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International Journal of Science Education

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tsed20

# Teaching and Learning Science Through Song: Exploring the experiences of students and teachers

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Available online: 14 Jun 2012

**To cite this article:** Donna Governor, Jori Hall & David Jackson (2012): Teaching and Learning Science Through Song: Exploring the experiences of students and teachers, International Journal of Science Education, DOI:10.1080/09500693.2012.690542

**To link to this article:** http://dx.doi.org/10.1080/09500693.2012.690542

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*International Journal of Science Education*
2012, 1–24, iFirst Article

Routledge
Taylor & Francis Group

# Teaching and Learning Science Through Song: Exploring the experiences of students and teachers

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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. Data gathered included three teacher interviews, one classroom observation and a student focus-group discussion from each of six cases. The data from each unit of analysis were examined independently and 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. The use of science-content songs engaged students by providing both situational and personal interest, and provided 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. 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.

Keywords: *Qualitative research; Conceptual development; Learning activities; Science music; Teaching strategies; Middle school science*

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ISSN 0950-0693 (print)/ISSN 1464-5289 (online)/12/000001–24
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http://dx.doi.org/10.1080/09500693.2012.690542

## Introduction

Music is the heartbeat of every adolescent. Students can be found in every middle school today who carry their favorite tunes to school on MP3 players. Even though music is a part of everyday 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 (Jensen, 2000; Jourdain, 1997). There is an entire genre of science-content-based music, rich in content and available for teaching science concepts. Jensen (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). Recommendations for implementation of science-content music into the curriculum include using songs at any point in the learning process as either the focus of a lesson or to supplement it by enhancing and enriching learning (Bennett, 2002; Crowther, 2006; Jensen, 2005; Wallace, 1994).

Because there is a limited amount of research in this area, a definition of science-content music must be generated from other sources, including the songs themselves. 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 which 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've 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).

These lyrics illustrate that science-based music can be rich in content and concepts. The lyrics presented here are provided to illustrate the science concepts that can be included in songs, rather than to suggest how they might be used for learning. Some songs involve changing lyrics to familiar tunes, while some songwriters compose melodies to fit original lyrics. Songs for learning 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*.

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*Research Questions*

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. 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?

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## Review of the Literature

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 within neuroscience and educational theory. Music's potential as a teaching strategy comes from an understanding of how it is processed in the brain and how the combination of melody and lyrics provide multiple neural pathways to store, access and retrieve memories. Songs carry content in lyrics and can be used to construct understanding of science concepts through experience.

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. A study by Calvert and Tart (1993) found that songs were powerful mnemonic devices that allowed for improved recall and were useful as a strategy to encode, retrieve and rehearse information. 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). 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

(Campabello, DeCarlo, O'Neil, & Vacek, 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.

### *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. Music is especially powerful for memory as it encodes learning in emotion. '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 (Jensen, 2008). Sousa (2006) summarizes, 'emotions consistently affect attention and learning' (p. 44) and strengthens the neural network that encodes emotionally laden memories. Emotions are biological responses to stimuli and when activated, insure that students will be more likely to attend to and remember associated content as 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).

Neuroscientists have begun to unlock the mystery of why music activates emotion. As a listener processes sensory input from music, the brain uses apparent patterns to predict what will come next. '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 focussing attention to establish stronger and multiple neural connections (Jensen, 2000).

Memories encoded in an emotional state are stronger and offer multiple paths for encoding and retrieval. 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). When multiple neural paths have been established, memories can be accessed using more than one stimulus. In this way, music also serves as a mnemonic device for enhancing memory. Bellezza (1981) defines mnemonic devices as 'learning strategies, which can often enhance the learning and later recall of information' (p. 247) and include visual images, or words in the form of sentences and rhymes. They work by building associations within cognitive structures. Bruning, Schraw, Norby, and Ronning (2004) identify stories, rhymes and songs as specific mnemonic devices associated with visualization and language devices.

Music's special capacity for involuntary recall means that it is possible for science-content songs to become 'earworms', or tunes that are overly repetitive, simple in

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nature but have unexpected elements (Cunningham, Downie, & Bainbridge, 2005). These melody echoes are generally small pieces of a song equivalent to the capacity of working memory, approximately 15–30 s in length (Levitin, 2006). These 'earworms' can be powerful for voluntary or involuntary memory activation and are a commonly reported occurrence associated with songs (Liikkanen, 2008). 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.

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*Factors Contributing to Effective Learning*

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. Science-content music provides a social learning experience which students can use to help construct new knowledge.

Conceptual change, constructivism and cognitive or brain-based learning theories all inform the recommendations for effective science instruction made by Banilower, Cohen, Pasley, and Weiss (2008) by addressing experiences and how they are processed as the foundation for learning. Learning, according to Duschl, Schweingruber, and Shouse (2007) in *Taking science to school*, is a result of the interaction between experience and instruction. In this report, Duschl et al. (2007) recommended using multiple resources and symbolic tools for building conceptual understanding of science as both a body of knowledge and a process by which knowledge is accumulated. One could argue that science songs, rich in content, provide one means by which students can construct meaning of science concepts.

Research in the socio-cultural tradition also stresses the importance of emotions and engagement in teaching and learning. 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). 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, & 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. Banilower et al. (2008) also suggest that students can learn regardless of

the technique, as long as they are 'motivated to learn and intellectually engaged in activities and/or discussions' (p. 5). Students can be motivated through either personal or situational interest (Duschl et al., 2007). Prensky (2001) refers to today's students as part of a new generation of digital natives and suggests that educators can help engage and motivate learning by using methods that reach out through familiar technologies. Music speaks to the current generation of digital learners in novel ways; they 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.

The authors of *Effective science instruction* (Banilower et al., 2008) suggested that to participate effectively in the process of science students must understand the language of science. Songs carry content information in the lyrics and have the potential to help students become familiar with the language of science. Using recommendations from *Effective science instruction* (Banilower et al., 2008), 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).

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## 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. 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. 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 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, and Mead (1987), case study research is best suited to exploring the experiences of participants while investigating a phenomenon in its natural setting. Cases are identified in terms of the bounded system in which the phenomenon is experienced and can be investigated either with an individual focus or by using multiple cases. In this study, each case was bounded by the middle school science classroom using science-content music for teaching and learning. Stake (2006) 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; in this research it was the use of science-content music for teaching and learning. 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.

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 3 January 2011. In this study, the research sites selected were six middle school science classrooms in the suburbs of a major southeastern city, based on geographical proximity and opportunity to observe science-content songs being used for teaching science. Six teachers were selected using a purposeful sampling method that agreed to implement teaching strategies using science-content songs for learning. Based on recommendations by Stake (2006), cases were selected based on relevance, diversity and opportunities to learn about experiences in context and the opportunities they provided to observe the quintain. Volunteers were solicited by email and in person at a district-level meeting. Teachers who volunteered to participate agreed to implement teaching strategies that use science songs for learning in the middle school science classroom for two or more lessons and included 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 with administrative permission and volunteer teachers became the research sites.

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 CDs from various artists. Student focus groups were used to collect data from students based on their experiences when using songs for learning. The number and composition of students in each focus group for this study were dependent on each teacher obtaining parental consent from students willing to participate. Students who participated in focus group discussions received a CD of science songs as an incentive.

At an initial meeting, each teacher was provided with some basic information about using songs for learning and was encouraged to choose songs from either provided or online resources that would best fit their curriculum in whatever ways they saw appropriate. All teachers were asked to include a lesson in which students read and analyze

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the lyrics of the songs selected for instruction as part of the study. 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 (Bennett, 2002; Crowther, 2006; Jensen, 2005; Wallace, 1994). Other suggestions for implementation were made based on recommendations by Crowther (2006), who advocated for selecting songs that have an easy-to-sing melody and that should be heard by students more than once to emphasize key points. 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 their lessons and to supplement instruction based on practices suggested in the literature (Bennett, 2002; Crowther, 2006; Jensen, 2005; Wallace, 1994).

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*Data Collection*

Three types of data were collected as part of this study. Teacher interviews were conducted before, during and at the end of the study. Observations of each classroom were conducted to better understand student–teacher interactions that took place during lessons implementing science-content songs. Student focus groups were conducted immediately following classroom observations.

*Interviews*. In this study, three interviews were conducted with each participating teacher 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 and Rossman (2006). Suggestions by Stake (1995) and Glesne (2006) guided the format of the interview and type of questions asked, such as using a semi-structured format and asking questions that were designed to elicit participants' experience, opinions, knowledge and feelings about the quintain. During the initial interviews, questions 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 teachers a chance to respond to observation data and information students shared in focus group discussions. 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, and identify the ways in which they believed science-content music could be used for conceptual development. A total of over four and a half hours of interview data were transcribed producing over 200 pages of text for analysis.

*Observations*. Observations can provide insights into, direct evidence about, and lead to greater understanding of the quintain in case study research (Stake, 1995). The observations included in this study were used to generate field notes and included

detailed descriptions of the actions and interactions of teachers and students during lessons employing science songs. Classroom observations occurred during a lesson in which teachers were using science-content songs as a teaching strategy and lasted between 20 and 30 min each. Notes taken during classroom visits focussed on key elements of setting and interactions as well as language and nonverbal communication while students were engaged in teaching activities using science songs for learning; all recommended strategies for observations (Patton, 2002). Primary questions that guided the observations included, 'How does the teacher introduce the song?' and 'What indications of the students' level of engagement can be observed?'

*Focus groups*. Focus groups are interviews with multiple participants which encourage discussion in a supportive environment and are especially appropriate for interviewing children and adolescents who may feel more comfortable talking with their peers when interviewed. Combining focus group interviews with observations in case study research is a strategy recommended by Marshall and Rossman (2006). To limit the size of focus groups in three of the classes having a high number of student participants, interviews were conducted in two groups. Therefore, a total of nine focus group discussions took place during this study with a total of 59 students participating. These interviews lasted between 7 and 16 min each, and took place immediately following classroom observations. 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. A total of just under 2 h of interview data were transcribed, resulting in over 120 pages of text for coding.

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### *Data Analysis*

In the multiple case study analysis, data from each case were first analyzed independently using an inductive, open coding process, which is the main activity in a cross-case analysis (Stake, 2006). Transcripts from individual teacher interviews, focus groups and field notes generated during observations for each case were analyzed to identify themes using the open coding method described by Saldana (2009) and Charmaz (2000). Analytic memos were written after the initial coding process for each interview and focus group discussion separately to summarize experiences and perceptions (Saldana, 2009).

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. Once individual cases were analyzed, the themes developed independently in each case were merged in order to learn more about the phenomenon. In this study, Stake's (2006) second technique for cross-case analysis was used to make generalized assertions about the quintain by comparing themes that emerged through a synthesis of findings. 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.* According to Patton (2002), triangulation 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). Denzin (1978, as cited by Patton, 2002) identifies several methods by which qualitative research data can be triangulated. One suggested method is data source triangulation, which 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, which 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 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.* 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. Because each teacher 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 cases reported in this study.

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## Results

Each case within this study was first analyzed to identify themes using case study methodology. Table 1 summarizes the major themes that emerged from the independent data analysis from each case. A summary for each of those cases is presented below.

### *Derek Martin: Eighth grade physical science*

For this teacher, the use of songs for teaching science was a valuable, new resource. When he first reviewed potential songs he recalled thinking, 'I could tell that these were not just songs that mention science words ... the lyrics themselves were packed with information and concepts and examples'. When Mr Martin used songs for instruction, he felt that his students grasped 'how these songs have deep meaning, deep layers in them and connect to the content'. 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 would 'rather read it in a textbook'. And while it was important to hear her voice, she was the only one in the nearly 60 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'.

### *Sandy Kingston: Sixth grade earth science*

Ms. Kingston admitted that she entered the study with reservations but was pleasantly surprised at the results she saw with her students. Within a week of our initial interview she sent an email message that said, 'We used the heat transfer song today! Kids were dancing, making up motions. We had a ball!' She later admitted, 'I came into it kind of halfhearted ... I didn't know how [students] were 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. 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'.

### *Martha Russell: Sixth grade earth science*

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 explained, 'It was something to look forward to; it was something

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Table 1. Major themes from individual case study analyses that emerged during inductive analysis

| | Question 1 | Question 2 | Question 3 |
|---|---|---|---|
| Derek Martin | Songs provide students with alternative explanations of science concepts | Novelty of strategy provides situational engagement | Analysis of lyrics helps students connect ideas |
| | Content-rich lyrics explain key ideas and give examples of concepts | Students engage with content longer | Songs can be used to interact with concepts on multiple levels of understanding |
| Sandy Kingston | Perception that test scores improved | Earworms help students engage with concepts longer | Songs are an instructional contagion that spreads beyond the classroom |
| | Songs involve active learning | Songs are used by students as a study strategy | The use of songs has a universal appeal |
| Martha Russell | Songs provide for visualization of concepts | Active participation in learning | Repetition builds ownership of content for some learners |
| | Enhance development of scientific vocabulary | Mnemonic device for helping students remember concepts | Presents scientific content to students in a way that they care about |
| Betty Taylor | Promotes discourse in language of science | Students engaged in active learning | Songs have socio-cultural appeal to these students |
| | Provides opportunity to address misconceptions | Mnemonic nature of songs make it easier to remember concepts | Connect ideas and organizes knowledge |
| Anna Darcy | Songs tell stories that promote sense making of science concepts | Provides a change of pace in the learning environment | Socio-cultural aspects of learning can conceal engagement |
| | Key concepts emphasized through repetition | Specific characteristics of science songs make them effective tools for engagement and learning | Analysis is necessary to connect content-rich lyrics to the curriculum |
| Max Cantor | Songs provide students with alternative explanations of science concepts | Novelty of strategy engages students | Music has a special appeal to students |
| | Content-rich lyrics explain key ideas and give examples of concepts | Students engage with content longer | Lyric analysis helps students connect ideas and organize new knowledge |

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

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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'. Mrs Russell's students also expressed the same sentiments, 'You're having fun and listening to it'. One student reported, 'I think it helps understand the ideas'.

*Betty Taylor: Eighth grade physical science*

Mrs Taylor's reaction to her first lesson using songs was one of surprise. 'I really did not expect this response from them. We use music so often when they're young to teach learning and stuff . . . and to see them at this age still enjoying that very elementary type strategy . . .. I've been surprised'. She added, '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 students in Mrs Taylor's classroom agreed; they all enjoyed learning science with songs. 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'.

*Anna Darcy: Seventh grade life science*

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'. Generally, she added, her experience has been that her students, 'like science, but they . . . love the music'. The students in Mrs Darcy's class agreed; they liked learning with science songs. They discussed how the power of songs for teaching comes from the role that music plays in their everyday world. According to one student, 'I think it's easier for kids to understand music better, because music is part of their everyday lives'. Another added, 'Sometimes kids even express their . . . moods through music'. For them, music's importance in their daily life made it an effective instructional strategy.

*Max Cantor: Eighth grade physical science*

Mr Cantor felt like his students were genuinely engaged during the song-based lessons. 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

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going to learn more'. And teaching with songs makes sense to Max for engaging students because '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"'. 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'. Generally, the eighth grade students in Mr Cantor's class confirmed what their teacher saw; they enjoyed learning science with songs. When asked what they thought about learning with songs they responded, 'science class is actually fun, if you listen to the songs, and stuff'.

## Cross Case Analysis

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. 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.

Across the six cases, there were a number of commonalities in terms of how teachers implemented science songs. Most of the songs selected for use by the participating teachers came from Morris's *Round the world with science* (Morris, 2010), which was produced specifically for use in this study. 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 literature review and discovered during a pilot study about songs for learning. Teachers had a variety of reasons for selecting these songs, most related to how they fit in with the curriculum. For songs to be chosen as a useful teaching tool Sandy Kingston said, 'the lyrics would have to be on target with our concepts and our content'. Derek Martin explained why he selected these songs, 'they had enough detail and content in them that they were very useful and I knew that from listening to them'. During the interviews, several of the 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.

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. 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. All the teachers in this study provided students with lyrics on a handout for the analysis activity but what they had students

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do with the lyrics differed. Two teachers, Derek Martin and Martha Russell, asked students to work in groups to interpret lyrics, and 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 lyrics. 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, or to add questions about the content presented in the lyrics.

Regardless of how teachers implemented the use of science-content songs in the curriculum, for students the concept of novelty appeared consistently across all cases. One student commented, 'If it's more fun to learn about something, it's easier to learn'. Another summarized, 'It's active learning. Music, it sticks in your brain'. 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 one student explained, 'With a song, it wraps it up and makes it easier to listen to'. Another reported, 'When the teacher is 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'. Consistently, students across all cases reported that they enjoyed learning with songs and were more likely to pay attention than when traditional teaching methods were used.

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 to provide 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. The cross-case analysis produced six assertions, each with a single focus that resulted from a process of comparing similarities and differences across cases. They represent binding ideas reached by examining correspondences and correlations between cases.

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

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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-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.

While the vast majority of students enjoyed learning science with songs, there was one student among the 59 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 did not concur with her opinion, they suggested that some songs that were too complicated, confusing or included irrelevant information might hinder learning. For songs to be helpful, one student advised, 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'.

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. Teachers thought that the lyric analysis activity had the potential to help students connect learning and build understanding of science concepts. 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'.

Most of the themes identified through analyzing data from each case indicated the use of science-content music had a positive impact on students; however, there were a number of themes that did not have enough support to be further developed during the cross-case analysis. While not having adequate support to develop into a cross-case assertion, most of these 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.

In Anna Darcy's case, one conclusion 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. During the discussion, they explained that they were self-conscious about singing and making motions in class and in front of their peers.

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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. This experience was not entirely unique. In Mrs Kingston's classroom where the engagement level appeared highest, a similar concern emerged. 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'. Max Cantor talked about this socio-cultural phenomenon, 'They all enjoyed doing it. Some of them were like kind of embarrassed... 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, 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.

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 understanding of the experiences of educators and students when science-content music is used for teaching and learning.

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## Discussion

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. 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 vocabulary used in the lyrics by providing new contexts for constructing meaning of science terms. 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'. A similar term 'talking science', as used by Duschl et al. (2007), was used to discuss the importance of students learning the language of science. According to Lemke (1990), '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. 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'.

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. The second assertion from this study 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. 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 for conceptual development. Duschl et al. (2007) suggested the importance of using multiple resources and symbolic tools for building conceptual understanding. According to Lemke (1990), 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' (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 students with diverse explanations and examples of science 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

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concepts by comparing explanations and engaging with ideas using different examples. 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 . . . in a non-scientific way'.

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. 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. 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. 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'. 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'. Novelty in instruction increases 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 in this study when students learned science with songs.

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'.

The use of songs as a mnemonic device for recall is not 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 explains 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). As a mnemonic device to trigger memory, students in this study recognized the potential for science songs to help them recall factual

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information. 'It helped me learn and it really did get stuck in my head', one student said. 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'.

The value of mnemonic devices of various kinds is commonly thought of as more consistent with a simple, transmission model of learning. However, the results of this study suggests that the mnemonic nature of songs can impact learning at a deeper and more meaningful level, based on constructivist learning theory which focusses on how students build concepts through experience to make sense of the world. By prolonged engagement with concepts presented in science songs, students interacted with concepts longer, which facilitated connecting ideas and organization of 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, and in an active rather than merely a passive manner. One student said, '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. 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.

Duschl et al. (2007) 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' (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. (2007) explains that, 'many students do not understand that science is primarily a theory building enterprise' (p. 175). Instead, the students in this study focussed on the usefulness of learning with songs because concepts were '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. Banilower 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)' (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.

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 with science concepts in a social context. Music has always had importance as one of the basic activities of all cultures and of humankind (Storr, 1992); however, for these students music is a part of their cultural experience through multiple media resources not provided to previous generations; these include

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television, movies and digital music downloads that are a part of every activity in their daily lives. The interest that these students have in music can be a powerful tool for engaging them in learning through personal interest. Max Cantor summarized the importance of music for his students, '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'. An eighth grader from Betty Taylor's class summarized the value of songs in science instruction. 'Music is worth something', he asserted. Music 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.

Every teacher in this study reported the importance of analyzing the lyrics of songs used for teaching science as a useful learning tool for connecting ideas and fostering conceptual understanding. Banilower 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. Multiple strategies are suggested to help students make these connections. 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, 'it was a synthesis and analysis process, so it required 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. Conceptual scaffolds are instructional techniques that help students build understanding of new concepts and connect learning to prior understandings and include activities 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; students 'have got to see the lyrics to make some connections with what the science is and what they're currently learning . . . 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.

## Implications

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. In *Effective science instruction: What does research tell us?* the authors suggest

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that to build an understanding of science concepts, learning experiences should intellectually engage students with content using multiple pedagogies (Banilower et al., 2008); the more ways science content is presented, the more opportunities students will have to connect ideas and organize knowledge. The experiences of teachers and students that participated in this study suggest that science-content songs have a place in the curriculum, providing a supplemental strategy that can build conceptual understanding of science concepts. To get the most out of songs for learning, the teachers in this study found that it is critical for students to 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.

Probably, the most interesting 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. 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. Further exploration of this dichotomy between educational goals and student perceptions is warranted. 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.

Directions for further research should consider exploring the use of songs for teaching science from a quantitative or mixed-methods design. The data from students and teachers in this study indicated the perception that songs helped facilitate both content knowledge when employed as a mnemonic device, and conceptual development through lyric analysis and prolonged engagement with science concepts. Therefore, research aimed at quantifying specific learning outcomes at different levels of understanding is recommended to further evaluate the use of science-content songs in science education. 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? Do science-content songs simply promote learning as recall, or facilitate deeper levels conceptual development? Additional questions that might be considered relate to music genres, additional instructional levels, students with special needs, teacher training, how different teacher or student backgrounds might impact the learning experience with science songs, 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? In future research, it would also be interesting to explore related constructs such as science teacher's majors, personality, gender, teaching experiences. And while some implications for what makes science songs useful learning tools are suggested based

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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 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. Final assertions suggest that content-based music helped students build a conceptual understanding of science concepts from a combination of cognitive, socio-cultural and constructivist research theories. Science-content music has implications for instruction from different learning theories, and suggests that science-content songs can effectively be used for conceptual development when implemented in sense-making contexts. 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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