

The Sound of Science Music: Utilizing Music to Teach Science

Gabrielle M. Ferreras

Point Loma Nazarene University

### **Abstract**

This study assesses the effectiveness of music as a teaching tool for science classrooms. Average test scores across three assessments were compared in two sixth grade classrooms to determine if exposure to content-rich music resulted in one classroom outperforming the other. In Test 1, neither classroom received a content-rich song to study with and the baseline of average test score between the classrooms was established. For Test 2, Class A received an original content-rich song to study with and Class B did not. For Test 3, the same procedure for Test 2 followed but instead Class B received the song. Quantitative analyses demonstrated that students studying with an educational song performed better on tests than students without. Qualitative surveys demonstrated that music had an overall positive impact on studying, recall, and classroom environment. Implications and limitations of the current study, as well as suggestions for successful implementation of music into the science classroom, are discussed.

### **Introduction:**

There's a growing body of research assessing the effectiveness of various practices that are used to differentiate learning in the classroom. Due to the various biological and psychological components of learning, research has demonstrated that students require multiple modalities of instruction to effectively engage with content and maximize retention of the material. For example, many teachers are encouraged to utilize various visual, audio, or kinesthetic supports to aid in instruction. Providing additional mediums for students to engage with material is particularly beneficial for students with different learning styles and disabilities that affect learning and attention (dyslexia, ADD, ADHD, etc.). The modality of instruction that this particular study will focus on is music. An extensive amount of research supports the idea that for a variety of reasons, music is an exceptional tool that aids in long-term recall, reduces stress, and promotes social bonds among students. The aim of this study was to quantify the effectiveness of music as a teaching tool by analyzing student test scores with and without songs with content-rich lyrics.

### *Literature Review*

Over time, education has grown and developed as people become more aware about the way we learn. In the last century researchers in science, psychology and education have learned more about the most effective teaching methods and have been making great strides to improve instruction. Up until the 20th century, the "traditional" style of teaching was the most prominent method of instruction in the education system (Mohamed, 2020). This involves a primarily lecture-based and teacher-centered classroom in which there is little engagement between students throughout class and instruction is exclusively delivered through lectures and reading alone. Since more research about the learning process has been generated, it's now understood that differentiated instruction is critical to student engagement, understanding of material, and long-term retention of information (Governor et al., 2012).

Proponents of traditionalist style of teaching hold the misconception that learners' minds are blank slates that could take the information as it was presented with no other confounding information or ideas. In reality, students come to class with preconceptions about the world and must reconfigure new information into their schema in order to make sense of it.; unless students are fully engaged in the classroom, this can be a significant barrier to learning and prevent students from being able to understand new content (Donova & Bransford, 2005). There are three essential requirements of being able to gain sufficient understanding in a given subject: a deep foundation of factual knowledge, the ability to understand facts and ideas in the context of a conceptual framework, and the ability to organize knowledge in ways of that facilitate retrieval and application (Donova & Bransford, 2005). The more advanced a learner becomes in a given subject area, the better they can synthesize previous knowledge with new content in order to apply it to other areas. For example, a case study demonstrated that when chess pieces were

configured into a meaningful pattern, “masters” were more likely to recall the positions than “novices.” However, when the pieces were placed in a random configuration, there was no significant difference between the ability to recall the position of pieces among masters and novices. The essential takeaway from this study is that “what novices see as separate pieces of information, masters see as organized sets of ideas” (Chase & Simon, 1973). The same holds true for education; an advanced learner is able to organize knowledge in such a way that it can be applied to new scenarios in order to analyze or evaluate a given problem or phenomenon. The teacher plays a significant role in this process by facilitating the student’s ability to “take control of their own learning” and presenting new knowledge in a way that the student can retain and understand within the context of previous knowledge (given that there are no misconceptions in previous knowledge) (Donova & Bransford, 2005).

Contrary to the philosophies of the traditionalist-style of teaching, the most effective way to teach new material is to incorporate multiple modalities of instruction that can support the different sensory learning needs of every student (Jensen, 2005). While there are some students who may be more adept to specific types of instruction and learning (i.e. auditory, visual, kinesthetic etc.), research demonstrates that *every* individual benefits from differentiated learning. By incorporating different ways for students to engage with material, students’ present understanding of content and long-term recall can be significantly improved. One strategy to differentiate learning that’s especially valuable is utilizing educational music as a teaching tool.

### **Music and the Brain**

One of the reasons that music has significant potential as an effective teaching tool is the way that it can facilitate strong long term memory and recall. According to science communicator and youtube creator Hank Green, memories in the most general sense are grouped into 2 major categories: short term and long term (CrashCourse, 2014). Short term memory allows people to hold onto small bits of information (limited to about 4-7 pieces of information) for a very short time (5-30 seconds). Though the duration is minimal, short term memory is the reason people are able to assess their surroundings at any given moment. Because their lifespan is so short, short term memories are either encoded into long term memory or they’re forgotten completely. Long term memory is the aggregation of several short term memories. In the hippocampus, a brain structure where most memories are stored, short term memories are played back and the brain creates connections between neurons which eventually become fixed in place. Based on certain senses, the brain can possess multiple combinations of connections that lead to the same memory (CrashCourse, 2014).

Because the brain is limited by both time and capacity, information is learned best when it’s repeated and broken up into chunks (CrashCourse, 2014). Songs help alleviate this issue because the structure of the song is information that is separated by verses with a melody that repeats, therefore it can be an easier way to deliver information to students (Governor, 2012).

Additionally, music can create multiple neuronal pathways that strengthen the ability to recall a particular memory (Jourdain, 1997).

One contributing factor as to why music aids in memory encoding and recall is due to structural components of music. Songs serve as both organizational and encoding mnemonic devices that can aid in the learning process as well as recall of new information. They generally can be considered organizational mnemonic devices in the sense that they structure information according to meter and rhyme, thereby limiting the possible lyrics that would fit which makes recall easier (Bower and Bolton, 1969). Songs may also operate as encoding mnemonic devices, in which difficult-to-remember words (such as vocabulary) are paired with more easily remembered words, images, or sounds (Bower and Bolton, 1969). Additionally, the verse structures provide “access points” that facilitate easy recall even when parts of the song are forgotten. For example, if someone were to forget the third line of a song, they’re much more likely to remember it if they’re able to recall the first two lines because they lead up to each other. The verse structure organizes the information in such a way that the person will associate the parts they can remember with the forgotten parts (Bower and Bolton, 1969).

Melody is another significant facet of music that allows it to be so effective for memory recall. Four experiments were conducted by Wallace (1994) that compared the recall of listeners who had listened to a text that was rhythmically spoken versus presented in a song. From these experiments, Wallace established that not only was music more effective in facilitating recall, but it also facilitated better recall than that of the text that was rhythmically spoken—even when the song was only heard once and the spoken text was repeated (Wallace, 1994). This demonstrates that all of the components of a song in conjunction with one another are more effective rather than one component alone.

Perhaps one of the most significant ways that music generates the formation of long term memories is its capacity to induce emotion-related memories (Jourdain, 1997). A vast amount of research has demonstrated that memories associated with emotion are by far the strongest and easiest to recall (Governor et al., 2012). There are a few evolutionary and biological reasons why memories associated with emotion are stronger. As humans evolved, being able to understand and analyze emotion became a critical component of strengthening community bonds and resolving conflicts (Jourdain, 1997).

Due to emotion-related brain damage studies, emotion has come to be understood as critical to reasoning (Jourdain, 1997). Individuals with reported cases of emotion-related brain damage (particularly in the frontal lobe) demonstrated a loss of self-organization. The frontal lobes are what allow for executive functioning and are particularly crucial for planning, short-term memory, and attention. They work in conjunction with the sensory cortex to reconstruct short term memories (Jourdain, 1997). For example, if one is attempting to think of the image of an elephant, the visual cortex would construct the image and the frontal lobe would sustain the image. The hippocampus works with the limbic system (responsible for behavior and

emotional responses) to evaluate what's happening in the world and to shift its focus to the most important thing. The brain's focus is largely dependent on motivation, a broader category that encompasses emotion.

According to discrepancy theory, emotion is said to arise from the perceived difference of expectation versus reality. When an individual has an expectation that is met, there is seldom an emotional response, however when there's a discrepancy between an individual's expectation and reality, an emotional response is generated. "Music sets up anticipations and then satisfies them" (Jourdain, 1997, p.312). Because of the way that the human brain is constantly analyzing its surroundings and predicting what will happen next, it will interpret an established melody and predict the sounds and rhythms that are going to follow. Musicians can generate an emotional response by intentionally deviating from musical patterns that were established and postponing the expected outcome of the listener. As author Robert Jourdain states in his book, "[Music] can withhold its resolutions and heighten anticipation in doing so, then to satisfy anticipation in a great gush of resolution" (Jourdain, 1997, p.312). Because of this, when people listen to music there's an emotional association tied to the memory of the song that will facilitate stronger recall.

### **Self-Efficacy**

Psychological and social factors play an integral role in a student's self-efficacy and ability to learn. Self-efficacy is defined as "an individual's belief in his or her own ability to organize and implement action to produce the desired achievements and results" (Bandura, 1997, p. 3). When a student doesn't have the confidence or motivation to learn a given subject, it can detrimentally impact their ability to succeed in the class (Jensen, 2005). In the science class in particular, there's evidence that interest in science is significantly decreased among students when they advance from primary to secondary school (Potvin & Hasini, 2014). Not only does interest decrease, but many students have reported that they "don't feel comfortable" in the science classroom (Osbourne et. al, 2003). One possible explanation for this phenomenon is that as content advances and becomes more challenging, students are deterred from learning due to an insufficient curriculum that may fail to support students' emotional and academic needs.

Because science and technology is a career perceived to attract high achievers, the data implies that pursuit towards a career in science and technology is more positively correlated with self-esteem than actual interest in science (Osbourne et. al, 2003). According to Osbourne and colleagues, science classrooms should therefore be more supportive and strive to cultivate the confidence and self-efficacy of students (Osbourne et. al, 2003).

### **Music as a Teaching Tool**

A particular area of education that could strongly benefit from the use of music as a teaching tool would be in STEM courses. Research suggests that a significant number of students decrease their interest in science classes as they advance from primary to secondary school and

seldom view it as a realistic career option (Potvin & Hasni, 2014). Research suggests that this loss of interest may be attributed to school and the structure of the curriculum—particularly pedagogical teaching (Potvin & Hasni, 2014). The most significant determinant of generating student interest in science is a classroom environment that would incorporate a variety of teaching strategies as well as unconventional learning activities (Osbourne et al., 2003). This data alone would implicate the effectiveness that music could have in both helping students learn in a creative way while simultaneously sustaining interest in science.

In addition to a lack of confidence, an unsupportive learning environment can lead to stress (Jensen 2005). Stress is extremely taxing on the brain and compromises a student's ability to learn. In one study, animals that were introduced to perceived threats had impairments to the hippocampus that hindered learning in subsequent experiments (Jensen, 2005). In students, chronic stress has been shown to hinder the ability to differentiate between what's important and what isn't (Jensen, 2005). One way to reduce stress for students and help build their confidence is by implementing music into the curriculum. In one survey, 75% of college sociology students reported that lecture-related songs preceding lectures made them feel more comfortable in the classroom (Albers & Bach, 2003).

Previous studies corroborate the positive effects of utilizing music as a learning tool. In one study where science students were asked to write song lyrics to the melody of a pop song of their choosing, students found their studying to be “more enjoyable and easier” and felt that they had gained a deeper understanding of vocabulary terms and concepts (Talens et al., 2015). In this process, students gained greater confidence in their ability to learn science and developed better relationships with peers that they previously hadn't interacted with as much in the class. This latter observation is of particular importance because social learning and peer support can significantly improve learning as well as attitudes towards science (Jensen, 2005). Furthermore, an additional study analyzed how utilizing content-rich songs affected teachers' and students' experience and found that it “enhanced 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” (Governor et al., 2012).

#### *Current study and research question*

Previous studies have been able to assess the impact of educational music from a primarily qualitative perspective. One study analyzed how utilizing content-rich songs affected teachers' and students' experience and found that it “enhanced 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” (Governor et al., 2012). Little to no research has been conducted that assesses if educational music can make a quantitative difference by improving student test scores. This goal

of this study therefore is to determine if a classroom studying with a content-rich song can score significantly higher than a classroom that does not. The research questions guiding this study are:

- Can utilizing music as a learning tool improve student test scores?
- Will students that study with content-rich music enjoy their engagement with content more than students who did not study with a song?

### Methods

Two 6th grade science classrooms at Linfield Christian Middle School were used for the study and will be referred to as “Classroom A” (N=24) and “Classroom B” (N=26). Parent consent and child assent forms were administered to, and collected from, the students prior to the song introduction. Content for “Unit 1: The Earth-Sun-Moon” and “Unit 2: The Solar System” were provided to the researcher by the teacher of the classrooms. Two songs with original melodies and lyrics were written and uploaded as lyric videos to youtube prior to song introduction. The teacher provided vocabulary lists from the two units which were used to write the lyrics for each song (*See Appendix A and Appendix B*).

In the first phase of data collection, Classroom A was introduced to the first song “Space to Learn” in class by the teacher about a week before their unit exam. Throughout the week, the song was played in class a total of 10 times, and students were invited to listen to the song outside of class by their own accord. Throughout this same period, classroom B underwent typical instruction with no song. After the unit test, the teacher administered two surveys to the students in Classroom A. Survey 1 asked the students how many times they listened to the song, when they listened to it and to what level they agreed that the song helped them study and recall information. Survey 2 contained open-ended questions that asked students about their overall experience with the song and if they found it to be helpful or unhelpful and why. In the second phase of data collection, Classroom B was introduced to the song “Solar System Song” while Classroom A received no song. The same procedure for the song intervention as above was followed for Classroom B, concluding with the administration of the two surveys following the administration of the unit test.

The scores of a previous test for both classrooms with no song introduction (Test 1), the test in which only Class A received the song (Test 2), and the test in which only Class B received the song (Test 3) were compared using a series of paired t tests (when comparing tests from the same class) and t tests for means assuming equal variances (when comparing test scores across the two classes). Three students were omitted from the quantitative analysis of test scores. One was due to a lack of consent and the other two was due to not being present for the tests. Responses for Survey 1 across Class A and B were compiled together and transferred to an excel spreadsheet; the proportions of students that agreed to the questions on Survey 1 were calculated and

represented graphically. For Survey 2, responses were annotated and the commonly observed answers were highlighted and ranked according to frequency.

## Results

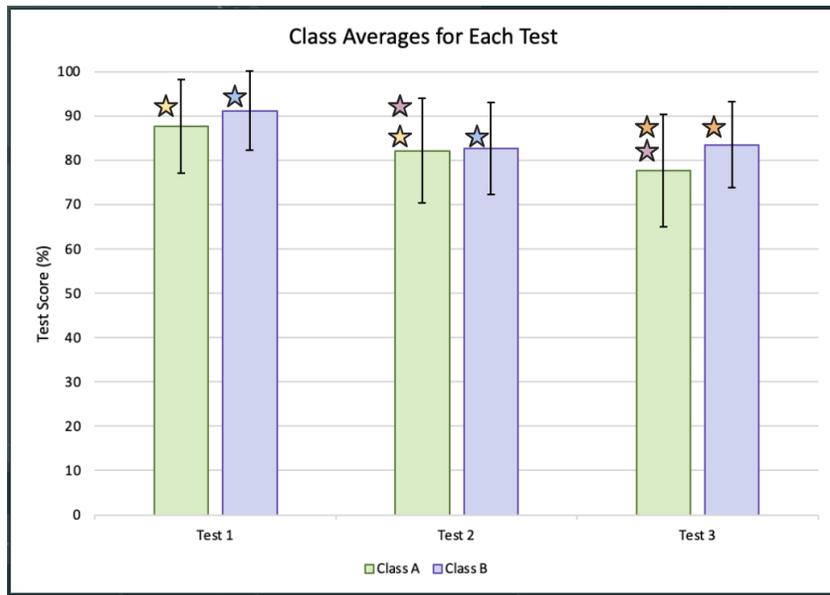
### *Quantitative Analysis*

The class averages for each test were compared between Class A and B (*see Table 1 & Figure 1*). A t-test confirmed that for Test 1, the average for Class A (87.74) and Class B (91.2) were not significantly different from each other ( $p=.22$ ), establishing the basis that prior to no song, there were no other reported variables that would lead to one class performing significantly better than the other. For Test 2, there was no significant difference ( $p=.87$ ) in average scores for Class A (82.2) and Class B (82.7). Paired t tests revealed that averages for both Class A and Class B significantly dropped between Test 1 and Test 2 and that the average scores for Class A dropped less significantly than they did for Class B. For Test 3, the average for Class B (83.5) was not significantly higher than Class A (77.7) for the two-tailed t-test ( $p=.09$ ), however it was significant in the one tail direction ( $p=.04$ ). The paired t-test showed that average for Class A significantly dropped between Test 2 and Test 3 ( $p=.02$ ). For Class B, the average test score increased although not significantly ( $p=.98$ ).

### *Qualitative Analysis*

Across the two classes, a total of 50 students responded to each survey. From Survey 1, students were asked how many times they listened to the song, if the song made it easier to study (*See Figure 2*) and if the song made it easier to recall (*See Figure 3*). Results showed that 10% of all 50 students strongly agreed that it made it easier to study. 64% agreed, 22% neither agreed nor disagreed, 4% disagreed and 0% strongly disagreed. 18% of students strongly agreed that the song made it easier, 48% agreed, 24% neither agreed nor disagreed, 10% disagreed and 0% strongly disagreed. Generally students that listened to the song more times (>5 times) were more likely to agree that the song helped with learning and recall.

From survey 2, responses were broken down into the following major themes based on frequent occurrence: “fun,” “helped learn,” “helped remember,” “helped get a good grade,” “unhelpful,” and “too long/hard to memorize.” The most frequently observed comments in descending order were “helped remember,” “helped learn,” “fun,” “unhelpful,” “helped get a good grade,” and “too long/hard to memorize.” Based on the comments students wrote on the survey, each was categorized as either reflecting a “generally good experience,” “neutral experience,” and a “generally bad experience. The quantification of these results (*See Figure 4*) showed that 77% of all 50 students had a generally good experience, 19% had a neutral experience, and 4% had a generally bad experience.

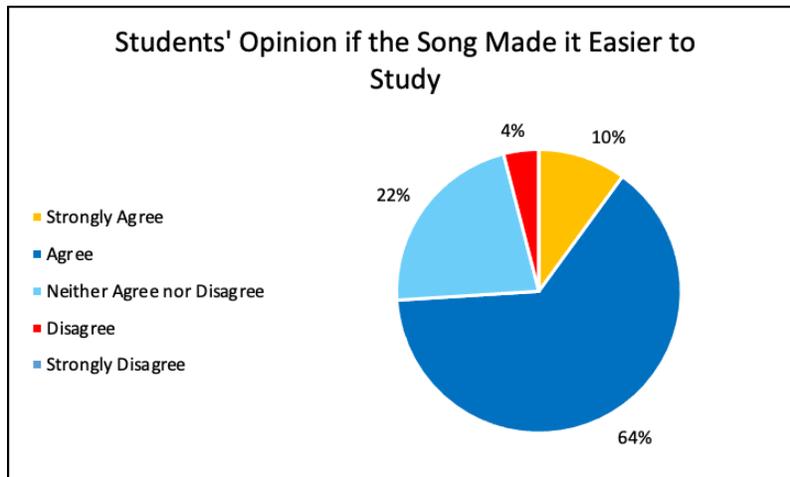


**Figure 1: T test Comparison of Class Averages for Each Test**

This figure displays the class averages between Class A and Class B across the three tests with standard deviation bars. Stars connote levels of significance ( $p < .05$ ). Stars of the same color represent significance between specific bars. \*Orange stars were significant in the 1-tailed test but not the 2-tailed t-test.

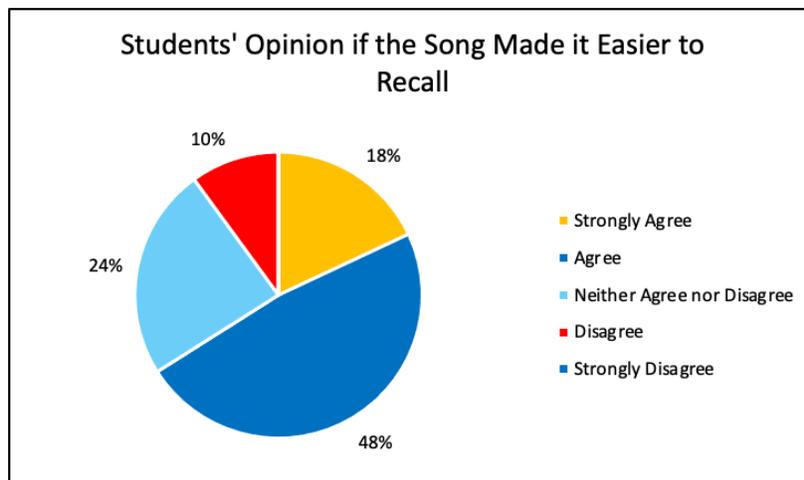
	Class Averages	
	Class A	Class B
Test 1	87.74	91.2
Test 2	82.2	82.7
Test 3	77.7	83.5

**Table 1: Class Averages between Class A and Class B**



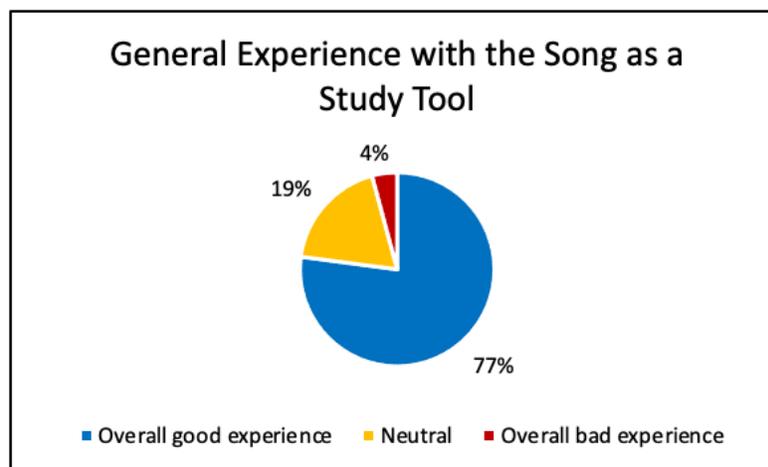
**Figure 2: Students' Opinion if the Song Made it Easier to Study**

*This figure displays the students' opinions of the extent to which songs aided in the learning process of material.*



**Figure 3: Students' Opinion if the Song Made it Easier to Recall**

*This figure displays the students' opinions of the extent to which songs aided in recall during their assessment.*



**Figure 4: Students' General Experience with the Song as a Study Tool**

*This figure displays the proportion of students that had a generally positive, neutral, and negative experience of studying with the song.*

### Discussion

Before either song was introduced to Class A and Class B, Class B had a slightly higher average score for Test 1, however there was not a significant difference in the way that they performed. This minimizes the possibility that there were any other confounding variables that would cause one classroom to outperform the other in terms of average score. When Class A had the song for Test 2 and Class B did not, both classes experienced a significant drop in scores, however Class A's score dropped less than Class B. This significant drop experienced in both classes likely indicates that the material for Test 2 was generally more difficult for most students relative to Test 1. Interestingly enough, Class A's average score dropped less than Class B despite them having a higher average for Test 1, suggesting that the song may have made a difference for this portion of the experiment. For Test 3 when Class B had the song and Class A did not, Class A's test score dropped significantly from their Test 2 average score, while Class B experienced a slight increase in their average test score. From this data, the argument can be made that music did in fact make a difference in improving test scores.

In addition to improving test scores, the songs also appear to have made a positive impact on student attitudes towards learning the content. Two surveys were administered to each classroom after the test in which they studied with the song. The purpose of these surveys was to assess how many times the students listened to the song and to gauge if and why the students thought that the song was helpful. The surveys were broken down into general themes that were talked about most frequently. On the survey, many of the students mentioned that the song was "fun" and aided them in learning the material. One of the students reported, "the song was just helpful

because a song is easier to memorize than just notes.” Most students commented on the fact that the song was helpful in facilitating recall—one of which claimed, “when I was stuck on a question on the test, I would play the song in my head.” Another comment that stuck out that relates to improving attitudes towards science is that the song helped the student “feel confident about the test.”

One of the most significant aspects of learning that was discussed in the introduction was a student’s self-efficacy. When a student believes that they have the capacity to fulfill their ambitions, they’re significantly more likely to learn information and have positive feelings about the content that they’re learning. Based on the comments of the surveys, the experience of each student was categorized as being “generally positive”, “neutral,” “generally negative. 77% of students had a generally positive experience, 19% had a neutral experience and only 4% had a generally negative experience. Some of the students critiqued that that song was “too long and hard to memorize,” or that the song was “annoying.” Like any other form of instruction, utilizing music to study is not going to appeal to or be equally effective for each student. Different preferences in song style will impact the student’s ability to enjoy the song and therefore may compromise its effect in helping with encoding and recall. For this reason, it’s important to note that while music can be an incredibly effective tool in the classroom, it’s simply that— a tool. Utilizing songs in education works best in conjunction with many other modalities of instruction because a diverse learning environment is more likely to stimulate students and encourage engagement. One reason for this is that our brains tend to pay more attention when things are changed. In other words, “our brains habituate to things that don’t change” (Jourdain, 1997). Despite the few students that didn’t find the song helpful, the high percentage of surveys with positive comments of their experience studying with the song demonstrates its benefit to the classroom environment regardless of test scores; therefore, it would be beneficial to integrate music into the classroom as a standard practice.

Another critical factor to consider with this experiment as well as general classroom engagement practices is negative impacts of the pandemic. The pandemic produced several adverse effects in students such as increased anxiety and a worse performance in sustained attention (Jun, 2021). Both of these may have had detrimental impacts on learning that may necessitate the development of different strategies of supporting student learning in the classroom that helps combat a compromised attention span and reducing anxiety. Incorporating different modalities of instruction has always been something that is integral to student learning and engagement and has since escalated since the unconventional learning experience that has taken place over the past couple of years.

### *Limitations*

Despite the various successes of this study, there were some notable limitations that may have impacted the results. Due to covid regulations, I was unable to be present for the song introduction and subsequent administering of the surveys. As a result, the authenticity of the students' reaction and opinions expressed through nonverbal cues of the song could not be observed directly. The qualitative surveys served as a means to gauge the students' attitudes towards the song, however the existence of response bias can't always be controlled for and may have confounded some student responses. There were caveats to some of the statistical analyses as two of the students that were included in the analysis for Test 1 and Test 2 were not included in the analysis for Test 3 as they had not taken the test. Though it may have made a small difference, there is a possibility that it altered the significance of the difference of average scores between Class A and B for Test 3. Additionally, there was a disparity in time frame between the administration of Survey 2 between Class A and B. The second survey was developed approximately two months after Test 2, therefore there was more time in between the experimental test and administration of Survey 2 for Class A than there was for Class B, which may have biased some of the responses.

#### *Future Research*

For future research, it would be relevant to study these two classrooms' long term recall of information from the songs relative to content from other units after a longer time frame. If students are more likely to recall content from the song than from other units that were not encoded using a song, it would further emphasize the notion that learning with music could be more effective in facilitating long term recall relative to other modalities of instruction. Additionally, this experiment could be held again at different grade levels to see if this type of instruction is more effective for students of a certain age or content at a particular level. By incorporating these other factors, it may demonstrate if music is more effective for helping to memorize terms or explaining concepts (or if it's helpful for both equally). Furthermore, future research could test the effectiveness of music as a teaching tool at different times in instruction; from this research, one could assess if music is more or equally effective when reviewing concepts versus introducing them.

#### *Recommendations for Teachers*

Due to the effectiveness of music as a teaching tool from the results of this study, it would be beneficial for teachers to incorporate educational music into their classroom as a standard practice. Although the procedure of this experiment only required students to listen to the songs, there are multiple ways to implement educational music. Students can be given activities in which they annotate lyrics after listening and highlight or define some of the terms that are incorporated into this song. This could facilitate better encoding and recall as students receive both auditory and written exposure to material. Additionally, a transcript of the lyrics with

missing vocabulary terms can serve as a “fill in the blank” activity that furthers engagement and can serve as a formative assessment that allows the student to see which content they know and which needs to be studied more. One activity that could be particularly effective is to have students write a content-rich song with a melody of their choice.

Previous research has reported the positive experience from this mode of instruction and has reported that it promoted social bonds, generated greater interest and engagement with content, and made students feel more confident in their knowledge and understanding of the material (Talens et al., 2015). Of course there are a multitude of other ways to incorporate educational music, these are just a few suggestions to implement differentiated instruction.

### *Conclusions*

Overall, this study sought to quantify the effectiveness of music as a learning tool in two 6th grade science classrooms. The results from this study support that music can be an effective educational tool that can improve academic performance. Beyond academic performance, qualitative surveys generated from this study demonstrate that students had an overall positive experience studying with the songs and felt that studying with it made the learning process “more fun,” made them feel “more confident,” and “helped [them] remember on a test.” Because student interest and self-efficacy are critical to student engagement and long-term retention of material, educational music should be seriously considered as a modality that’s implemented as a regular part of the curriculum; in doing so, future students can gain multiple academic and psychological benefits and future classrooms will be all the more enriched.

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## Appendix A

The following are the lyrics written for the study song given to Class A:

Circumsolar star, you know who you are  
When i'm standing here, you never leave the sky  
When the earth orbits the sun, and we're having so much fun  
So many things can happen, me oh my...

We spin around our axis, that imaginary line  
And orbit 'round the sun, once a year, right on time!  
The plane in which we spin in is our orbital plane  
Spinnin' round the fiery ball of flame

We take a trip to the tropics, the farthest north and south  
We can feel the sunshine on our face  
When you're standing at the tropics, there at the latitude  
You're at a perpendicular place

During the equinox, the sun is right above us  
The night and day precisely the same time  
The solstice is quite different, the sun is at the tropics  
With night and day so different, it's a crime

Let me give you a model of the phases of the moon  
There's four to learn, so let's start right away  
The new moon, you can't see it, it's all dark around the front  
The new moon, she's not comin' out to play

The third quarter moon, only half lit on the left  
First quarter moon's the same, just on the right  
And finally the full moon is high in the sky  
The whole surface is lit up, big and bright

The moon one day was wanderin' and covered up the sun  
Celestial bodies blocking one another  
This is called an eclipse, something's getting in the way  
Don't you think that's rude? Oh brother!

A penumbra's like a shadow, just not quite so dark  
It's different from the umbra, 'cause that's the darkest part!  
So if you're looking up at the sky one night or day  
Remember all these words so you can sayyyyyy...

Circumsolar star, you know who you are  
When I'm standing here, you never leave the sky  
When the earth orbits the sun, and we're having so much fun  
So many things can happen, me oh my...

### Appendix B

The following are the lyrics written for the study song given to Class B:

When the sun's behind the moon  
It's not something you wanna miss  
You cannot look right at it  
But it's called a solar eclipse

There's two types of shadows  
You may wonder where they come from  
The dark inners um-, The light outers pe-  
They're the umbra and penumbra

But if you see them switched around  
Don't think you need a tutor  
When the moons behind the earth shadow  
That eclipse is now a lunar

There's so much to learn about the sun  
Let's see if we can list them  
Well it's a star planets revolve around  
Known as the solar system

Moons comets and astroids  
Follow this elliptical course  
And they don't fall out of orbit  
Due to the sun's gravitational force

Particles of rock ice dust  
Are what comets are made of  
And an asteroids a rocky metallic substance  
That revolves around the sun

Here's some info on the planets  
I think could be of some use  
Like how Pluto is now a dwarf planet  
Cause the NASA gave'em the boot

Jupiter and Saturn's gravity  
Holds hydrogen and helium best  
While Venus and Uranus rotate  
From the east to west  
And Neptune has the smallest volume of the gas giants  
While earth's temperature allows for liquid water to exist

The possibilities of space are endless and the knowledge we hold dear  
So I hope you take away the few facts included here