning environment. Music has a socio-cultural appeal for students that can be utilized in science instruction.

Assertion 1: Songs help students develop scientific vocabulary.

The use of science-content music to develop vocabulary was one of the instructional outcomes described by half of the teachers who participated in the study. All of the teachers, however, discussed ways in which science songs helped their students understand key terms and develop definitions of important science words and phrases. Derek Martin said that using songs helped his students build science vocabulary: "I think it introduces key terms, key ideas, key vocabulary." Mastering the language in science is critical to student success in learning as one can only participate effectively in the process of science if its specialized terms and style of language are understood. From a constructivist perspective, these songs helped students build understanding of science terms used in the lyrics by providing new contexts for constructing meaning of science terms. This assertion connects to the literature on the importance for students to learn the language and discourse of science for participation. Science, according to Martha Russell, is a vocabulary-rich subject. She found that

using songs for teaching science helped students develop that specialized vocabulary; "by choosing those key words, I was able to point things out." One sixth-grader in Sandy Kingston's class explained from the student perspective, "the lyrics helped you because it would give you a definition, but in kid version." In *Taking Science to School,* the authors explain that learning to "talk science" involves a specialized structure and style, and students must have opportunities to negotiate the language of science in a variety of activities. The ability to verbalize concepts and use terms appropriately in context is critical for students to be intellectually engaged and participate in the activities of science. The authors of this publication suggested that students learn to negotiate science concepts by participating in activities to bridge language and scientific discourse (Duschl, et al., 2007). The finding in this study that science songs helped students develop scientific vocabulary provides one opportunity for addressing this suggestion.

In stressing the importance of developing scientific language with her students, Mrs. Taylor told them they needed to learn to "speak science." She said, "It's 'speaking science,' because I think it is the vocabulary that brings them down." A similar term "talking science," as used by Duschl, et al. (2007), was based on a suggestion by Lemke who described the language of science as specialized discourse that includes "abstract generalizations and logical relationships" (1990, p. 158). According to Lemke, "Every specialized kind of human activity, every subject area and field, has its own special language" (p. 130), and mastery of language is key to understanding any subject. According to Lemke, "Terms get their meanings from the way they are used" (1990. p. 98). Max Cantor said that when teaching science, "We focus a lot of times on

key words," then cited an example of how terms were used to build meaning, "like convection, we talk about hot air rising and cold air sinking." The use of songs in this study provided students with an important opportunity to hear science words in context, which facilitated a better understanding of their meanings. According to the teachers in this study, the use of key terms and phrases in science-content music helped students build their understanding of specific vocabulary based on how terms were used in the songs, which helped them learn to "talk science."

Assertion 2: Songs provide students with an additional resource to construct meaning of science concepts.

According to Lemke (1990) 'talking science' is much more than just building vocabulary. It involves learning how to use terms in context, applying semantic relationships and understanding how terms are combined to generate complex meanings. He explains:

> In teaching science, or any subject, we do not want students to simply parrot back the words. We want them to be able to construct the essential meanings in their own words, and in slightly different words as the situation may require. Fixed words are useless. Words must change flexibly to meet the needs of the argument, problem, use, or application of the moment. But they must express the same essential meanings if they are to be scientifically acceptable and, in most cases, practically useful. This is what we mean when we say we want students to 'understand concepts.' (p. 91)

It isn't enough that students learn the words used in science; they need to know more. This second assertion builds on the first by suggesting that songs go beyond simply helping students develop scientific vocabulary by providing an additional resource with explanations and examples to help them construct meaning of science concepts. For students to build their understanding of science concepts, they need opportunities to

explore the relationships between different terms in science, their meanings, and how they are interlinked, in order to build their understanding of concepts in science. According to Derek Martin, songs provided these connections because “the lyrics themselves were packed with information and concepts and examples” that provided students with alternative explanations and examples to construct meaning of science concepts.

Using a constructivist model of learning, content-rich science songs often helped students in this study build knowledge by providing multiple examples and explanations to build understanding. This assertion connects to the literature on conceptual development. Duschl, et al. (2007) suggested the importance of using multiple resources and symbolic tools for building conceptual understanding. According to Lemke, concepts are developed during learning activities symbolically through language. He explains that, concepts and meanings are “constructed by our speaking or picturing; constructed through our use of words or other signs” (1990, p. 98). As a symbolic tool that is language based, songs, according to Max Cantor, “bring to mind a picture, and that really enhances learning in science because it’s something if [students] can see it in their mind, it’s going to be deeper for them.” Anna Darcy explained the potential for songs as an additional resource for learning in terms of “telling a story” and Martha Russell talked about how songs helped students “visualize” concepts. In these ways songs provided an alternative resource for these teachers to intellectually engage students with science content by providing different explanations and examples of concepts.

Lemke (1990) suggested the strategy, “Repetition with Variation” as one method to help students build conceptual understanding. In this strategy, different terms are used to explain the same ideas or terms as students master the meaning of new concepts by comparing explanations and engaging with ideas using different examples. Based on the second assertion, the use of science songs correlated with this strategy. The element of repetition was evident as Sandy Kingston acknowledged that in the songs, “the repetition in the lyrics is clever.” Mrs. Russell said not only did her students ask to hear the songs repeated, but she additionally found her students, “taking the phrases from the song [and] repeating them to themselves.” Meanwhile, Max Cantor described how science songs provided variation, “I think it gave them a lot more examples than I can typically give them. And also it gave it to them a lot of times in a non-scientific way.” The students in this study also recognized that the concepts were presented in an alternative formats in the songs. One student said, “Sometimes we don’t understand what the teacher says. Maybe you’ll understand better how the song says it.” Derek Martin concluded, “students need to meet it, wrestle with it a little bit; more than just one time, and that you know, that just makes pedagogical sense period.”

Assertion 3: Songs provide novelty and variety in the learning environment.

Science-content music provided students in this study with a novel way to learn; one that got their attention and engaged them in learning science. Derek Martin explained, “When something’s new, something’s different, you’re really challenging them.” Students in every class reported that because of the novelty in learning with songs, they were more engaged learning science. Only one student out of the fifty-seven interviewed reported otherwise. From the simple comments like, “it’s more

exciting," and, "the way you're learning is more interesting," to more elaborate explanations about why songs are better than teacher-talk or textbooks, students overwhelmingly reported that songs brought novelty and variety to learning. This assertion connects to the literature on the importance of engagement in science education. From a socio-cultural perspective, learning is a social process through active engagement with others to understand new ideas and experiences; this is how both teachers and students described learning with songs. Newmann suggested that active involvement and attention to learning are elements of engagement (1992), which characterizes the experiences described by these students. Students and teachers described learning with songs as an active process. According to Anna Darcy when songs were used for teaching science her students were "more actively involved, rather than passively." Students in several classes called learning with songs "active," and students in Sandy Kingston's class were certainly actively involved in learning as they were observed dancing and making motions to represent ways heat is transferred.

Duschl et al. (2007) recognized the difference between engaging in the activity of science and in engagement in terms of interest in learning. Engagement, as described by teachers and students in this study, refers to student interest in learning, rather than active involvement in the process of science. One student expressed a high level of engagement when she commented, "It's better than just doing anything ordinary. And it's better for the soul." In *Taking Science to School* the authors addressed the importance of interest and its connection to learning. Max Cantor said that he could tell his students were interested because, "they're singing the song, and they're asking questions [and] they're underlining things. So they're involved with it." When students

are more interested, they are more likely to see learning as worthwhile, exert effort, and learn at a conceptual level. Novelty in a learning task increases students' situational interest and has a positive effect on learning. Situational interest is influenced by "characteristics of the classroom and the nature of the task" (Duschl, et al., 2007, p. 200), which is characteristic of the type of engagement evident when students learned science with songs.

Banlower, et al. (2008) discussed the importance of using principles of engagement as a way to "hook" student interest in learning early in the instructional process, which corresponded with how Sandy Kingston suggested songs could be used to get students interested in new concepts. While often the use of songs was considered a beneficial review activity, she suggested that songs might be used "as a launch activity before we've covered a concept, to play that as an initial, kind of, hook thing," and added that songs could be used in this way to engage students, "as an introduction, kind of like a launch activity and then get deeper." Derek Martin said that he thought science-content songs provided novelty for his students and could be "a good way to initiate a lesson that is a different format."

Engagement is critical for learning, according to Schlechty (2002), who suggested that students learn more when authentically engaged. The students in this study agreed and said that when they are more engaged, they are more likely to learn. One student said, "We always go with the fun one, and that always works. We learn more stuff from that." While another said, "if it's more fun than it is to learn about something, it's easier to learn." Another said, "When you learn with songs you are more likely to remember it." One of the teachers, Max Cantor, summarized the benefit of

having his students highly engaged: “Any time you have kids enjoy an activity more than you think they would; that makes it better.”

Assertion 4: Songs are mnemonic devices that aid students in learning.

The use of songs as a mnemonic device for recall isn’t a new learning strategy, as Derek Martin stated, “that sort of learning is a trick used at all levels.” This assertion seems simple on the surface, but is more complex than it appears. The literature on what constitutes learning is divergent, depending on the theoretical perspective that is applied to the use of songs as mnemonic devices. Brain-based theory explores learning from a neurological perspective; exploring how neural networks are built and how information is coded and retrieved; suggesting the benefits of mnemonic devices in aiding recall (Sousa, 2006). From a brain-based, or cognitive approach to learning, the use of songs works because of how information is stored and retrieved in the brain. Songs are encoded by the brain using both emotional and sensory networks, and according to Jensen, “this means that when information is imbued with music, there’s a greater likelihood that the brain will encode it in long-term memory” (2008, p.75). Because songs are stored in the brain using multiple pathways, information can be retrieved using various neural networks. As a mnemonic device to trigger memory, students in this study recognized the potential for science songs to help them recall information. “It helped me learn and it really did get stuck in my head,” one student said. Facilitating recall is one of the benefits these students see for learning science with songs, “I think the best part is you can go back to it and you can keep it in your head since its catchy,” one student reported. Even the teachers in the study saw this

advantage. In discussing teaching scientific classification with a song Anna Darcy reported, “I’ve never had that many kids get it that quickly.”

Constructivism as a learning theory is focused on how students build concepts through experience to construct meaning and make sense of the world, and provides different insights into how the mnemonic nature of songs impacted learning. By prolonged engagement with concepts presented in science songs, students interacted with concepts longer, which helped them connect ideas and organize knowledge (Fox, 2001). The students in this study recognized that when songs became ‘earworms’ and were “stuck in their heads,” they engaged with the concepts longer. One student said, “If you have memorized the song, you think about it.” Another reported, “I just sing the song and then… I start thinking about it.” The mnemonic nature of songs that induced prolonged engagement with concepts further helped students make sense of ideas as they reflected longer on the concepts presented in the songs. This metacognitive aspect of learning is presented by Banlower, et al. as part of the final stage of instruction to build understanding of science concepts in *Effective Science Instruction* (2008). When students engage with content included in science songs for extended periods because of their mnemonic nature, they are spending more time processing ideas to make sense of the concepts presented.

The primary use these students saw for science songs as mnemonic devices was to perform better on tests rather than to build conceptual understanding. One student reported, “the song gets stuck in your head, and then you know the definition and then you’re able to do well on your test.” A sixth-grader in Martha Russell’s class said, “On the test we could say it in our heads and we’d remember and get good

grades." Another student said, "I can actually think of the song in my head and I can get the answer right." Duschl, et al. describes science as "both a body of knowledge that represents current understanding of natural systems and the process whereby that body of knowledge has been established" (2007, p. 26). This includes, "learning the facts, concepts, principles, laws, theories, and models of science" (p. 38). The purpose for learning key ideas in science is to build conceptual understandings that can be used for reasoning, problem solving, explaining the natural world and engaging in the practice of science. Duschl, et al. explains that, "many students do not understand that science is primarily a theory building enterprise" (2007, p. 175). Instead, the students in this study said the songs were useful because it was "easier to remember." For them, key ideas in science are things that need to be remembered and recalled rather than a process of conceptual development.

Since students considered recalling information for test an important use for content-based songs, it is important to consider how students are assessed in science. In discussing assessment for science in the 2008 government publication, *Science Framework for the 2009 National Assessment of Educational Progress,* the authors suggested that content-based test questions should be contextually framed and require students to do more than simply recall facts. They recognized that in science some assessment items require students to do little beyond recall knowledge, but added that more complex questions can be difficult, "if they cannot easily recall the science content" (Winick, Avallone, Smith, & Crovo, 2008, p.99). Banlower, et al. (2008) addressed recall as a purpose for learning in terms of extrinsic motivation: "The reality is that there are, and will always be, extrinsic motivators (e.g., deadlines, tests, college

entrance requirements)" (2008, p. 5). For these students the use of songs as a mnemonic device served multiple purposes. It helped build conceptual understanding due to prolonged engagement with the ideas presented in the lyrics, and it helped them recall and remember science content for assessment purposes.

Assertion 5: Music has a socio-cultural appeal for students that can be utilized in science instruction.

Music has a special appeal to learners of all ages. One student in this study reported, "I think it's easier for kids to understand music more because music is part of their everyday lives." From a socio-cultural perspective learning with songs has cultural significance by engaging students in a social context with science concepts. When songs are used for instruction, according to Derek Martin, "You're bringing in something they already identify with: music." According to Martha Russell, teaching with content-based songs "was something to look forward to; it was something [students] could relate to, because of the music." The cultural role of music is not unique to this generation of learners. Music has always has importance as one of the basic activities of all cultures and of humankind (Storr, 1992). From a historical perspective, songs have had their place in teaching, from prehistory history through Dewey's ideas for a progressive education and curriculum integration (Shiraishi, 1995). The socio-cultural appeal of music today is similar to that in the past; however, for these students music is a part of their cultural experience through multiple media resources, including television, movies and digital downloads that are discussed and shared as part of their daily lives.

The literature that connects to this assertion suggests that when students have a personal interest in an activity it influences attention, effort and willingness to participate

in learning. Personal interest in learning is a form of intrinsic motivation and connected to achievement (Duschl, et al., 2007). The interest that these students have in music can be a powerful tool for engaging them in learning. Max Cantor summarized the importance of music for his students,

> They all have their iPods, they all want to listen to music, and it kind of makes them feel like, "Okay, you know something about me. You know that I like music. You know so you're trying to teach in a way that you think I might enjoy." And so that raises that level of engagement.

An eighth-grader from Betty Taylor's class summarized his engagement in science when songs were used for instruction. "Music is worth something," he asserted. It is valued by these students and has cultural significance. Learning is "an inherently social and cultural process" and involves factors of engagement related to interest and attention (Duschl, et al., 2007). The socio-cultural appeal of music has the potential to engage students in personal ways when science songs are used for learning.

Assertion 6: Lyric analysis can help students connect ideas and build conceptual understanding.

Every teacher in this study reported the importance of analyzing lyrics of the songs used for teaching science as a useful learning tool for connecting ideas and fostering conceptual understanding. According to Betty Martin, as students engaged in the process of analyzing lyrics it "helped them connect science to some of their experiences." Martha Russell reported that the lyric analysis activity "was kind of like taking the songs, taking those pieces, and trying to put it into a puzzle to make a whole idea." This assertion connects to the literature in that Banlower, et al. (2008) stressed the importance of sense making activities in helping students to connect ideas and develop understanding of science concepts. Sense-making activities allow students to

draw conclusions from their experiences, connect activities to content, apply concepts to new situations, organize new knowledge and integrate what they learn into their existing mental models of concepts. From a cognitive learning perspective, students are able to build neural networks for understanding new ideas as experience and cognition interact. Multiple strategies are suggested to help students make these connections, and analysis of song lyrics could easily be included as one such activity. When learning science with songs, Derek Martin said that students "make connections to see what the songs about; or to apply the song to the situations, the labs, the activities and the things in real life." As a sense-making activity, the process of analyzing lyrics, helped students to, "piece [ideas] together and get the whole conceptual idea together." Max Cantor added that when his students engaged in analyzing lyrics, "it was a synthesis and analysis process, so it just required some higher level thinking skills."

Duschl, et al. (2007) discussed instructional practices for supporting student learning. Among the suggestions presented for developing understanding of new ideas, these authors included providing conceptual scaffolds for students. Scaffolds are people, processes or activities that facilitate learning. Conceptual scaffolds are instructional techniques that help students build understanding of new concepts and connect learning to prior understandings. Suggested activities include ones that "help students examine, scrutinize, and critically appraise their understanding of key scientific concepts" (p. 277). In this study Max Cantor discussed the importance of the lyric analysis activity as a conceptual scaffold for his students to help connect ideas and build conceptual understanding. He explained that during the activity his students "have got to see the lyrics to make some connections with what the science is and what

they're currently learning. They can see some of the pictures and examples, but to get to that really deeper factual stuff, they really got to see the lyrics." The use of lyric analysis activities when songs are used for instruction is critical if they are to be used to help students build cognitive structures for deeper conceptual understanding of science content.

Recommendations and Implications

As educators, teaching strategies are often employed based on experience and instinct; something tells us they are working but we are not always able to articulate what is happening with our students in terms of conceptual development. During this study, exploring the experiences of students and teachers when science-content music is used for learning helped identify the pedagogical implications for this teaching strategy. The assertions developed through cross-case analysis have some implications for classroom instruction and the science education community at large. The results also suggest recommendations for further research.

Implications for classroom instruction

Songs have been used for learning across all cultures throughout history, yet today they are easily dismissed as an instructional tool. The results of this study suggest that the use of science-content music has potential for learning outcomes that are more complex and versatile than one might initially suspect. During the course of the study it was discovered that, for the teachers and students who participated in this research, songs worked by engaging students, building vocabulary, supplying students with alternative examples and explanations of concepts, helping them remember science content, and providing a conceptual scaffold for developing concepts.

Educators have always sought new ways to engage students and more than one science teacher who participated in this study said they did so because they wanted to find new ways to involve and interest their students in learning. What was discovered was that both students and teachers reported a high level of engagement when songs were used for instruction by getting students interested in learning on both a personal and situational level. Music, like learning, is socio-cultural in nature and speaks to students in ways other strategies cannot. Every teacher in this study reported that students enjoyed learning with songs. Every student, save one, said that learning with songs was an engaging alternative to either the textbook or teacher-talk. The social aspects of learning with songs present only one caveat: greater engagement requires that either teachers or strong student leaders must appear to be involved and having fun in order for some students to "buy-in" to the activity. Otherwise, while students may still have higher levels of engagement with songs, they may find it embarrassing to be seen participating in the lesson. The single student who said she did not like learning with songs reminds educators that even with music, no teaching strategy will engage all students. However, music does have a broad social and cultural appeal that, for most students in this study, got their attention. In the words of one student, it is "worth something."

In *Effective Science Instruction: What does Research Tell Us?* the authors suggest that to build an understanding of science concepts, learning experiences should intellectually engage students with content using multiple pedagogies, ranging from lab activities to interactive lectures that help students construct meaning (Banlower, et al., 2008). Activities for sense-making in science are not limited to labs

and inquiry; there are other ways to build concepts with students. The more ways science content is presented, the more opportunities students will have to connect ideas and organize knowledge. In this study the various assertions presented for using science-content music as a teaching strategy suggested that it is one such activity that can help students develop science concepts when integrated into instruction, much in the same way an interactive lecture would for learning. In *Effective Science Instruction* the authors of this document describe how an effective lecture would work. They indicate that to facilitate sense-making, "in a lecture, the teacher may place facts within a broader framework and provide analogies that connect the ideas to students' previous experience" (Banlower, et al., 2008, p. 11). This was what songs provided when used for teaching science in this study.

It is not suggested that songs be used to replace other learning activities, but that they have a place in the curriculum as providing an additional experience that can be used to help students build conceptual understanding of science concepts. To get the most out of songs for learning, these teachers found that it is critical for students to participate in a lesson in which they analyze song lyrics; an activity that includes pulling out key words and definitions, identifying alternative examples, and exploring analogies and puns embedded in the song. Lemke's suggestion for building concepts through repetition and variation was met as students explored lyrics and heard main ideas repeated in the chorus and while the song was replayed, often at the request of students (1990). One of the strengths of using songs for learning is that, according to these teachers, they pack a lot into a brief activity. Content-rich songs usually are less than five minutes in length, but based on the findings in this study, allow for multiple

ways in which they can be used to help students develop conceptual understanding. Teachers need every instructional tool they can get to engage students and understand concepts in science. However, as indicated by one of the teachers in the study, using songs for teaching is a unique strategy that requires some understanding of how best to implement if it is to be an effective teaching tool in the science classroom. Max Cantor found that it was helpful to have been provided materials and suggestions about how to use science songs for teaching, "The way you did it was helpful and that's you give them some resources and you give them some ideas of how to do it." Other teachers who want to integrate songs for teaching into the curriculum may wish to participate in a professional development experience or read some of the resources cited in the review of literature to carry out successful implementation of this strategy with students. As indicated by the experiences of the students and teachers in this study, from dancing, to illustrating, to serving as a springboard for discussion, the use of songs for teaching science is a versatile resource. The potential for using content- based music for teaching stems from both its ability to engage students and the ways in which the teachers and students in this study found they could use songs to help understand science concepts.

Implications for Science Education

The potential for using songs for teaching science concepts is rarely, if ever, presented in the literature. The nature of science and activities such as inquiry and argumentation are usually the focus of what is considered to be good science instruction. These are valuable, research-based instructional strategies for developing science concepts that cannot be substituted. However, there is room in the curriculum

for additional strategies to help students construct meaning in science, especially if they are both highly engaging and help students build concepts. In *Effective Science Instruction* the authors stressed including activities in the science curriculum that promote sense-making "through skillful questioning, facilitation of class discussion, and/or explanations" (Banlower, et al., 2008, p. 10). They further indicated that opportunities for students to connect ideas and build understanding of science concepts in science are often inadequate or missing in instruction. The use of songs should be explored and considered as a viable teaching strategy that can be used to fill that gap by helping meet the need for sense-making activities.

Probably the most important implication from this study for the science education community comes from the different ways in which students and teachers saw learning in science. The assertions presented in this study based on data gathered from teachers suggested that science-content music could be used to foster deeper understanding of concepts. However, the students viewed science learning as a body of knowledge to be remembered, then recalled for a test. Banlower, et al. in *Effective Science Instruction* addressed recall as a purpose for learning as a form of extrinsic motivation; "The reality is that there are, and will always be, extrinsic motivators (e.g., deadlines, tests, college entrance requirements)" (2008, p. 5). The focus of instruction for teachers in this study and in the literature on science education concentrates on how students develop concepts. In *Taking Science to School,* while the authors acknowledged that science includes a body of knowledge, they primarily address conceptual development as the outcome of instruction, not the recall and retention of science content (Duschl, et al. 2007). This poses the question, "Why the difference?" If

students are primarily concerned with learning in science as a set of facts to be recalled, then the broader goals of science education to develop conceptual understanding are not being made clear to them. The implication for science education related to this issue is based on the perceived differences of the purposes for learning.

Some answers might be found in why students in this study appreciated using science songs as mnemonic devices. In the document, *Science Framework for the 2009 National Assessment of Educational Progress,* the authors discussed assessment in science based on three levels of knowledge: knowing that, knowing why, and knowing when and where to apply knowledge. They described declarative knowledge as "basic science facts, concepts, and principles," and added that students "should be able to recall, define, represent, use, and relate these basic principles as appropriate" (Winick, et al., 2008, p. 92). While they recommended that testing include items for all levels of knowledge, the authors of this publication recognized that different levels of cognitive knowledge are often interdependent; higher-level questions frequently require students to call on declarative knowledge to respond. It is worth examining more closely this dichotomy between educational goals and student perceptions. It is perhaps worth noting that, based on the assertions presented in this study, the use of science music is particularly valuable in bridging student goals for recalling content on tests and educational goals of developing understanding of science concepts.

Implications for further research

This research was designed as a qualitative study and provides insights into the experiences of the six teachers and their students who participated. A number of assertions were presented as the outcome of the research based on a limited number of

cases at the middle school level. Directions for further research should consider exploring the use of songs for teaching science from a quantitative or mixed-methods design. Are there measureable learning differences when students use songs for learning? Considering the cognitive levels of knowledge that students are expected to have in order to participate in science, are there specific types of knowledge that science songs are most useful for developing?

Because the population used in this study was from a limited demographic due to accessibility, additional studies should also consider a broader population with greater diversity to explore how science-content music can be used in teaching. Additional questions that might be considered relate to music genres, additional instructional levels, students with special needs and different implementation strategies. In building on the findings of this study, areas for further research should focus on students who do not find science songs engaging or helpful for learning. Are there instructional implications that should be considered that could be revealed by exploring their experiences? And while some implications for what makes science songs useful learning tools are suggested based on the findings of this study and research in the field of musical imagery repetition, research identifying the most effective elements of songs for teaching could prove useful.

Conclusions

The purpose of this study was to explore and interpret the experiences of students and teachers when science-content music was used as a strategy in the middle school science classroom. Insights about teaching and learning with science music were sought to explain, describe and understand the experiences of teachers and

students. According to Stake, assertions formed in a multiple case study should be the result of a convergence of themes, “sometimes created or at least partly [chosen] to promote the quintain or to advocate the spread of its policies and practices” (2006, p. 84). The findings of this study go far in suggesting that there is a place in science education for the use of content-based music for instruction. As a teaching resource, songs are more than a mnemonic device; they engage students in novel ways and help build conceptual understanding as a sense-making activity.

A great deal of the research based presented to frame this study was based on brain-based or cognitive learning theory, as most of the literature related to using songs for teaching was developed from that perspective. However, in the course of summarizing the results of this study, most of the findings suggested that content-based music helped students build a conceptual understanding of science concepts based on socio-cultural and constructivist learning models as well. The assertions presented here suggest that there is more to learning science with songs than simply understanding how music is processed in the brain. Science-content music has implications for instruction from different learning theories, suggesting that it can effectively be used for conceptual development when implemented in a sense-making context.

The premise for this study came from my experiences as a middle school science teacher with a background in early childhood education; I knew science songs worked for instruction, but didn’t know how they helped students learn science or if my success could be extended to other classrooms. The pilot study provided insights into former students’ perceptions, but in order to discover the potential for science-content music to be an effective teaching tool, experiences of other teachers and their students

was necessary. Teachers are always looking for new ways to engage their students with science concepts, and for the teachers in this study, they reported overwhelming success. One teacher recently sent me an email that simply said, “I can't thank you enough for this wonderful addition to my class!” The conclusions presented in the form of assertions suggested that learning with songs is more meaningful and has implications tied to best practices and research that go far beyond simple engagement or recall of facts. The research questions that guided this study asked how teachers and students used songs and what their potential is for learning. The findings presented would seem to indicate that science songs have a variety of uses at different levels of learning, and have the potential to enhance student understanding of science concepts in different ways.

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APPENDIX A: School District Approval Letter

FORSYTH COUNTY SCHOOLS
Quality Learning and Superior Performance for All

1120 Dahlonega Highway • Cumming, Georgia 30040 • Telephone 770.887.2461 • Fax 770.888-1158

July 6, 2010

To Whom It May Concern:

I am writing this letter in support of Donna Governor's dissertation research project "Teaching and Learning Science Through Song: Exploring the Experiences of Students and Teachers." She has permission to pursue the study subjects and school sites for evaluation in this research project. She may us the school district email list to contact school administrators and teachers relative to this research project. In accordance with all University of Georgia IRB requirements, Donna Governor will provide all required documents to school administrators , teachers and students.

Dr. Kelly Price
Curriculum Coordinator
Science, Math, Health/PE & Gifted Programs
kprice@forsyth.k12.ga.us
770-887-2461, x202251

APPENDIX B: Administrator Email Request

Dear (Principal),

I am a science teacher at Liberty Middle School and a doctoral student in the department of Science Education at the University of Georgia.

I would like to ask permission to invite your science teachers to participate in a research study entitled "*Teaching and Learning Science Through Song: Exploring the Experiences of Students and Teachers"* that is being conducted under the supervision of Dr. David Jackson at UGA during the fall of 2010 as part of my doctoral dissertation research. The purpose of this study is gain information about the experiences of teachers and students when science songs are used for teaching and learning. Should you allow me to conduct research at your school site, participation will involve:

- Inviting your science teachers to participate in the study. The teachers that volunteer to participate will implement two lessons during the course of a unit in which science songs are used for teaching.
- Interviewing the teachers who agree to participate three times at their convenience (before, during and after the study).
- Observing one class in which each teacher who participates in implementing a lesson using songs.
- Conducting a student focus group interview with a few students from that class in which they tell about their experience using songs for teaching and learning. Only students whose parents sign consent forms will be allowed to participate in focus group interviews.

From the findings from this project, I hope to provide information that will provide information about how to use songs for teaching, to help other teachers implement the use of songs for teaching science to better engage students and improve learning. For teachers the only foreseeable risk may be that they feel some stress taking time out of

their schedules to meet for interviews. For students, they may experience discomfort during the observation or focus group discussions. Any teachers or their students who agree to participate may withdraw from the study at any time.

Teachers who agree to participate will be provided with a book about teaching with songs and one or more CDs with science-content music. Students who participate in the focus group will also receive a CD of science music.

Additional information about the use of songs as a teaching strategy can be found in the results of my pilot study, which I am attaching. Last year as a Class Act Awardee for Channel 11 News my class was filmed during a lesson in which science songs were used for teaching. That video is available upon request for you to see one way in which songs can be used for teaching, if that would help.

If you have any questions about this research project, please feel free to call me at 770-781-4889, ext. 290330 or send an email to vogannod@uga.edu or dgovernor@forsyth.k12.ga.us. You may also choose to contact my supervising professor, Dr. David Jackson (UGA) at 706- 542-4194. Questions or concerns about the rights of any research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 612 Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

If you agree to allow teachers and students at your school to participate in this study, please respond by email so that we can proceed. I will need a letter from your school that authorizes me to invite your teachers to participate and to observe their classes. Thank you for your consideration!

Donna Governor, Doctoral Student, UGA

Science Teacher, Liberty Middle School

APPENDIX C: Administrative Letters of Approval

LIBERTY MIDDLE SCHOOL

Ronnie McNeese
Assistant Principal

Connie Stovall
Principal

Robin Sweat
Assistant Principal

July 5, 2010

To Whom It May Concern:

This letter is to acknowledge permission granted to Ms. Donna Governor to conduct her dissertation research at Liberty Middle School. I understand that teachers, who are willing to participate, and students, with parental permission, will be active participants in both quantitative and qualitative data collection.

I would also like to assure Dr. David Jackson and other members of the dissertation committee that Ms. Governor will have my support has she conducts her research and completes her dissertation.

If you have any questions for me, please feel free to contact me at the school.

Sincerely,

Connie Stovall

7465 Wallace Tatum Road
Phone: 770-781-4889

Home of the

Cumming, GA 30028
Fax: 678-513-3877

Otwell Middle School

Beth Holder, Assistant Principal Steve Miller, Principal June Tribble , Assistant Principal

August 26, 2010

Donna Governor –

Thank you for including us as one of your schools for your doctoral program. The science teachers here at Otwell are really excited about being part of this wonderful study and we hope to see large gains for our students as we progress through the year.

Looking forward to seeing results!

Regards,
Steve Miller
Principal

Little Mill Middle School
6800 Little Mill Road
Cumming, GA 30041
Phone: 678-965-5000
Fax: 678-965-5001

Cheryl Riddle
Assistant Principal

Connie McCrary
Principal

Carl Jackson
Assistant Principal

June 28, 2010

To Whom It May Concern:

Donna Governor has my permission to conduct her doctoral research at Little Mill Middle School. The research will be conducted with volunteer teachers. Please let me know if you require additional information.

Respectfully,

Connie F. McCrary

Connie F. McCrary, Ed.S.
Principal

VICKERY CREEK MIDDLE SCHOOL

6240 Post Road
Cumming, Georgia 30040
(770) 667 – 2580

Van Lewsader, Assistant Principal | Kathy Rohacek, Principal | Barbara Vella, Assistant Principal

June 30,

2010

To whom it may concern,

This letter is to confirm that Donna Governor has my permission to invite VCMS science teachers to participate in her doctoral research study. There are no known risks or discomforts associated with this research and any teachers or their students who agree to participate may withdraw from the study at any time. I understand that her request includes:

- Inviting VCMS science teachers to participate in the study. Any teachers who volunteer to participate will implement two lessons during the course of a unit in which science songs are used for teaching.
- Three interviews by Ms. Governor of the teachers who agree to participate, at their convenience (before, during and after the study).
- An observation by Ms. Governor of one class per participating teacher during which the teacher is implementing a lesson using songs.
- Conducting a student focus group interview with a few students from that class in which they tell about their experience using songs for teaching and learning. Only students whose parents sign consent forms will be allowed to participate in this study.
- All observations and interviews will be requested with the teacher or students at least three days in advance and be approved via email by Mrs. Rohacek.

Teachers who agree to participate will be provided with a book about teaching with songs and one or more CDs with science content music. Students who participate in the focus group will also receive a CD of science music.

Sincerely,

Kathy Rohacek, Principal

APPENDIX D: Teacher Invite & Consent Forms

Dear Colleague,

I am a science teacher at Liberty Middle School and a doctoral student in the department of Science Education at the University of Georgia. Many of you already know me and are aware of my interest in researching teaching strategies that involve the use of science songs for learning.

I would like to invite you to participate in a research study entitled "*Teaching and Learning Science Through Song: Exploring the Experiences of Students and Teachers"* that is being conducted under the supervision of Dr. David Jackson at UGA. The purpose of this study is gain information about the experiences of teachers and students when science songs are used for teaching and learning.

Your participation will involve implementing two or more songs during a unit of study this fall that relate to the concepts and content you are teaching, then allowing me to meet with you and interview you three times (before, during and after the unit of instruction), observe your classroom during one lesson and conduct one focus group discussion with your students. I anticipate needing no more than 3 to 4 hours of your time over the course of the next several months. The only anticipated risk is that you may feel some stress by scheduling a few blocks of time you meet with me during the upcoming semester. Recognizing that this may take some time from your busy schedule, as an incentive you will be provided with a book about teaching with songs and one or more CDs with science songs for teaching. Your involvement in the study is

voluntary, and you may choose not to participate or to withdraw from the research at any time without penalty or loss of benefits to which you are otherwise entitled. The results of the research study may be published, but your name will not be used. In fact, the published results will be presented in summary form only. Your identity will not be associated with your responses in any published format.

From the findings from this project, I hope to provide information that will help other teachers implement the use of songs for teaching science to better engage students and improve learning. There are no known risks or discomforts associated with this research other than those mentioned above. You may withdraw at any time.

If you have any questions about this research project, please feel free to call me at 770-781-4889, ext. 290330 or send an email to vogannod@uga.edu or dgovernor@forsyth.k12.ga.us. You may also choose to contact my supervising professor, Dr. David Jackson (UGA) at 706- 542-4194. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 612 Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

If you agree to participate in this study, please respond by email or phone so that we can proceed. Thank you for your consideration! Please keep this email for your records.

Donna Governor

Doctoral Student, UGA

Science Teacher, Liberty Middle School

Informed Consent Form
(Teacher Participants Only)

I agree to take part in a research study titled "**Teaching and Learning Science Through Song: Exploring the Experiences of Students and Teachers**" which is being conducted by Donna Governor, Science Education Department, University of Georgia, phone 770-781-4889 ext. 290337, under the direction of Dr. David Jackson, faculty advisor, Department of Science Education, University of Georgia, phone number: 706- 542-4194.

I understand that my participation is voluntary; I can refuse to participate or stop taking part at any time without giving any reason, and without penalty or loss of benefits to which I am otherwise entitled.
I can ask to have information related to me returned to me, removed from the research records, or destroyed.

The purpose of this qualitative research study is to explore and interpret the experiences of students and teachers when science-content music is used as a strategy for teaching and learning in the middle school science classroom. The researcher will be looking for and open to insights about teaching and learning when science songs are used for teaching to explain, describe and understand the experiences of teachers and students. Middle school science teachers who participate in this study will implement lessons that incorporate science-content music using implementation strategies suggested by research. Teachers and students will be asked to share their experiences and insights about the use of science songs for teaching and learning to learn more about the benefits or usefulness of music in the classroom using multiple case study methodology. Data collection methods will include teacher interviews, classroom observations and student focus groups. Through an inductive analysis approach to open coding, themes will be identified to explain, describe and understand the experience of teachers and students when science songs are used for learning. Hopefully, information may be obtained that will help provide insight into patterns of practice and use of songs for teaching that can be extended to other classrooms to engage and assist students in learning science.
The benefits of participating in this study include assisting in developing a strategy for teaching and learning that can improve engagement and learning in the classroom. As an incentive I will be given a book on using songs for teaching and music CDs with songs that can be implemented in my classroom.

The procedures for this study are as follows:

1. I will meet with the researcher for an initial meeting in September 2010. At that time I will be provided with the incentive materials and be given an introduction to professional practices suggested for using songs for teaching based on research and past studies. I will be interviewed for the first time at that meeting. That meeting is expected to last between 30 and 60 minutes.
2. The researcher and I will decide on a class to be observed and in which a focus group interview can take place with my students.
3. I will distribute information to parents in the class that is selected about the interview and invite students to participate in a focus group discussion with the researcher. Consent forms will be collected from parents of students agreeing to participate in the focus group.
4. I will implement two lesson plans during the course of a normal teaching unit that uses science content songs for teaching.

5. The researcher will observe the class selected during the implementation of a lesson plan where science songs are being implemented as a teaching strategy. This observation will last approximately 30 minutes (first half of a class period).
6. The researcher will conduct a focus group interview with students immediately following the observation. I understand that I will need to provide an alternative activity for students who do not participate in the focus group interview. The group interview will last approximately 30 minutes (second half of a class period).
7. I will meet with the researcher approximately a week after the observation and focus group interview occurs for a second interview. This interview is expected to last 30 - 40 minutes.
8. After conclusion of the unit in which I teach the observed lesson, I will meet with the researcher for a final interview, which is expected to last 30 - 40 minutes.
9. Following the final interview the researcher will analyze all data using an inductive approach to data analysis.
10. I will receive a summary of the data collected in my class no later in January 2011, in which I will be invited to respond. This summary will be based on the interviews, observations and focus group discussions. At this time I will be asked to provide feedback, including an opportunity to correct, revise, delete or add to the summary.

The only foreseeable risk may be that I may feel some stress taking time out of my schedule to meet for interviews. However, I understand that I may choose not to answer any questions or withdraw from the research at any time. No other risks are expected.
I understand the individually identifiable data collected in this study will be kept confidential. My name and any information that can identify me personally will never be used publicly or released to another source. I understand that interviews will be recorded digitally then transcribed using a pseudonym for my identity. I understand I have the right to review all audio materials and transcripts. All files, including emails, audio and text files, will be kept electronically for a period of twelve months by the researcher then be destroyed. Internet or email communications collected during this study are insecure and there is a limit to the confidentiality that can be guaranteed due to the technology itself. However once the materials are received by the researcher, standard confidentiality procedures will be employed. Text will be copied into a text file and all personal identifiers removed, then the original email deleted. No individually identifiable information about me, or provided by me during the research, will be shared with others, unless required by law. The researcher will answer any further questions about the research, now or during the course of the project, and can be reached by telephone at: 770-781-4889 ext. 290337.

My signature below indicates that the researcher has answered all of my questions to my satisfaction and that I consent to volunteer for this study. I have been given a copy of this form.

Donna L. Governor	_____	_____
Researcher	Signature of Researcher	Date
_____	_____	_____
Participant	Signature of Participant	Date

Additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 629 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

APPENDIX E: Teacher Instructions Handout

Teaching & Learning Science through Song

Why Use Songs?

- ENGAGEMENT!
- Brain-based learning research
- Socio-cultural aspect
- Digital natives
- Mnemonics
- Metacognition

When to Use Songs?

- Initial engagement
- Introduce vocabulary & concepts
- Review content
- Scaffold for learning
- Metacognitive processing

How to Use Songs?

- CRITICAL REQUIREMENT: One lesson MUST involve lyric analysis
- Background reinforcement
- "Musical Imagery Repetition" (earworms) – Minimum of 3 times
- Multi-media presentations
- Bell ringer
- HAVE FUN!

How to Select Songs?

- Catchy, simple melody
- NOT a lecture!
- Humor & Analogies
- Key ideas repeated in chorus
- Check for accuracy of concepts

Where to Find Songs?

- Songs for Teaching: http://www.songsforteaching.com/index.html
- Science Songwriter's Association: http://www.science-groove.org/SSA/
- Massive Data Base: http://www.science-groove.org/MASSIVE/
- Pop Culture (They Might Be Giants: The Sun is a Mass of Incandescent Gas)

WHAT TO DO

Allow me to conduct an initial interview today to get some basic information about you.

Select two or more songs to use during a teaching unit you will be covering between now and Thanksgiving.

1. Plan to include a lesson for each song where students analyze the lyrics.
2. Include other activities related to the songs as you see fit. I am interested in seeing how you make use of songs for teaching science concepts.
3. Reinforce the songs by playing them in class at other times; for example, during working on activities or projects, or as a bell ringer.
4. Arrange a class for me to observe where you will include a lesson with the second song you decide to use for teaching.
5. Send home and collect parental consent forms for participation in the focus groups with students that will be in the class I observe. Parental consent is not required for me to observe, but for participation in the focus groups. Students who agree to participate will receive a CD of science songs (Professor Boggs 2010 release: "Around the World with Science")
6. Allow me to observe the first half of that class period where you are using a song for the lesson.
7. Allow me to pull students for a focus group discussion during the second half of that class. Please have an assignment for students who do not return permission to participate in the focus group.
8. Meet with me about a week after the observation so we can discuss what I saw and what your students said.
9. Meet with me a third and final time between Thanksgiving and the end of the semester to discuss how you used songs for teaching.
10. Review the summary I will write about how you used songs for teaching science in January and make any comments that you think are important.

APPENDIX F: Student Invites & Consent Forms

Parents,

I have agreed to participate in a research study that may help improve your child's engagement in science and learning in my class. Ms. Donna Governor, who is a teacher a Liberty Middle School, is conducting the study as part of her doctoral dissertation. Ms. Governor has been a teacher for 26 years and at Liberty since 2003. She was the 2007 Presidential Awardee for Excellence in Science Education from Georgia and has been working on her doctorate degree at UGA since 2007. Attached is a letter she has asked me to send to you requesting your child participate in a group interview after one of our class lessons. I hope you will read her request and consider allowing your child to participate in this study.

Thank you,

Teacher's Name

Letter to be sent to parents from the researcher:

Parents,

Thank you so much for taking the time to read and consider my request. I am a science teacher in Forsyth County and doctoral student at the University of Georgia. I am conducting research on the use of science-content music for teaching and learning in the classroom. Last year I conducted a pilot study with former students who felt that the songs I used in my classroom helped them learn. In this study I will be seeing how other teachers use science songs and if their students can also benefit from this practice.

For this study your child's teacher will be implementing two or more lessons during an instructional unit, which use science songs for teaching. These songs have the potential to help engage your child in science and aid in learning content material.

As part of my research I will be interviewing your child's teacher and observing his/her class during one of these lessons. During my observation I will be watching to see how the teacher implements science songs into the curriculum and how the students in the class respond. This observation will occur during the course of a normal class situation, but if for any reason you object to your child being in the class while I am observing, please notify your child's teacher and I will help the teacher find an alternative learning activity that your child may complete in another classroom while I am observing the lesson.

As an additional source of information for my study I would like to interview a small group of students and ask questions concerning what they think about learning with songs. These focus group interviews will last approximately 30 minutes and be conducted during the second half of the class in which the observation occurs outside the classroom, for example in the media center. In order for your child to participate in the group interviews, I must obtain your written permission. As an incentive, I will give a CD of science songs as an incentive to the students who do participate in the interviews. For those students who do not participate in the interview, an alternative classroom activity will be provided by your child's teacher. However, neither the interview nor the alternative activity will be graded and your child will not be penalized regardless of which group he/she participates in.

While these group interviews will be audio recorded and transcribed, at no time will your child be individually identified either by name or description. Group interviews have been selected to help your child feel more comfortable while meeting with me. The only risk anticipated with your child's participation in the interview is that he/she may become nervous or experience some discomfort during the interview. If at any time during the interview process your child feels uncomfortable, he/she may withdraw from the study without penalty. At no time will your child's grade be affected by his/her choice to either participate or not participate in this study.

If you are willing to allow your child to be included in the focus group interview, please sign and return the attached consent form. Your child will not be interviewed unless you give permission. If you have any questions about the research you can contact me at 770-781-4889 ext. 290337, or by email at vogannod@uga.edu or dgovernor@forsyth.k12.ga.us. You can also call my supervisor, Dr. David Jackson at UGA at 706- 542-4194 or email djackson@uga.edu if you have any questions or concerns you would like to address with him.

Thank you for your consideration,

Donna Governor

Liberty Middle School Science Teacher

UGA Doctoral Student

Parental Permission Form

I agree to allow my child, _____, to take part in a research study titled, "*Teaching and Learning Science Through Song: Exploring the Experiences of Students and Teachers*" which is being conducted by Donna Governor, Science Education Department, University of Georgia, phone 770-781-4889 ext. 290337, under the direction of Dr. David Jackson, faculty advisor, Department of Science Education, University of Georgia, phone number: 706- 542-4194. I do not have to allow my child to be in this study if I do not want to. My child can refuse to participate or stop taking part at any time without giving any reason, and without penalty or loss of benefits to which she/he is otherwise entitled. I can ask to have the information related to my child returned to me, removed from the records, or destroyed.

The purpose of this qualitative research study is to explore and interpret the experiences of students and teachers when science-content music is used as a strategy for teaching and learning in the middle school science classroom. The teachers who participate in this study will implement lessons that use science-content music for teaching and learning in their classrooms. The researcher will observe students in my child's class during one of these lessons. Additionally, students may choose to participate in focus group interviews outside the classroom after the lesson and will be asked to share their opinions and thoughts about the use of science songs for learning to learn more about their experiences. Through participation in this study my child will be involved in a teaching strategy that may improve interest and engagement, thereby enhancing his/her learning. The researcher hopes to learn more about how this strategy can be used by other teachers to engage and improve student learning. Informed consent must be obtained for my child to participate in focus group interviews. This permission form is to give my consent for my child to participate in a focus group interview. As an incentive, if my child participates in the focus group interviews, he/she will be given a music CD with songs that are used for teaching science.
The procedures are as follows:

- My child's science teacher will implement some lessons that include songs for learning.
- My student will participate in a group interview about his/her experiences for approximately 30 minutes during the second half of a class period in which his/her class is observed by the researcher.
- The interviews will be taped and transcribed then deleted no later than twelve months after the interview.

It is possible that my child could experience some discomfort during focus group discussions and I understand that he/she can quit at any time. No other risks are expected with my child's participation in this study. My child's grade will not be affected if my child decides not to participate or to stop taking part. Students who do not take part in the focus group interviews or choose to quit will return to a teacher directed activity in the regular classroom.

Any individually identifiable information collected about my child will be held confidential unless otherwise required by law. My child will never be referred to by name in the transcripts or other documents created for this study, and no personally identifiable data will be collected or kept by the researcher. Audio recordings will be stored for no more than twelve months then destroyed and will not be publicly disseminated. Any master list of students who participate and their codes generated during the study will be kept confidential by the researcher in digital form then destroyed within twelve months. The data and research generated in this study may be used for publication, but my child's identity will never be disclosed. All information obtained will be treated confidentially. Dr. David Jackson from the University of Georgia will supervise the research (706) 542-4194, djackson@uga.edu. The researcher will answer any further questions about the research, now or during the course of the project, and can be reached by telephone at: 770-781-4889 ext. 290337 or by email at: vogannod@uga.edu. I understand that I may also contact the professor supervising the research, Dr. David Jackson, UGA, Science Education Department, at 706- 542-4194.

I understand the study procedures described above. My questions have been answered to my satisfaction, and I agree to allow my child to take part in this study. I have been given a copy of this form to keep.

Donna L. Governor	_____	_____
Researcher	Signature of Researcher	Date
_____	_____	_____
Parent Name	Parent Signature	Date

Additional questions or problems regarding your CHILD'S rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 629 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

Student Assent Form

You are invited to participate in a research project about using science songs for learning in your classroom. If you choose to participate in this study you will meet with Ms. Governor and a group of students from your class after a lesson. Ms. Governor will ask you and the group some questions about learning with songs. There are no right or wrong answers; we just want to know what you really think.

Ms. Governor will record your discussion using a digital audio recorder. Then she will take home the recording and transcribe (type) it up, word for word. She will keep the recording for about twelve months, until her project is complete, in case you have any questions then destroy it. She will never refer to you by name in any of the transcripts or any of the papers she writes about her study.

If you decide to do the project with us, your responses will be used in learning more about teaching with music. You can also decide to stop at any time or can choose not to answer questions that you don't want to answer.

Do you have any questions? Would you be willing to do the project with us?

Researcher	Signature of Researcher	Date
Donna L. Governor		
Researcher	Signature of Researcher	Date

APPENDIX G: Interview Protocol - Teachers

All initial teacher interviews began with the following script:

I'd like to thank you for taking the time to meet with me today to help me with my research study. Before we begin, there are some things I need to be sure to tell you. I'm a science teacher at Liberty and am working on a doctorate degree in science education with UGA. As part of my program I am conducting a research study titled, "**Teaching and Learning Science Through Song: Exploring the Experiences of Students and Teachers"** to gather information about science-content music and teaching.

As I mentioned in my emails I plan to record our conversation today and all later interviews. Today's interview should take no more than an hour of your time, including some time to provide you with some general information about teaching with songs. The second interview will occur a few days after I observe your class, and our final interview will be scheduled for when you complete the instructional unit in which you use songs for teaching. The second and third interviews should take only about half an hour each. After I get home I will transcribe each of our interviews. After I complete my process for analyzing the data I get from you and your students, I will send you a summary of what I learn. This should happen by January. You will then have a chance to clarify, correct or add anything you think I should know.

I will be using the information I gather from you and your students to make some generalizations about what you think about using content-based music in science class. I hope to be able to describe, explain and understand your experiences in a way that might help other teachers better implement this strategy for learning. I plan to write up the results and share them with my professors and the science education community. I hope to eventually publish the results, or use the information as the basis for a more in-depth study for my dissertation. At no time will I mention you by name, you will always be referred to using a pseudonym, and your identity will be kept confidential. Do you have any questions?

NOTE: Case study research methodology requires more of an open interview format for this type of study. Questions shown below and their probes are representative of the kinds of questions asked at each interview, but varied depending on the experiences of each teacher and previous interviews. All questions shown were starting places for interview questions, and not designed to be a comprehensive or exclusive list of questions that were asked.

First Teacher Interview:

Can you tell me something about your background as a teacher?

PROBES:

- How many years?
- Subjects?
- Places

Have you ever used songs for teaching before?

PROBES:

- When? How?
- What songs?
- What was the experience like?

Why are you interested in participating in this study?

PROBES:

- Incentives?
- Pure research?
- Improve teaching and learning?

Do you remember ever learning with songs?

PROBES:

- What was the experience like?
- Schoolhouse Rock?

Based on the information I provided you about how songs can be used for teaching from my research and others, do you have any questions?

PROBES:

- How do you think you will use songs?
- Which unit will you include songs in?

Do you have anything you want to add that we have not talked about today?

Do you have any other questions?

Again, thank you very much for your time!

Second Teacher Interview:

What songs have you used for teaching so far?

How have you used these songs in instruction?

PROBES:

- Analyzing lyrics?
- Background?
- Other strategies?

How have your students responded?

PROBES:

- Engagement?
- Learning?

From the teacher's perspective, what do you think so far about using songs for teaching?

PROBES:

- Implementation?
- Facilitation of learning?

When I observed your class I noticed some things. I saw _____. Can you tell me a bit about that?

When I interviewed your students, they told me _____. Would you please respond to that?

Do you have anything you want to add that we have not talked about today?

Do you have any other questions?

Again, thank you very much for your time!

Third Teacher Interview:

Do you think that these songs enhanced your students' learning in any way? If so, how?

PROBES:

- Engagement?
- Learning?

How do you think your students responded to lessons with songs?

PROBES:

- Participation?
- Enthusiasm?

What instructional strategies did you use when using songs for learning?

PROBES:

- From those we talked about initially?
- In addition to those?

If you were looking for songs to use with teaching, what characteristics would you use to select them?

PROBES:

- Lyrics?
- Melody?
- Humor or wit?

Will you continue to use songs or recommend using them for learning to other teachers?

PROBES:

- Why?
- Why not?

Do you have anything you want to add that we have not talked about today?

Do you have any other questions?

Again, thank you very much for your time!

APPENDIX H: Interview Protocol - Students

Focus group interviews will be more structured and less open ended due to students being minors and in an attempt to both narrow and standardize the interview process across cases.

All focus group interviews will begin with the following script:

I'd like to thank you for taking the time to meet with me today to help me with my research study. Before we begin, there are some things I need to be sure to tell you. I'm a science teacher at Liberty and am working on a doctorate degree in science education with UGA. As part of my program I am conducting a research study titled, "**Teaching and Learning Science Through Song: Exploring the Experiences of Students and Teachers"** to gather information about science-content music and teaching.

While I talk with you today I will record our conversation so that I can remember what you all have to say. Today's interview should take no more than a half hour of your time. I will be using the information I gather from the students in this group to make some generalizations about what you think about songs for learning in science class. I plan to write about what I observe and share it with my professors and other teachers. At no time will I mention you by name and your identity will always be kept confidential. I will talk to your teacher about what the group says, but I will not tell your teacher what comments you make individually. I am interested in you telling me about what you think and there are no wrong or right answers. You can choose to leave the discussion group at any time and quit the study. You won't be graded on our discussion

or penalized in any way if you don't want to continue. Do you have any questions? Okay, let's begin.

1. I saw that in today's class you were learning about _____ with a song. Can you tell me what you thought about today's lesson?
    a. Clarify the intent is to find out about the lesson, not the song.
2. Have you ever learned with songs before?
    a. Can you tell me more about that?
3. What did you think when your teacher told you he/she was going to teach with a song?
4. What was it like learning with a song?
    a. Best part?
    b. Worst part?
5. Do you think the songs can help you learn science?
    a. How would that work?
6. Does the song make you want to hear it again?
7. Do you think the song can help you when you are studying?

Follow up questions may be asked based on student responses that are not listed, however all questions will focus on having students relate their experiences about learning with songs.

APPENDIX I: Classroom Observation Protocol

Classroom observations will occur during a lesson in which teachers are using science content songs as a teaching strategy. The observation will utilize a loosely structured methodology. Of primary interest for this study is:

- Student engagement
- Teacher implementation strategies

During these observations I will:

- Sit in the back of the room quietly, apart from the students
- Observe for approximately 30 minutes
- Take notes on observable behaviors of students and teachers during lesson.
- Not identify any student by name

Primary questions that guide the observations include:

- How does the teacher introduce the song?
- What activities does the teacher include in the lesson?
- How do the students respond to the song?
- What indications of their level of engagement can be observed?
- How many times is the song repeated?
- What is the teacher doing while the song is played?
- What are the students doing while the song is played?
- Do students ask to have the song repeated?
- Do students join in with singing the song?
- What materials are used with the song activity?

APPENDIX J: IRB Approval

From: KIMBERLY C Fowler <kfowler@uga.edu>
Date: Fri, 23 Jul 2010 13:41:18 +0000
To: David Jackson <djackson@uga.edu>
Cc: Donna Governor <vogannod@windstream.net>
Subject: IRB Approval - Jackson

PROJECT NUMBER: 2011-10010-0
TITLE OF STUDY: Teaching and Learning Science Through Song: Exploring the Experiences of Students and Teachers
PRINCIPAL INVESTIGATOR: Dr. David F. Jackson

Dear Dr. Jackson,

The University of Georgia Institutional Review Board (IRB) has approved the above-titled human subjects proposal that was reviewed by the Expedited review procedure authorized by 45 CFR 46.110(a).

Your approval packet with your date-stamped consent forms will be sent by mail. Please remember that any changes to this research proposal can only be initiated after review and approval by the IRB (except when necessary to eliminate apparent immediate hazards to the research participant). Any adverse events or unanticipated problems must be reported to the IRB immediately. The principal investigator is also responsible for maintaining all applicable protocol records (regardless of media type) for at least three (3) years after completion of the study (i.e., copy of approved protocol, raw data, amendments, correspondence, and other pertinent documents). Any HIPAA-related research documents must be retained for a minimum of six (6) years. You are requested to notify the Human Subjects Office if your study is completed or terminated.

Good luck with this study, and please feel free to contact us if you have any questions. Please use the IRB project number and title in all communications regarding this study

Regards,

Kim Fowler, CIP Human Subjects Office 627A Boyd Graduate Studies Research Center University of Georgia Athens, GA 30602-7411
kfowler@uga.edu
Telephone: 706-542-5318
Fax: 706-542-3360 https://www.ovpr.uga.edu/compliance/hso/

Appendix K: Lyrics to "Some Kind of Energy," Morris © 2010

Chorus:
Energy, it's a mystery
In all of its forms, what can it be
It's a mover, It's a shaker
It's the heat light sound electric chemical maker
No matter how it dances through its many forms it will always be...
Some kind of energy

Now there's a lot of different ways to store it, potential energy's the word for it.
When you stretch a rubber band or lift up a weight
Potential energy is what you create
and when it's released into motion -- that's kinetic energy
Now mechanical energy is what we're callin' it
When mass starts movin' or spinnin' or fallin,
It's the turning crank, it's the waterfall, The windmill, the race car, the bouncing ball
Mass in motion must...have mechanical energy

(chorus)

Now when you start electrons movin' around, Makin' a current from hot to ground
Then you have a mighty force at your command
You can light a light or spin a magnet on demand
And conductors are your friend -- that's electric energy
Now when you hear that mighty sound, feel the bass want to knock you down
You can feel that pressure in your bones
From the thundering drum or the big trombone
As the pressure waves bring it to you -- it's sonic energy

(chorus)

Now there's energy in chemical bonds, It's the atoms that are singin' the song
When the atoms join together into molecules
Some energy is given back into the world
and things that burn are examples of chemical energy
Now light's an electromagnetic wave
It can move through air or the vacuum of space and it brings energy to the planet Earth
from the sun our star that gives us birth
Just lift your face and feel -- radiant light energy

(chorus)

Appendix L: Lyrics to “Conduction, Convection, Radiation,” Morris © 2010

Chorus:

Conduction, convection, radi-adi-ation
These are all the ways that heat can move from a location
Temperature's a risin', molecules are moving
Heat will flow from hot to cold it's really not confusing at all!

Talk about conduction --
Heat is movin' through a spoon
Stir a cup of coffee & you'll feel it pretty soon
Hotter solid molecules they bump into the cool
And a wave of heat will move along conductors as a rule -

(chorus)

Now there's convection
That's when heat moves through the air
Or some water or a substance that can move from here to there
Warmer currents rise, and cooler currents sink
But it mixes up and evens out, it makes you want to think about...

(chorus)

Now radiation
Like the sun upon your face
It spreads by waves of light that even move through outer space
The waves they hit the molecules and make them dance around
The darker colors do it best, at least that's what we've found!

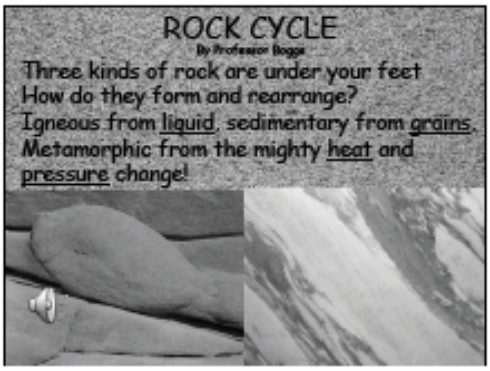
(chorus)

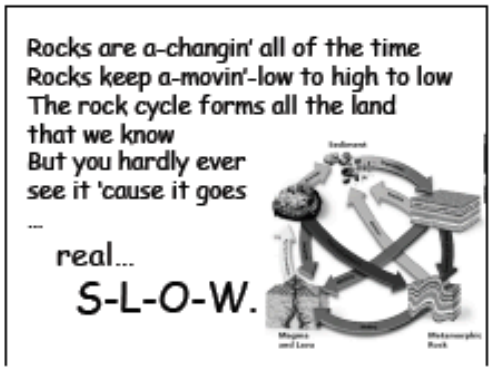
Bridge:

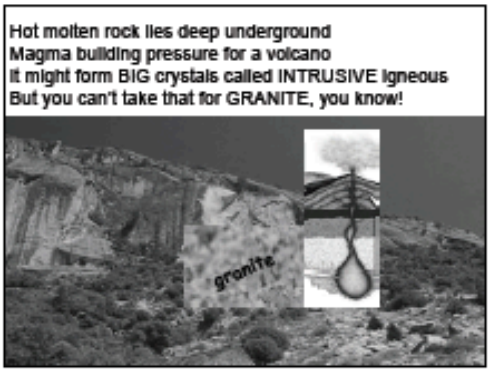
So next time that you got a hot potato in your hand
If you want to cool it down you got to understand
Solids can conduct, air and water can convect
But radiation is the one that light waves can detect...

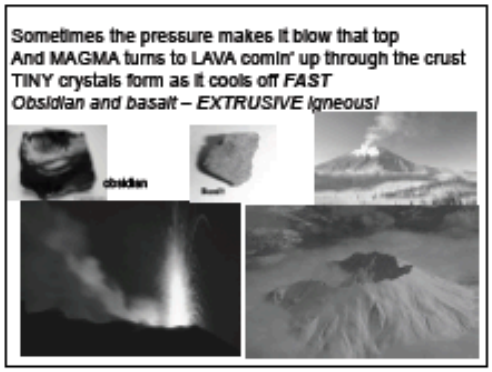
(chorus)

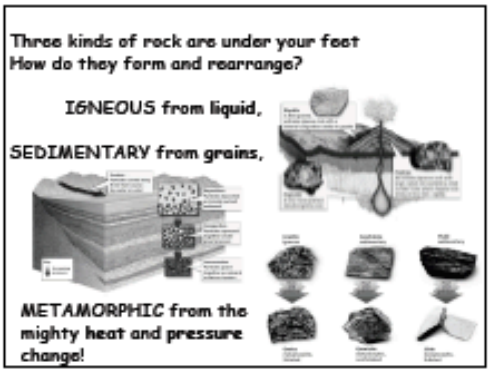
Appendix M: Slideshow Sample From Russell Analysis

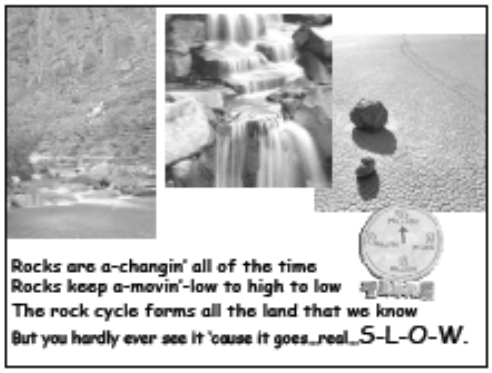












Appendix N: Lyrics to "Rock Cycle," Morris © 2010

Chorus:

Three kinds of rock are under your feet, How do they form and rearrange?
Igneous from liquid, sedimentary from grains,
Metamorphic from the mighty heat & pressure change!
Rocks are a-changin' all of the time, Rocks keep a-movin' - low to high to low
The rock cycle forms all the land that we know
But you hardly ever see it cause it goes.....real.....slow.

Hot molten rock lies deep underground
Magma building pressure for a volcano
It might form big crystals called intrusive igneous
But you can't take that for granite, you know!
Sometimes the pressure makes it blow that top
And magma turns to lava comin' up through the crust
Tiny crystals form as it cools off fast
Obsidian and basalt -- extrusive igneous!

(chorus)

Weathering, erosion, and chemical change
Breaks and washes rock down into sediment
Layers of pebbles, silt, and sandy grains
We say deposition is the name of this event
Sandstone, mudstone, limestone and shale
Compression, cementation and the ticking clock
Will take loose grains like dirt in a pail
And glue it into sedimentary rock!

(chorus)

Now if a rock is buried miles underground
That rock can undergo a metamorphic change
The heat and the pressure are squeezing all around
The crystals reform and layers rearrange
Shale turns to slate, limestone to marble
Rocks metamorph into different types
All those neat layers get squeezed up and garbled
But foliated rock still has zig zaggy stripes

(chorus)

Appendix O: Lyrics to "Tectonics Rocks," Morris © 2010

We're all living on floating plates of rock (tectonic rocks)
And if you dug way down you'd get a shock (cause it's all molten rock)
Now all these plates are moving but they go...real...slow
We only feel it when we hear that rumble from below...and there's an

Chorus:

Earthquake, a volcano
Tectonics rockin' down below
Along the edges of the plates
They grind together and separate
and slide and shift where two plates interlock
Tectonics rocks

Divergent plates are where they move apart (that's where new crust starts)
Like the mid-atlantic ridge at the ocean's heart (down in the deep and dark)
Sea floor spreads, magma rises, new mountains to create
And Africa and South America slowly separate...and there's an

(chorus)

Convergent plates they crash together slow (where does the old rock go)
Subduction is when one plate goes below (and melts into the flow)
The denser plate goes low while the light one rises high
And on the continents new mountains reach up to the sky...and there's an

(chorus)
In transform boundaries they slip and slide (that's one rocky ride)
Plates are passing by from side to side (a fault's identified)
And underneath the earth the stresses build and break
Like the San Andreas Fault where you might often feel it shake...and there's an

(chorus)

Appendix P: Lyrics to "Evolution," Morris © 2005

Chorus:

Evolution, Is not so scary
Even if you think your ancestors weren't hairy
It's minor changes, through generations
To watch it happen would require lots of patience.

Since the first cells, we've come so far now
Six hundred million times we've orbited our star now
We've had to face, adverse conditions
The species pool has had subtractions and additions.

The fossil record, with carbon dating
Provides the clues that set us all to cogitating
Why is it life, becomes complex, now?
How does an arthropod evolve into T.Rex, now?

It's like a puzzle, with missing pieces
We can't explain the gaps for all the species
But what we do see, all fits together
It seems that life adapts to changes in the weather

(Chorus)

It's adaptation, and it's selection
We never see the changes that led to rejection
But some mutations, are beneficial
And the survival of your genes makes it official

Now evolution, as explanation
Of how we got here has its strengths and limitations
But learn the science, and read the commentary
Cause evolution really isn't all that scary!

(Chorus)

(ch) Evolution – is not so scary
It's just a way of building things that takes a lot of time
Evolution – is not so scary
It's really an intelligent adaptable design

Appendix Q: Lyrics to “The Evolution Revolution" Jeffrey Moran © 1995

Chorus:

If you got the genes, then you got the means. To mutate and change your traits.
Unless you want to stay a bacteri-a. Or be a fungi for eterni-tie.

It’s the evolution revolution. And it’s gonna change your career.
No more a wriggly, squiggly worm. You’re getting out of here.
Yeah, your descendants will be new creatures some day if the right genes do combine.
And if they wake up and have six legs. A lot of insects are doing fine.

It’s DNA, that’s what I say. That mutates now and then.
You exceed your ration of radation. And when you count to ten
Some genes are missing a base or two. And much to your dismay,
When the ‘somes get together to mitose. They replicate that way.

(And you end up a couple of enzymes short of a full cell, if you know what I mean: the spiral staircase isn’t going all the way to the end of the chromosome; you aren’t playing with a full tank of phosphates; some of the purines and pyrimidines don’t have partners to take to the next metaphase dance; there’ll be some amino acids on the outside looking in; there’ll be some lonely codons standing around wondering where everyone else went . .)

(Chorus)

It’s hard to state when a gene mutates. What the results will be.
In fact in could even be good. For the fortunate mutatee.
A new variation of enzymation. Could make you top dog,
Growing eyes where your ears should be. Or maybe breathing smog.

It’s the evolution revolution. When your DNA does change.
You get a protein with a different amine. When the bases rearrange.
And that might be an advantage. When it comes to being alive.
More of that gene will appear. If more of your offspring do survive.

(And you end up with more grandkids than you can count, and they start eating you out of house and home; then some of them got to seek out some new territory and they’re a marrying strangers, and pretty soon you got folks showing up at the annual species reunion with names you don’t recognize.)

Appendix R: Lyrics to "Atom Shack," Morris © 2005

I had a little atom shack, Way in the woods out back.
Had a couple kids (electron kids!), And I stuck 'em in a room called "S."
(Why's it called "S," Dad? Because, that's what it's called. Ok.)

Had a couple more and the shack was too small, Build a bigger house around its walls.
Built a couple rooms while the new kids squalled, And I stuck 'em in a room called "S."
(*But dad, you called the other room "S*." I know. *Why'd you call this one S, too?*
No, "2S." *Huh?* "2S," not "S2." *Why not just call it "T"?*
Shut up, kid, you're confusing me. *Sorry, Dad.*)

Had a couple more of those little punks, Stuck 'em in a room with three sets of bunks.
That'll hold six and all their junk, And we'll call this new room "P."
(*Why'd you call it "P?"* Well, ya gotta have a room to "P." *Oh, Dad.*)

Four more kids and that house was packed, Hung a big neon sign out back.
It said, "No more room at the atom shack." And then we had the twins.
(Twins?! Yeah, they were mean little cusses, too. Spit every time you got 'em near bath water.
This isn't about our family, is it, Dad? Sure hope not!)

Built a big barn to enclose it all, Couple more rooms, threw up some walls.
Bundled up the twins and got them installed, In a nice little room called "S."
(*DAD! Not again!* Sorry, kid, call it "3S," ok? *You're confusing your kids!* Nah, we lock 'em in their rooms. *That's mean.* This isn't about our family, is it, kid? *Sure hope not.*)

Finished out a room and called it "P." The next six kids, that's where they'll be.
But finally the beds Are Gone, ya see, And we still need more room.
(Was that "3P," Dad? You got it. Like C-3PO!! Shut up, kid, you're confusing me.
Sorry, Dad.)

Finally we build a big citadel, With three big rooms for those kids that yell.
Four "S," Four "P," that's all swell, And that old barn loft sleeps ten.
(What's the loft called? "3D" for Dorm room? Yeah, I guess. That's where I'd want to sleep!
Yeah? I couldn't get them to settle down, they all wanted to sleep in "4S" instead!)

Now anytime we got a bit of extra space, the kids tell friends "come over to our place!"
No sense letting empty beds go to waste, So they have a big slumber party.
(Ooh, that sounds like fun! Yeah, they call it valence bonding or something like that. Dad, can we have a valence bonding party? No. Awww…)

So if you wanna build a little atom shack, Better get ready for some periodic flack.
And keep some extra building supplies out back, Cause the kids all want more room!
(Dad, can I sleep in a loft called D? No way I'm building a loft. Awww…)