MUSCIQ- A MUSICAL CURRICULUM FOR MATH

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DEDICATION

This dissertation is dedicated to my mom and dad, Alan and Kimley Tyson. Not for a second do I believe I'd be where I am without you.

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I first want to thank Jesus. My whole life has reminded me that in every moment, He is enough. This entire process has shown me even more that His strength is perfect in my weakest moments and what He started, He is faithful to complete.

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MUSCIQ- A MUSICAL CURRICULUM FOR MATH

Music and math are related in that 1) they both rely on the basic understanding of numbers, proportions, intervals, measurements, and operations and 2) both require levels of abstract thinking and symbolic notation. Studies link music and math by examining, for example, how music may play a role in math performance. There are, however, few studies that examine how a musical curriculum may impact not only math performance, but math related variables including math anxiety, math self-efficacy, and math motivation. This study sought to develop and assess the feasibility of MuSciQ, a music technology-based curriculum, and explore how it might impact math anxiety, math self-efficacy, math motivation, and math performance in twelve fourth-grade students. Additionally, acceptability of the MuSciQ curriculum was assessed by students, a teacher, and a school administrator by using the Technology Acceptance Model.

Participants experienced large, significant improvements in math anxiety scores and significant improvement in math motivation. Math performance and self-efficacy showed small, non-significant improvements. When split by gender, only math anxiety scores showed statistically significant improvement in males. As expected, there was a significant positive correlation between motivation and self-efficacy before and after the curriculum was introduced. There was also a significant positive correlation between technology acceptance and motivation. Surprisingly, although there were significant positive correlations between the pre- anxiety and motivation measures, there were no significant correlations after the curriculum was introduced. There were no significant correlations found between anxiety and technology acceptance. There was, however, a significant correlation between technology acceptance and self-efficacy. Technology acceptance and additional qualitative comments provided by students and administrators suggest MuSciQ is an easy and useful platform to promote music and math learning. These findings point to a need for further investigation into the influence of MuSciQ on math related variables.

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LIST OF ABBREVIATIONS

BEAMMS- Beliefs, Engagement, Attitudes and Motivation Math Scale
BPM- Beats Per Minute
CRE- Culturally Responsive Education
CRP- Culturally Responsive Pedagogy
CRT- Culturally Responsive Teaching
DAW- Digital Audio Workstation
MSEAQ- Math Self-Efficacy and Anxiety Questionnaire
STEM- Science Technology Engineering and Mathematics
STEAM- Science Technology Engineering Arts and Mathematics
TAM- Technology Acceptance Model

CHAPTER 1: INTRODUCTION

Music and math are closely related subjects as both rely on a basic understanding of numbers, proportions, intervals, measurements, and operations (Anderson, 1983). The similarities in abstract thinking and symbolic notation (Azaryahu et al., 2020) have prompted the introduction of music in educational curricula to support learning in Science, Technology, Engineering, and Mathematics (STEM) fields (Freeman et al., 2014; Heines et al., 2017; Johnson-Green et al., 2020; Maloney et al., 2010). Some studies of music and math have strategically incorporated math-related tasks within musical curricula (Azaryahu et al., 2020), while other studies have taken a more indirect approach by testing the implicit transfer of problem-solving skills across musical and mathematical domains (Bahr & Christensen, 2000). A third category of studies incorporates the use of song to promote learning (Lesser, 2021; *Muzology*, 2020).

Although educators have explored different curricula that link music and math achievement, there are few studies assessing how a music curriculum that teaches math may directly impact math self-efficacy, math motivation, math performance, and math anxiety. Additionally, the relationships between these variables within a music curriculum are unclear. Thus, the purpose of this study was to determine if a technology-oriented music curriculum for math might impact math self-efficacy, motivation, performance, and anxiety. Additionally, technology acceptance was assessed to gain insight into the curriculum's usefulness and ease of use.

Music Technology involves the use of electronics, computers, networks, and related accessories with the purpose of expressing new ideas, solving problems, and making life easier for those who use them (Manzo, 2016). Music Technology has been used in areas such as performance, research, composition, and learning. Despite its widespread presence, the field is thought to suffer from a lack of clarity and inclusivity (Walzer, 2017). However, there are opportunities to broaden the scope of the field, resulting in a more inclusive perspective of what music technology is and how it serves individuals and groups who are often underrepresented. The same is true for the field of mathematics (Berry et al., 2013).

Mathematics educational reform in the United States has focused on content - what should be taught; pedagogy - how it should be taught; and quality- who should teach it (Berry et al., 2013). Despite ongoing discussions, minority students are still usually given the least access to advanced mathematics content, fewer opportunities to learn outside of basic memorization and mimicking teacher behavior, and the least prepared teachers (Berry et al., 2013). Thus, this study incorporated elements of Culturally Responsive Education (CRE) to address approaches that may limit learning for some students (Allsup & Shieh, 2012; Benedict, 2012; DeLorenzo, 2012; Johnson Jr, 2004; Williams, 2011).

CRE uses the cultural characteristics, experiences, and perspectives of ethnically diverse students to teach them in the most effective ways (Gay, 2018). Western European approaches to learning are often linear, focusing on individual disciplines (Claypool & Preston, 2011). As a result, these practices sometimes exclude individuals from non-mainstream cultural backgrounds, resulting in cultural discontinuity between learners and their learning environment (Ogbu, 1982). CRE recognizes students' differences, validates their cultures, acknowledging that culture and classroom practices should coincide to increase student success in schools (Ragoonaden & Mueller, 2017). Axiological assumptions surrounding CRE are centered around the idea that learning is more meaningful when it is presented in a way that reflects students' lived experiences and frames of reference (Gay, 2002).

Math anxiety is defined as a negative reaction to math situations (Ashcraft & Ridley, 2005). Math self-efficacy is one's own beliefs about his or her ability to do math related tasks (Usher & Pajares, 2009). Math motivation is described by the extent to which individuals embrace math challenges, value the importance of math, and are willing to perform well in math (Gottfried et al., 2007). Lastly, math performance is the ability of an individual to formulate, employ, and interpret math in a variety of contexts (Ashcraft & Ridley, 2005; Stacey, 2015). Math self-efficacy, motivation, performance, and anxiety interact with one another during the learning process (Luttenberger et al., 2018). In a study conducted by Akin and Kurbanoglu (2011), math anxiety was negatively related to positive attitudes and self-efficacy and positively related to negative attitudes. Research in math education has also pointed to math anxiety negatively impacting math performance (Ashcraft, 2002; Higbee & Thomas, 1999).

The interventional component in this study was adapted from a math anxiety framework (Luttenberger et al., 2018) that highlights how each variable interacts with the other. Because math anxiety varies from person to person (May, 2009), the pathway that leads to potential low performance is also unique. In one scenario, math anxiety can lead to math avoidance, which can lead to low competency and ultimately low performance (Ashcraft, 2002; Ramirez, Shaw, et al., 2018). In another scenario, math anxiety can disrupt cognitive resources and can directly lead to low performance (Ashcraft & Faust, 1994; Ramirez, Shaw, et al., 2018). In both examples, math anxiety is thought to have a negative impact on math performance. Decreased performance due to anxiety, however, is not unique to math. Anxiety surrounding music performance can also negatively impact music performance (Kenny, 2004). More recently since the pandemic, attention has been placed on acknowledging the anxiety some students face when they are asked to turn on their cameras in learning environments (Castelli & Sarvary, 2021). In these examples, these forms of anxiety are thought to contribute to a decrease in performance, further demonstrating the connection between anxiety and performance, not only in math, but also music and virtual learning.

To provide a rationale for music as means to reduce anxiety, it is important to note that music has also been utilized in other fields such as foreign language arts and healthcare to help reduce anxiety in students and patients (Bennett et al., 2020; Fortin, 2020). The implications for this study can lead researchers to further understand how music can be used as a tool to reduce anxiety while increasing self-efficacy, motivation, and performance in math-based learning environments.

CHAPTER 2: REVIEW OF LITERATURE

This literature review highlights key components of music technology, education, math constructs and measures, and technology acceptance in a way that complements the core of the study. There are platforms such as *Chrome Music Lab*, *Groove Pizza,* and *The Mathematical Foundations of Indian Rhythm* that connect music technology and STEM in creative ways (*Chrome Music Lab*, n.d.; Hein & Srinivasan, 2019; Hirsch, 2016); however, few studies empirically explore the effectiveness of these platforms. This review of literature will describe available programs, applications, and explain how they work; as well as discuss available empirically based studies.

Music Technology

As an academic discipline, music technology is considered a relatively young field (Rees, 2012). Consequently, providing a uniform definition for the field is difficult (Manzo, 2016; Rees, 2012; Walzer, 2017). Rees (2012) defines music technology as a systematic study of tools and techniques used for music production, performance, education, and research. Manzo (2016) describes music technology as including electronic, networked, and auxiliary equipment that allows performers, composers, artists, designers, and musicians to create and express new ideas. While the field lacks a clear definition, the integration of music technology within STEM education provides innovative opportunities to support student success.

In 2016, the Herbie Hancock Institute of Jazz partnered with the U.S. Department of Education to create *Math, Science, and Music,* an initiative to elevate the use of music in STEM learning (Hirsch, 2016). Developed by experts in music, STEM, and grade-level education, the initiative resulted in a free toolkit of resources using music to support

STEM learning. Some of the programs described below are directly connected to the initiative, while some are independent efforts.

Music Technology and STEM

EarSketch, developed by researchers at the Georgia Institute of Technology, supports students in acquiring a strong foundation in electroacoustic composition, computer music research, and computer science (McCoid et al., 2013). It combines Python and JavaScript programming languages within a web-based digital audio workstation (DAW). Students can incorporate traditional music production methods with programming techniques to compose music. In a pilot study, Freeman et al. (2014) found significant gains in positive computing attitudes for female and minority students after 10 weeks of a computer science curriculum with *EarSketch*. A follow-up study resulted in greater intention to persist in computing when students used the *EarSketch* platform (Wanzer et al., 2020). Attitudes towards computing and the perceived authenticity of *EarSketch* were significant predictors of one's intent to persist.

Johnson-Green, Lee, & Flannery's (2020) Ecosonic Playground Project, developed at the University of Massachusetts Lowell in 2016, acknowledged that STEM educators sometimes like to include arts and vice versa; however, the attempts made are often not fully integrated, leaving one discipline diluted in comparison to the other. To counteract this practice, project developers aimed to advance the connections between the arts and STEM subjects by allowing students to build PVC structures with student-designed instruments attached to them. The project was designed so that students utilized skills equally across STEM and the arts to accomplish the common goal of experimenting, designing, building, and playing a musical instrument. The results of the study found that the project supported applications of cognitive, social-emotional, and STEM practices within an arts framework while promoting connections among skill areas.

Interactive coding programs such as *Scratch* (Maloney et al., 2010), a coding program developed by the Massachusetts Institute of Technology (MIT) Media Lab, are used to promote music technology and STEM education. The program allows students to create their own interactive stories, games, and animations by snapping coding blocks together to control pictures, sounds, and other elements (Lamb & Johnson, 2011). Programs like *Scratch* are thought to be useful because as block-based languages, they are powerful tools for teaching programming (Aivaloglou & Hermans, 2016). Although *Scratch* is not exclusively a music application, there are musical components to the platform that have been explored with the purpose of integrating music and computing (Heines et al., 2017).

"Teaching a Computer to Sing" (Heines et al., 2017) was an after-school program that utilized *Scratch.* It was developed for middle schoolers to learn coding fundamentals by incorporating popular songs. The findings in this study demonstrated that students were able to follow the pathway from singing to digitized sound to computer notation, helping students learn to code using songs they like. Additionally, the program contributed to the gains in student's ability to sing in three-part harmony.

In 2015, cognitive psychologist Lana Israel and music industry veteran Bob Doyle founded *Muzology*, a program that uses high quality music video and music production to make learning fun (*Muzology*, 2020). The three steps of the program include *warmup*, *videos*, and *post challenges*. In the *warmup*, students answer questions to activate learning. In step two, students watch multisensory music videos to learn and retain math content. Lastly, in step three, students apply what they have learned by playing gamified quizzes. Results from a 2019 Arkansas statewide pilot show that pre-/post-test scores improved from an average of 50 percent before watching math-music videos to 80 percent after the videos were watched (*Muzology*, 2020). A smaller pilot study at a low performing school showed eight percent of students scored a perfect score on the Proficient Level Pre-Test before utilizing the *Muzology* music videos, and 94 percent earned a perfect score on the Proficient Level Post-Test (*Muzology*, 2020). Similar trends were observed in Florida and Tennessee statewide pilots (*Muzology*, 2020).

Perhaps the most popular and accessible platform for learning music and STEM principles is *Chrome Music Lab*, an interactive website built with various web technology including Audio API, WebMIDI, and Tone.js (*Chrome Music Lab*, n.d.). Teachers use *Chrome Music Lab* as a tool to explore music and its connections to science, math, art, dance, and live instruments (*Chrome Music Lab*, n.d.). There are multiple interactive functions within *Chrome Music Lab* connected to STEM education including *Rhythm, Spectrogram, Soundwaves, Harmonics, Strings,* and *Oscillators* (*Chrome Music Lab*, n.d.). *Spectrogram* is an application that shows a picture of the frequencies that make up a sound over time. *Soundwaves* shows how sound moves different particles. *Harmonics* is a visual representation of how musical intervals emerge from the harmonic series. Similar to *Harmonics* is *Strings*, which shows the mathematical relationships between a string's length and its pitch. Lastly, *Oscillators* provides an audio-visual example of different types of oscillators and frequencies.

Making Music Count is a curriculum designed for grades 4-6, to help students explore the inherent connection between music and mathematics (Bamberger, 2000). The curriculum utilizes *Impromptu*-a DAW-like teaching tool that encourages students to use proportions, ratios, fractions, and common multiples to engage in musical concepts. Students listen to music from various cultures and use a feature in the software called *Drumblock* to create their own groups, beats and subdivisions.

Groove Pizza and *aQWERTYon* are both programs developed by New York University professor Alex Ruthmann and his colleagues (Hein & Srinivasan, 2019; "Math Science Music," n.d.). *Groove Pizza* is an app that helps individuals understand rhythm by adding or removing "toppings" to change the groove. It helps students understand mathematical concepts such as shapes, angles, and patterns by relating the shapes and angles to drumbeats. According to Hein and Srinivasan (2019), this app may illuminate the structure and functioning of real-world drum patterns because it visually presents rhythms in a circular fashion. *aQWERTYon* is an improvisational app that utilizes letters on a typing keyboard to generate notes for improvisation and music making ("Math Science Music," n.d.). There is also a pitch wheel visualization design that allows learners to associate geometric shapes with chord patterns.

Lim et al. (2018) created a virtual reality math and music game. Researchers recruited 5 math educators to use the game and comment on their experiences. The game utilized a system of beat making to teach fractions. The initial components of the game were kick, hi-hat, and snare. Participants were asked to make phrases of varying lengths. After creating the beat, they were asked to explain the difference between the different phrases. If the answer was correct, a virtual drum object was added to the participant's inventory. Each subject also completed a survey and semi-structured interview to record their experiences and perceptions of the game. Three themes were identified from the detailed thematic analysis of the data—transformative presentations of fractions via musical concepts, integration of music into math to enhance learner motivation, and learning-constructive game design features (Lim et al., 2018). The study showed that fractions can be accurately represented in the beat making process.

Music and Math

Understanding rhythmic hierarchies requires an understanding of subdivision and fractional concepts (Azaryahu et al., 2020). Fractions are one of the most difficult mathematical concepts for elementary school students to master (Behr et al., 1984; Cramer et al., 2002; Moss & Case, 1999). Consequently, because math is cumulative, when students do not master fractions there is a risk of lower competency, which can lead to low math performance (Ramirez, Shaw, et al., 2018).

A study conducted by Courey et al. (2012) examined the effects of a musical curriculum on understanding of music notation, fraction symbols, fraction size, and equivalency. Academic music instruction included twelve 40-minute sessions that were delivered two times per week. Music notation and temporal value were the focus of the first six lessons. The last six lessons focused on understanding proportional values of music notes to other musical signs or fraction representations, and then to formal math fraction symbols. There were two third grade groups, an experimental group who received the musical curriculum and the control group who received fraction instruction. In the post assessment, students in the experimental group outperformed students in the control group. Additionally, students in the experimental group were less likely to make mistakes in the numerator and denominator when adding and subtracting fractions.

Azaryahu et al. (2020) examined the impact of two different curriculum programs, *MusiMath* and *Academic Music*. Three fourth-grade classes attended twelve lessons on fractions. One class attended the *Academic Music* acoustic program (Courey et al., 2012), which used rhythm only to teach fractions. Another class, a control group, received traditional fraction instruction only. The third group received the *MusiMath* holistic program, which incorporated both rhythm and melody to teach fractions. Measures for music and math were assessed before, after, and three- and six-months post curriculum. Although both music groups outperformed the control groups in the three- and six-month post curriculum, only the *MusiMath* group showed increased performance with unpracticed fractions. This research highlights the effectiveness of music-based curricula for fraction learning. Additionally, it points to rhythm and melody curricula being more effective than rhythm only curricula.

There are also lesser-known platforms that creatively explore relationships between music and math. *The Mathematics of Music* is a college course developed by Johns Hopkins University Mathematics professor Daniel Naiman (Hirsch, 2016; Naiman, n.d.). The course is designed on the notion that all who appreciate music must, at some level, appreciate its mathematical structure. Naiman states:

> In order to share the richness and beauty of mathematics with as many people as possible, we try to point out the significance of mathematical thinking by pointing out mathematical links to things that excite people. This is where music can play a crucial role (Naiamn, n.d., para. 2)

The purpose of the course is to introduce and expose students to the mathematical ideas surrounding music.

Harvard pianist, scholar, and composer Vijay Iyer developed an elementary school program that uses mathematical proportions, symmetric musical shapes, and combinations to demonstrate ways of visualizing and counting rhythm. *("The Mathematical Foundations of Indian Rhythm," n.d.)* The program exposes students to the creative methods and aesthetics of South Indian rhythms. Additionally, the program incorporates cultural immersion to help students identify how math and music are connected around the world.

While the programs mentioned may be innovative, many of them fall short of determining improvements in math performance, motivation, self-efficacy, anxiety. The experiments in this dissertation underscore how a musical curriculum may impact overall math performance and other variables such as math anxiety, math self-efficacy, and math motivation.

Math Anxiety

The fear of math-related tasks can compromise math performance, eventually limiting an individual's choice of career paths (Ashcraft, 2002). Approximately ninety-three percent of US adults reported experiencing some level of math anxiety with seventeen percent indicating high levels of math anxiety (Ashcraft & Moore, 2009). Math anxiety includes feelings of fear, tension, and apprehension when individuals engage in math-related tasks (Ashcraft, 2002). Tobias (1993) describes it as helplessness, panic, paralysis, and mental disorganization occurring when individuals are required to engage in math-related concepts. In fact, most adolescents worry that math classes will be difficult (Luttenberger et al., 2018). Approximately thirty-three percent of 15-16-year old’s reported tensing up when they were asked to complete math homework and get nervous when asked to perform math problems (Co-operation & Development, 2013).

Researchers have developed conceptual frameworks to explain factors that contribute to math anxiety. Luttenberger et al. (2018) point to environmental and personal antecedents such as culture, family, gender, genetic disposition, and general anxiety proneness as having an impact on self-efficacy, motivation, and anxiety. Ultimately, these interacting variables have an impact on performance, learning behavior, and choices (Luttenberger et al., 2018). A study found that parental expectations and home support reduces children’s math anxiety in word problems and algebraic reasoning (Vukovic et al., 2013). Another supporting study found that parents with high math anxiety who attempted to help their children played a role in their child’s increased math anxiety (Maloney, 2016). A possible explanation for this is parents may have poor math helping skills that conflict with teachers’ strategies, creating confusion and ultimately anxiety for children (Ferguson et al., 2015).

According to Ramirez, Shaw, et al. (2018), there are two primary accounts of math anxiety. The first and most widely accepted cognitive theory is the disruption account. The disruption account suggests that math anxiety leads to poor performance through transient reduction in cognitive resources that are needed for success in math (Ramirez, Shaw, et al., 2018). One of these resources is working memory.

The correlation between math anxiety and math performance can be attributed to the disruptions of working memory resources (Ashcraft et al., 1992). Working memory is a short-term memory system responsible for controlling, regulating, and maintaining a discrete amount of information relevant to a specific task (Baddeley, 1992). It is used to manipulate information, keep necessary information, and disregard unnecessary information. Intrusive thoughts can disrupt working memory leading to a negative impact on performance (Eysenck & Calvo, 1992). When required to do math problems, math anxious individuals are thought to be performing two primary tasks. First, they are attempting to manage thoughts/feelings about math and secondly, they are attempting to solve math problems despite negative thoughts and/or emotions (Ramirez, Shaw, et al., 2018).

The disruption account is supported by studies focused on basic arithmetic performances between individuals who had math anxiety and those who did not. Individuals with high math anxiety take more time and make more errors when performing operation-based arithmetic tasks (Ashcraft & Faust, 1994). In their study, Ramirez et al. (2016) also found that the relationship between math anxiety and math problem solving strategies is strongest in children with higher working memory capacity.

The second framework for math anxiety is the reduced competency account which suggests that math anxiety is simply a result of poor math ability (Ramirez, Shaw, et al., 2018). In this account, an individual experiences low math performance which then triggers an anxiety response. Unlike the disruption account which focuses on working memory problem solving strategies to increase math performance and reduce math anxiety, the reduced competency account highlights other theories such as the theory of numerical and spatial alignment. This theory states that individuals who struggle with numerical and spatial skills tend to have issues with math performance (Maloney, 2016).

A six-year longitudinal study by Ma and Xu (2004) provided evidence for the reduced competency account. Ordering between math anxiety and math performance demonstrated that higher math anxiety predicted lower math performance in following years and lower math performance in previous years predicted higher math anxiety in the following years (Ma & Xu, 2004).

Another study, Maloney et al. (2010), asked undergraduate students to count the number of squares on a computer screen. When five or more squares were present, high math anxious individuals made more errors and were slower at counting in comparison to their low anxious peers. Other spatial alignment studies had similar findings (Ferguson et al., 2015; Maloney et al., 2011; Maloney et al., 2012).

Another framework within reduced competency suggests that low math performance and high math anxiety lead to math avoidance (Ramirez, Shaw, et al., 2018). This is supported by studies that positively link the two (Ashcraft & Kirk, 2001; Eccles, 1984; Hembree, 2016; LeFevre et al., 1992; Meece et al., 1990; Parsons et al., 1984).

Although the disruption and reduced competency account are mentioned exclusively from one another, the two accounts are not completely in conflict. Math anxiety and performance are thought to be bidirectional, meaning math anxiety and math performance can influence one another (Carey et al., 2015). In another study, Jansen et al. (2013) found that the same appeared to be true about high math performance performance—success in math leads to more practice and higher math performance. Poor instruction and curriculum can lead to poor performance and understanding which can lead to math anxiety. Studies like these indicate the need for competency-based interventions.

Wang et al. (2018) showed the multi-faceted nature of math anxiety. In a study that sought to understand interactions between math anxiety, math motivation, and math achievement in 927 high school students, they found that students who achieved high math performance scores also had modest math anxiety coupled with high math motivation; students who were most engaged had a combination of high math anxiety and high math motivation. Additionally, high exam math anxiety was negatively associated with math performance in individuals with higher math motivation. This research highlights the complexity of the connections between math performance, math anxiety, suggesting a need to go beyond linear relationships.

There are also studies that investigate the differences between math anxiety in men and women. Although women sometimes report being more anxious about math related tasks, some studies show that they do not differ in number skills performance tasks (Devine et al., 2012; Dowker et al., 2016; Goetz et al., 2013; Hembree, 1990; LeFevre et al., 1992). Women do, however, typically perform worse than men on standardized measures of spatial skills performance tasks (Maeda & Yoon, 2012; Reilly & Neumann, 2013; Uttal et al., 2013; Voyer et al., 1995). This observation may indicate a relationship between gender and anxiety to spatial skills and not number skills (Douglas & LeFevre, 2018).

Students spend most of their academic life in the classroom, so naturally much of their formal educational experiences involves their teachers. Literature suggests that teachers, especially elementary school teachers, also suffer from math anxiety (Battista, 1986; Beilock et al., 2010; Guillory Bryant, 2009; Hembree, 1990). These findings are connected to studies that link math anxiety to negative experiences with elementary school teachers (Chapline, 1980; Chavez & Widmer, 1982; Markovits, 2011). Beilock et al. (2010) found that female teachers' math anxiety has a negative impact on girls' math achievement and beliefs about math. Ramirez, Hooper, et al. (2018) also found a correlation between teachers' math anxiety and 9th grade math achievement. These correlations were mediated by process-oriented teaching practice and student perception of teacher fixed mindset endorsement. Because teachers play an influential role in predicting behavioral, emotional, and cognitive indicators, this article indicates a potential need for teacher as well as student intervention.

Math anxiety also has an impact on physiological outcomes such as heart rate, neural activation, and cortisol (Ramirez, Shaw, et al., 2018). Specifically, individuals who experience more anxiety experience higher heart rates. Moreover, when asked to perform math related tasks, these individuals show neural activations that are consistent with that of pain (Lyons & Beilock, 2012).

Pletzer et al. (2015) discovered that individuals with low math anxiety showed neural efficiency represented by increased activation in the dorsolateral prefrontal cortex, which is a sign of engagement in cognitive and attentional control. They also experienced decreased activation in the default mode network which represents a sign of decreased self-reflection and emotional processing. High math anxious individuals, however, showed increased activation in the dorsolateral prefrontal cortex but also less deactivation of the default mode network. This research was important because it showed that low math anxious individuals showed task relevant neural activation, whereas high math anxious individuals showed both task relevant and task irrelevant activation. These findings support the disruption account.

Because math anxiety is multi-faceted (Wang et al., 2018), curricula for math anxiety can be approached in a variety of ways. For example, a curriculum that targets the disruption account would need to focus on mitigating worry as a factor (Ramirez, Shaw, et al., 2018). A reduced competency approach would assume that the removal of worry would not necessarily guarantee increased math performance, because math anxiety individuals may lack the math skills to perform well. Interventions that focus on competency through exposure help address issues surrounding reduced competency (Ramirez, Shaw, et al., 2018).

Interventions for Math-Anxiety

Frameworks for math anxiety inform what types of approaches should be taken to help reduce it. For example, according to the reduced competency account, interventions that improve math skills may help reduce math anxiety. In an intensive eight-week, one-on-one cognitive tutoring program, Supekar et al. (2015) observed a decrease in children's math anxiety. Forty-six third graders participated in a tutoring program. The eight-week program consisted of four lessons on basic number properties, two counting lessons, and sixteen lessons on number families. After tutoring, the result was high math anxious children showed a significant reduction in math anxiety. Additionally, fMRIs showed that tutoring decreased basolateral amygdala activity, suggesting a decrease in anxiety response. The study suggests that continuous exposure to math stimuli can reduce math anxiety and help researchers further understand the role of the amygdala in the process.

As mentioned previously, avoidance tendencies may be partly responsible for the lack of development in students (Ashcraft, 2002; Ramirez, Shaw, et al., 2018). Fitting within the reduced competency framework, if avoidance is the issue, focus should be placed on increased engagement (Attard, 2012; Bodovski & Farkas, 2007; Ramirez, Shaw, et al., 2018). Laski and Siegler (2014) tested the hypothesis that encoding the numerical-spatial relations in a number board game is a contributing process in promoting learning. The study was broken into two experiments. In the first experiment, children utilized a board game to count-on from their current number. The result was the board game improved their number line estimates, numeral identification, and count-on skills. In the second experiment, children played the same game using the "count from one procedure". In this experiment, improvement in number line estimation did not occur. This study highlights the potential efficacy of interactive and engaging interventions. Additionally, it points to a need for strategy-based interventions that have targeted approaches. In this case, whether children counted from one or counted-on from another number had an impact on overall learning. The results of this study were consistent with previous studies involving board games (Ramani & Siegler, 2008; Whyte & Bull, 2008).

Although games and interactive platforms may encourage students to be more engaged and appraise math as enjoyable, not all math related tasks are games. Math is not always fun and there is much that can be learned in productively struggling and engaging in sense making processes around math (Hiebert & Grouws, 2007). According to Ramirez, Shaw, et al. (2018), the way an individual interprets anxiety can impact outcomes. An example of this was shown by Jamieson et al. (2016), who examined the benefits of appraisal among college students who were enrolled in a remedial math course. In the study, one group was given information about how physiological arousal was optimal for performance (appraisal condition), while another group was given information about the importance of ignoring stress (control condition). The appraisal group showed greater improvement and reported less math anxiety in comparison to the control participants. Findings in this study point to the potential benefits of individuals processing their feelings about math in positive ways instead of avoiding them.

Interventions can also help individuals reduce or regulate anxiety surrounding their negative appraisals of math. Park et al. (2014) conducted a study that involved an expressive writing technique. The goal was to reduce the number of intrusive thoughts of math anxious individuals. In the study, Park and colleagues asked both high and low math-anxious adults to write openly about their feelings concerning an upcoming math test. After only one session, higher math individuals experienced a boost in math performance, narrowing the gap between the high and low math-anxious groups. Park et al. (2014) indicates improvement may have occurred because high math anxious individuals may have gained some beneficial insights that are not expressed by individuals who suppress or avoid concerns, giving them the opportunity to make sense of their ongoing experiences.

Math Self-Efficacy

Math self-efficacy is defined as an individual's beliefs or perception about his or her abilities in mathematics (Bandura, 1997). It is thought to have a positive relationship with learning motivation, making it more likely that students will persevere when given challenging tasks (Pajares & Graham, 1999; Pajares & Kranzler, 1995; Zeldin et al., 2008). Like math anxiety, there are four contributing factors that impact math self-efficacy. They are mastery experience, vicarious experiences, social persuasion, and physiological state (Hampton & Mason, 2003; Lopez & Lent, 1992; Usher & Pajares, 2009). Of the four sources, mastery experience-ones interpreted result of his or her own previous attainments, is thought to be the strongest predictor (Bandura, 1997) of math self-efficacy. This is because mastery experiences are influential when students overcome challenges. Additionally, most students are not quick to dismiss feelings of mastery (Usher & Pajares, 2009). Several studies link a positive relationship between math self-efficacy to math performance (Aksu & Güzeller, 2016; Cagirgan Gulten & Soyturk, 2014; Erkek & Isiksal-Bostan, 2015; Tasdemir, 2016; Zimmerman, 2000). For example, Hall and Ponton (2002) found that developmental mathematics students had lower math self-efficacy than calculus students. There are several studies that highlight relationships between math anxiety and music, especially when it is used for relaxation or reliving purposes (Bryce, 2016; Feng et al., 2014; Gan et al., 2016). However, there are no studies to date that examine how a music curriculum for math might impact math self-efficacy.

The most common scale used for student math self-efficacy is the Mathematics Self Efficacy-Scale (MSES) (Betz & Hackett, 1983). The scale highlights three domains of math self-efficacy: solving math problems, using math in everyday tasks, and obtaining good grades. It is a Likert confidence scale ranging from 0 to 9 in their ability to perform a total of 18 math related tasks, correctly solve 18 math problems, and get a B or better in 16 related math courses.

To further explore the relationship between math anxiety and math self-efficacy, May (2009) created the Mathematics Self-Questionnaire (MSEAQ). The questionnaire is based on a general expectancy -value model, and the questions were adapted from previous self-efficacy and math anxiety scales (Betz & Hackett, 1983). It is a 29-item five-point Likert scale, broken up into five factors; general math self-efficacy, grade anxiety, math self-efficacy on assignments, math self-efficacy for students' futures; and self-efficacy and anxiety in class assignments. Although the scale was designed for college students, the language of the scale, with the permission of the researcher, was adapted for the current study to exemplify language that is fitting for fourth graders.

Math Motivation

According to Wang et al. (2018), math motivation is described by its ability to capture the degree to which an individual values the importance of math abilities, are interested in math related activities, and are inclined to perform well in math. Although some studies point to negative correlations between math anxiety and math motivation (Ashcraft & Krause, 2007; Luo et al., 2011; Meece et al., 1990) their relationships are thought to be more complex than linear associations (Wang et al., 2018). For example, Wang et al. (2018) gives an example of a student who may feel competent in his or her math ability but may still worry about making a mistake. This example conceptualizes the multi-faceted nature of not only math motivation, but its relation to math anxiety.

Brophy (2010) shows that the field of math motivation encompasses several teaching and learning definitions due to its many theoretical perspectives. For example, researchers have examined cognitive, affective, and behavioral definitions through distinct literatures of math education, math classrooms, and educational psychology (Orosco, 2016). Orosco (2016) acknowledges that each focus is slightly different. In educational psychology literature, motivation research focuses on students and individual differences in terms of their achievement goals, values and efficacy for mathematics (Turner & Meyer, 2009). Math education literature focuses on the process students take to gain math understanding and problem-solving skills (Turner & Meyer, 2009). Lastly, classroom literature focuses on defining motivation through socially driven behaviors such as teacher-student interaction (Turner & Meyer, 2009). According to Orosco (2016) each field has yielded deep, reliable, motivational knowledge. However very little of it is applicable to teachers because of its complex nature, implying a need for instruments that can be used efficiently and practically by classroom practitioners. For this reason, Orosco (2016) developed the Beliefs, Engagement, and Attitude Math Motivation scale (BEAMMS).

The BEAAMS is a math motivation survey created specifically for elementary school students (Orosco, 2016). The survey consists of a 10-item, dichotomous scale. Math motivation in this measure is defined in terms of a student's beliefs toward math., attitudes toward math, and engagement towards math. Each one of these sub-constructs are combined as a measure of overall math motivation. With the permission of the researcher, the BEAMMS was used in the current study to measure math motivation.

Problem Solving and Performance

Performance can be assessed in several ways, including problem solving strategy analysis. Problem solving strategies are a crucial part of math understanding and the foundation of the math discipline because they serve as a guide in the problem-solving process (Morton, 2014; Polya, 1981). Assessing students' problem-solving strategies can be beneficial because they provide insight into students' mathematical thinking and level of understanding. Written responses from open-ended tasks are traditionally valid and feasible methods for assessing problem solving approaches because they provide accounts, and therefore understandings and misconceptions, to students' math reasoning (Cai, 1997; Morton, 2014).

Technology Acceptance

Technology Acceptance has been an important field of study for over three decades (Chuttur, 2009). The Technology Acceptance Model (TAM) was first introduced by Davis (1985). After several iterations of the model, the final version created by Venkatesh and Davis (1996) included perceived usefulness and perceived ease of use as the foundation for technology acceptance. Perceived usefulness is defined as the degree to which an individual believes that using the technology system enhances his or her job performance (Davis, 1985). Perceived ease of use is defined as the degree to which an individual believes that using a technology system would be free of physical and mental effort (Davis, 1985).

TAM was a model used almost exclusively within the workplace. Over time, it has become an attractive trend in the teaching and learning context (Granić & Marangunić, 2019). In a review of literature focused on the TAM in an educational context, Granić and Marangunić (2019) found that the TAM represents a credible model for facilitating assessments of diverse learning technologies. The current study utilized the Technology Acceptance Model to assess the perceived usefulness and perceived ease of use of the music technology-based curriculum.

Culturally Responsive Approaches to Teaching

Culturally responsive education (CRE), sometimes referred to as culturally responsive pedagogy (CRP) or culturally responsive teaching (CRT) emphasizes cultural, knowledge, prior experience, frames of reference, and performance styles of ethnically diverse students to make learning encounters more effective (Gay, 2013). CRP argues that understanding about cultural diversity is an important component of meeting the educational needs of students because culture provides a reference for students to access a framework for learning. (Gay, 2002; Harding-DeKam, 2014).

Demographic shifts in the United States have created a need for teachers to teach students with unique backgrounds linguistically, racially, ethnically, and economically (Bond, 2017; Brown-Jeffy & Cooper, 2011). Culturally responsive approaches are thought to be effective because they validate students' experiences in and out of the classroom setting (Bond, 2017). The demand for CRE has extended to all subject areas, including music and math (Aguirre & del Rosario Zavala, 2013; Barton & Riddle, 2022; Bond, 2017; Gay, 2002, 2018; Harding-DeKam, 2014; Ladson-Billings, 1995). Culturally responsive mathematical teaching (CRMT), for example, is pedagogical knowledge that has become a more popular approach to teaching (Abdulrahim & Orosco, 2020; Bonner, 2014). CRMT focuses on incorporating culture, language, heritage, and community experiences into mathematical instruction to improve mathematics achievement

(Abdulrahim & Orosco, 2020; Mukhopadhyay et al., 2009). An example of CRMT was demonstrated by Quintos and Civil (2008) when family members were invited to the classroom to observe mathematics lessons to bring their "out of school" life, into school, ultimately bridging the gap between the two. Also in the music community, there has been pressure placed on educators to extend the principles of CRE to music by reevaluating traditional teaching approaches that rely exclusive on Eurocentric, Western Art music structures and ignore the rich heritage of minoritized musicians/composers. (Allsup & Shieh, 2012; Benedict, 2012; DeLorenzo, 2012; Johnson Jr, 2004; Williams, 2011).

Although this study did not include measures for CRP, it was a tangential goal of the researcher to include components of CRP to create a meaningful experience for students.

CHAPTER 3: METHODOLOGY

There are known connections between math-related variables (Luttenberger et al., 2018). For example, Akin and Kurbanoglu (2011) found math anxiety to be negatively related to self- efficacy and positive attitudes. Likewise, existing literature highlights the connections between music and math (Azaryahu et al., 2020; Jones & Pearson Jr, 2013); however, the relationship of some math variables is unclear when a music-based math curriculum is introduced. Thus, this project utilized standardized procedures and measures to explore the connections between music and math variables to determine the extent to which a music curriculum can impact each variable.

This research was guided by three primary research questions.

1. To what extent does a music curriculum for math impact math motivation, math self-efficacy, math anxiety, and math performance in a fourth grade, underrepresented elementary school class?
2. What correlational relationships exist between math anxiety, math self-efficacy, math motivation, math performance and technology acceptance when a music curriculum for math is introduced?
3. Do teachers and students accept MuSciQ as useful and easy to use?

   Hypothesis 1: After the curriculum is completed, an increase in math self-efficacy, math motivation, and math performance would be observed, along with a decrease in math anxiety.

   Hypothesis 2: There would be positive inter-correlations between math self-efficacy, math motivation, and math performance; there would be negative correlations between math anxiety and math performance; math anxiety and math self-efficacy; and math anxiety and math motivation.

Hypothesis 3: The Technology Acceptance Model (TAM) would reveal the music-based curriculum as generally useful and easy to use among teachers, students, and administrators.

Theoretical Framework for Math Anxiety and Related Variables

The framework for this study was developed by applying existing frameworks for math anxiety and math/music instruction. Illustrated in Figure 1, students' previous experiences, culture, relationships, and personal variables influence interacting variables that influence important academic outcomes including learning behavior. Interacting variables, such as math anxiety, math self-efficacy, math motivation impact each other and in combination influence targeted outcomes (Luttenberger et al., 2018). The relationship between interacting variables and outcomes is bi-directional, demonstrating that interacting variables have an impact on outcomes and vice versa. The illustration is unique because it clarifies that the outcomes and interacting variables are continually impacting the other.

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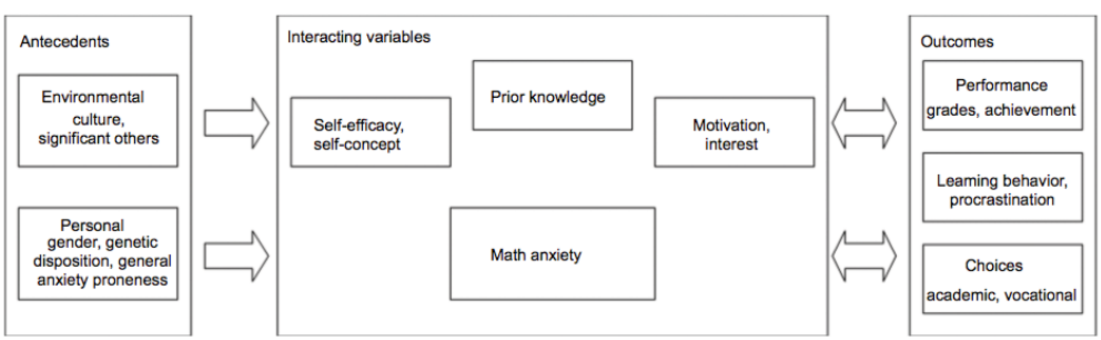


Figure 1. A framework for understanding math anxiety (Luttenberger et al., 2018)

Adaptation of Math Anxiety Framework

As previously noted, there are several studies that highlight math anxiety or the math-music relationship separately; however, there are fewer that examine the influence of music on math anxiety within one conceptual framework. For this study, the math anxiety framework was expanded to include a music curriculum for math. The approach for the curriculum, represented in Figure 2, was centered around exposure to math through technology-oriented, music-based math curriculum. It was expected that exposure would impact one or more math-related interacting variables, which in return would have an impact on math-related outcomes. The outcomes box was also modified to identify the targeted math outcomes. To make the curriculum culturally responsive, the curriculum was developed with the antecedents, specifically family and culture at the forefront. For example, culture played a significant role in the music choice of the study, as the songs reflected the stylistic choices of the students. Also, along with teachers and administrators, families were involved in the process. They were made aware of the the study and encouraged to practice workbook activities with their children outside of the designated meeting times.

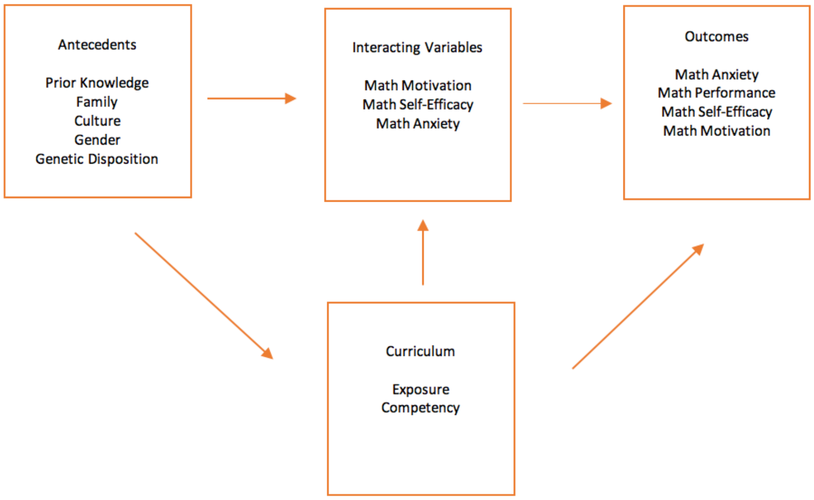


Figure 2. MuSciQ Curriculum Framework (Adapted from Luttenberger, et al., 2018)

Measures

The primary variables for data collection were math anxiety, math motivation, math self-efficacy, math performance, and technology acceptance. Technology acceptance and basic demographic info were collected from students and teachers/administrators involved in the study. Only students completed math-related measures.

Math Anxiety and Self Efficacy Questionnaire

Math anxiety and math self-efficacy were measured using the Math Anxiety and Self-Efficacy Questionnaire (MSEAQ, Appendix F). The questionnaire was built on a general expectancy-value model, making it ideal and applicable for exploring students' self-efficacy and anxiety (May, 2009). Items from the MSEAQ were adapted from previous math self-efficacy and math anxiety scales and correlation analysis to establish psychometric properties (May, 2009). In the study the internal consistency, measured by Cronbach's coefficient alpha was .94. Math anxiety and math self-efficacy were measured individually with an internal consistency of .91 and .90, respectively.

Scores for math anxiety and math self-efficacy were scored individually, as they are separate constructs within the same questionnaire. Items in the math anxiety subscale were reversed scored prior to summing so high math anxiety scores were an indication of low math anxiety.

With the permission of the MSEAQ developer, the language was slightly adjusted to fit language that was consistent with fourth graders. “Mathematics” was changed to “Math”. Also, item number five originally stated “I worry that I will not be able to use mathematics in my future career when needed”. It was changed to “I worry that I will not be able to use math when I get a job one day”.

Math Motivation

Math motivation was measured using the Beliefs, Engagement, and Attitude Math Motivation Scale (Orosco, 2016). Although the survey was initially designed to explore two separate constructs: beliefs/attitude and engagement, confirmatory factor analysis revealed no difference in a unidimensional model (Orosco, 2016). Consequently, the BEAAMS is interpreted as a one latent construct, general math motivation (Orosco, 2016). The BEAMMS is a ten-item dichotomous scale with positive responses scored as 1 and negative responses scored as 0. The maximum possible score was 10 and the minimum possible score was 0. For this scale, each item level coefficient alpha was greater than .80. The overall scale has strong internal reliability (a= .85).

Math Performance

Math performance was measured using a pre- and post-math assessment. Items 6, 7, 8, and 10 on the assessment were chosen and adapted from the Mathematical Identity Development and Learning (MIDDLE) Project (Morton, 2014). The assessment included eleven questions, each one highlighting one or more math components of the MuSciQ curriculum. Each question consisted of three components. The first was calculating the answer. Secondly, the student described how they derived the answer. Lastly, the student identified how confident they were about their derived answer by choosing a number from 1 to 6 on a Likert scale (Appendices H & I). The rubric for grading was chosen from the MIDDLE Project (Morton, 2014). It was a scale from 0 to 4 (Appendix L).

Technology Acceptance

The Technology Acceptance Model was used to measure technology acceptance. The model is a 12-item Likert scale ranging from “extremely disagree” (1) 1 to “extremely agree” (7). Two sub-constructs make up the model- perceived usefulness and perceived ease of use. As mentioned previously, the model was first developed to assess technology acceptance in the workplace but has widely been accepted as a model to use in education (Granić & Marangunić, 2019).

Culturally Responsive Framework

Although CRP was not a measured construct in the study, components of CRP were used during the developing and administering the curriculum. Bond (2017) highlights five areas of focus that were also considered in the study.

1. Identity and Achievement
2. Equity and Excellence
3. Developmental Appropriateness
4. Teaching Whole Child
5. Student Teacher Relationships.

Identity and Achievement

Student and teacher identity development are a starting point for CRE because they focus on embracing multiple perspectives, validating cultural origins, viewing diversity as an asset, and connecting home and school experiences (Bond, 2017). Literature highlights the importance of knowing students individually and within their social context (Abril, 2009, 2013). During the implementation of the MuSciQ curriculum, the class size was small, consisting of twelve students. Although the target number of students was thirty-five, having a smaller classroom size allowed for more personalized instruction. It helped the researcher go beyond making assumptions about culture of reference based on culture of origin (Shaw, 2012). Instead, culture of reference was determined in some instances by directly seeking out students' musical repertoire choice.

Shaw (2012) highlights that one's culture of reference might be different than one's culture of origin. Although the MuSciQ songs were pre-arranged to reflect Top 40 music styles, there was an understanding that the songs would possibly need to be re-arranged based on students' musical preferences. After each class, the researcher allowed each student to pick a song that was a part of their repertoire. By doing this, it helped the researcher tailor the arranged MuSciQ songs, connecting them to the styles that students preferred. Also, at the beginning of each class, styles of music that reflected the researcher's musical preferences were played. Student agency was apparent when students commented on what they liked and disliked about each song, ultimately giving them the opportunity to experience ownership and decision-making power (Cremata, 2017). As the curriculum progressed, they were able to communicate their thoughts using more musical terminology. Student preferences about songs and compositional style were integrated into lessons to acknowledge and validate cultural and family backgrounds. According to Bond (2014), sharing and validating multiple viewpoints is an important component of a culturally responsive classroom.

Equity and Excellence

Equity and excellence can be described in terms of equal access and incorporation of multicultural curricular content (Bond, 2017). The added expenses of participation in school music programs can discourage participation for those who have fewer financial resources. This was taken into consideration for current study. All material expenses, including the Workbook, MuSciQ app, and Canvas platform, were provided for free. Bates (2012) suggests that in order to promote greater equity, musical resources should be free; cultural backgrounds should be understood and respected between all parties; and, there should be a keen awareness of social factors that perpetuate issues of poverty. It is also important to note that when speaking of poverty, it is not limited to financial poverty. According to McAnally (2013), it can also be a poverty of opportunity. Lack of opportunity can also be observed in the form of pedagogical approaches that give priority to certain types of content over others. Although socio-economic information of students was not collected, their verbal responses to the curriculum were collected

Developmental Appropriateness

According to the conceptual framework for CRE, developmental appropriateness includes the learning styles, teaching styles, and cultural variation of psychological needs including motivation, morale, engagement, and collaboration (Brown-Jeffy & Cooper, 2011). Because culture and society have a substantial impact on learning and teaching practices, it is important for teachers to use a variety of teaching practices with students.

In the MuSciQ curriculum, one of the goals was to direct attention to the method the children were being taught as well as the content. How the material was presented was considered equally as important as what was being presented. For example, mathematical ratios were one of the areas covered in the curriculum. Music intervals and ratios were used to derive new notes and compare different notes and frequencies (See Appendix K). This approach went beyond explaining math ratios. Instead learning basic understanding of math ratios was immediately connected to something students wanted to do, learn a new melody. Traditionally, classroom math instruction has lacked contextualization, leaving some students unmotivated to learn (Reyes, 2019). In MuSciQ, a real-world application was introduced in the beginning with the intent of motivating students to want to learn the content.

Developmental appropriateness also includes learning styles and learning preference. Although there were no measures for learning style in the study, the researcher observed and confirmed by teachers/administrators, that most of the students in the study were kinesthetic learners- learning best through body movement and experience (Wallace, 1995). Much of the curriculum included hands-on participation through clapping, dancing, and singing.

Teaching the Whole Child

Teaching the whole child overlaps with other parts of the CRE framework as it encourages teachers to utilize students' "cultural capital" in the teaching process. (Bond, 2017; Lareau, 2001; Lareau & Weininger, 2003; Pierre, 1986; Weininger & Lareau, 2007). It involves skill development in a culturally responsive context, bridging home, and community; learning outcomes, supporting learning environment, and empowering students (Brown-Jeffy & Cooper, 2011). With an understanding of the importance of both home and school support, the researcher intentionally aimed to develop supporting relationships not only with the students, teachers, and admin, but also with parents. The school that was chosen for the study already had a well-established system for bridging the home-school connection. While obtaining parental consent for the study, the researcher spoke with several parents about a wide range of topics surrounding the study.

Learning outcomes were connected to the MuSciQ curriculum. Although there are literature and studies that connect music and math, few of them provide measurable learning outcomes. In the current study, measures were connected to each math-related variable, including math performance.

A tangential aim of the MuSciQ was to help empower students. This was attempted in multiple ways. First, the researcher intentionally used language that was affirming, even when an answer was incorrect. According to McMillan and Moore (2020) when students are wrong, it can be an opportunity to enhance learning and motivation. For example, when a student gave an answer that was incorrect, the researcher was careful to not use negative language, but instead, saying "Are you sure?" or "Let's take another look", instead of "no" or "that's wrong". In some instances, students gave incorrect answers, but their thought processes were correct. In those scenarios, the researcher was quick to acknowledge thoughtful approaches.

Another way this was accomplished was by employing student agency within the classroom learning environment (Cremata, 2017). The researcher attempted to empower the students by attempting to help students see themselves as contributors in the curriculum, giving them a sense of ownership, and ultimately allowing opportunities for self-referential learning (Monk et al., 2013). Often, language towards the students was used to communicate that the curriculum was designed for them and it was theirs. This was especially true for the original songs that were tailored to fit genres that the students enjoyed, along with the songs they created themselves. The songs were originals, meaning they had access to something that no one else had access to. Moreover, when they created their own affirmations, they were able to do so knowing that everything about it was "theirs".

Student-Teacher relationships

Two important components of *Student-Teacher Relationships* are caring and classroom atmosphere. Caring involves 1) having a safe and supportive school environment, and 2) an accepted understanding of varied communication styles (Bond, 2017). Although the curriculum took place on Zoom, there was still an intentional effort made to ensure that the environment was safe and supportive. Towards the beginning of the curriculum, it was apparent that some of the students were nervous because they did not know what to expect about the curriculum. However, as time passed, they became more comfortable in the environment. One of the ways this was observed was when students attempted to answer questions, even when they were unsure of the answer. Most of them did not have a problem trying. Their attempts could be considered a form of risk-taking because of their willingness to attempt an answer, despite being uncertain of the result (Atkins et al., 1991). Risk-taking is more likely to occur in safe learning environments (Sharma, 2015).

MuSciQ Curriculum

Overview

MuSciQ teaches mathematical concepts rendered in a musical fashion. It strategically utilizes music as a tool to cover concepts including fractions, arithmetic, intervals, and algebraic thinking. The curriculum includes two primary musical components—rhythm and melody. Students were first introduced to basic concepts of music theory. The theory was coupled with loops and musical activities that were produced to reflect popular, culturally relevant styles of music. Once a foundational presentation of music theory was provided, students were given multiple in-class projects to complete. The goal of each project was to use math to identify song melodies. First, students were given a rhythmic phrase to be written out completely. After the rhythm was written and analyzed, as a group, the rhythm was performed. Next, students used the MuSciQ App and were asked to find new notes by using their understanding of frequency ratios. Students were given mathematical hints to identify the new frequency. The last part of the project was melodic and rhythmic synthesis. The rhythms and melody were played simultaneously by either the teacher or student, and the "hook" was revealed.

MuSciQ Workbook-Rhythm

The Rhythm portion of the workbook curriculum focused on understanding parts of a whole by using musical measures to represent one whole and individual notes and rests representing the parts of the whole (Appendix K). Notes and rests ranging from whole notes to sixteenth notes were taught and explained in detail using the MuSciQ Workbook and Presonus Studio One. Studio One is a digital audio workstation (DAW) used for recording and music making (Langford, 2013). The rhythmic hierarchy was the primary method for identifying and conceptualizing different note values or beat subdivision. In-class exercises from the workbook as well as improvisational exercises in Studio One were utilized to reinforce rhythmic concepts. Improvisational exercises consisted of the instructor calling out different types of note patterns and students were asked to perform the accurate subdivision in real-time.

Another component of the rhythm section was the teaching of dotted notes. The duration of dotted notes receives the value of the original note plus half of the original note. The approach required students to perform algebraic math calculations, especially when asked to determine how many of one type of note fits within another note.

Understanding musical measures was another rhythmic component of the curriculum. Different time signatures, which indicated how many beats were placed within a measure, were explored with the purpose of reinforcing fractions as part of a whole. In this case, one measure represented one whole and the notes and rhythms within the measure represented a part of the whole. Exercises provided students with the opportunity to complete the rhythmic phrases within a bar, each of which were performed in real-time by clapping to a rhythmic loop pattern created by the instructor.

Note and rest duration was taught in terms of seconds and milliseconds. This approach helped students understand duration in a unique way. For each rhythm that was taught, students were given the exact duration of one bar with an understanding that each note and rest within a bar could also be analyzed in terms of seconds and milliseconds. Moreover, students were able to see the DAW environments, both Studio One and Reason Studios, where the songs were created. Both environments contain a visual grid representing seconds and milliseconds. When notes are played, the duration of the note can be seen on the grid. This approach helped students conceptualize duration in a unique way while also connecting it to technology.

Within the rhythm portion of the curriculum, students were taught to parse, or provide a rhythmic account, for each rhythmic note. Students had to identify the type of note, where it was placed in the measure, the duration of the note, and where it fit in a bar represented by a sixteen-step sequence. By learning to parse rhythms, students were given an additional method of deriving, and ultimately performing the rhythm. To help reinforce the parsing concept, in-class exercises were provided. To help connect the concept to real-world technology, the curriculum included examples using a 16- step sequencer in Studio One and Reason Studios.

MuSciQ Workbook- Melody

Melody was taught using the concept of distinguishing ranges of pitch, and then correlating musical pitches with notes. Once students understood the concept of notes, they were introduced to notes as frequencies using the MuSciQ Application. The students also used the MuSciQ app to complete in-class practice exercises in which students were asked to calculate the frequency of a given note.

Teaching the melodic portion of the curriculum was done using frequency ratios and the half step method. Students were asked to count the number of half steps between two notes and based on the number of half steps, they were asked to use a chart to determine what the interval would be called. Additionally, the workbook chart included intervals ratios to derive frequencies of new notes based on a given note. Once the new frequency was determined, students were asked to determine a new frequency-note pair using the MuSciQ app. In class exercises were provided as a practice tool. In the exercises, students were given a frequency and asked to determine an interval above the given frequency using the app.

MuSciQ Songs

The songs strategically combined rhythmic and melodic instruction. Each song included rhythm and melodic sheets in the workbook (See Appendix K) . The rhythm sheet contained the tempo of the song in terms of seconds/milliseconds per measure as well as a tempo for a quarter note in terms of beats per minute (BPM). Each rhythm sheet had a chart for students to complete. The chart was designed to account for each rhythmic note in the song. In the chart, students were asked to identify the type of rhythmic note for each word. Secondly, they were asked to determine where each beat was placed within a measure. Next, they had to determine the duration of the note in terms of a quarter note. They were then asked to determine the length of the note in terms of seconds or milliseconds, given the entire duration of one measure in seconds or milliseconds. Lastly, students were asked to identify the beat in a segment of sixteen boxes. Each box represents a sixteenth note in a measure of 4/4 time signature. Once the placement of the beat was identified, students used their understanding of the musical hierarchy and subdivision to determine how many boxes were to be shaded in.

Each song was written and produced by the researcher. Each song contained a "hook" or musical phrase that was designed to capture the students' attention. The "hook" was also the rhythm and melody line students learned using math. Three of the songs contained positive affirmations as "hooks". One of the songs was a dance song with instructional lyrics. The last song was an instrumental piece to serve as an accompaniment to student-created positive affirmations as an in-class exercise.

MuSciQ Standalone Application

The MuSciQ Keyboard Tool is an application created in *MaxMSP*, a programming environment that enables the construction applications known as *Max Patches*. A *Max Patch* is a series of objects in *MaxMSP* that are used to create one functioning application. The MuSciQ *maxpatch* was exported from *MaxMSP* to a standalone application for both Mac and PC. The MuSciQ keyboard *maxpatch* is an 88-key virtual piano consisting of a sound bank of 123 different sounds (Figure 3). Each note is identified with the alpha letter name to help students learn the notes. Underneath the virtual keyboard, numbers represent the octave ranges to help students conceptualize the relationships between octaves and frequencies. Students choose between using a hardware Musical Interface Digital Instrument (MIDI) controller or a *QWERTY* keyboard that coincided with the notes on the piano. Finally, the application includes a number display that identifies the frequency of the note being played.

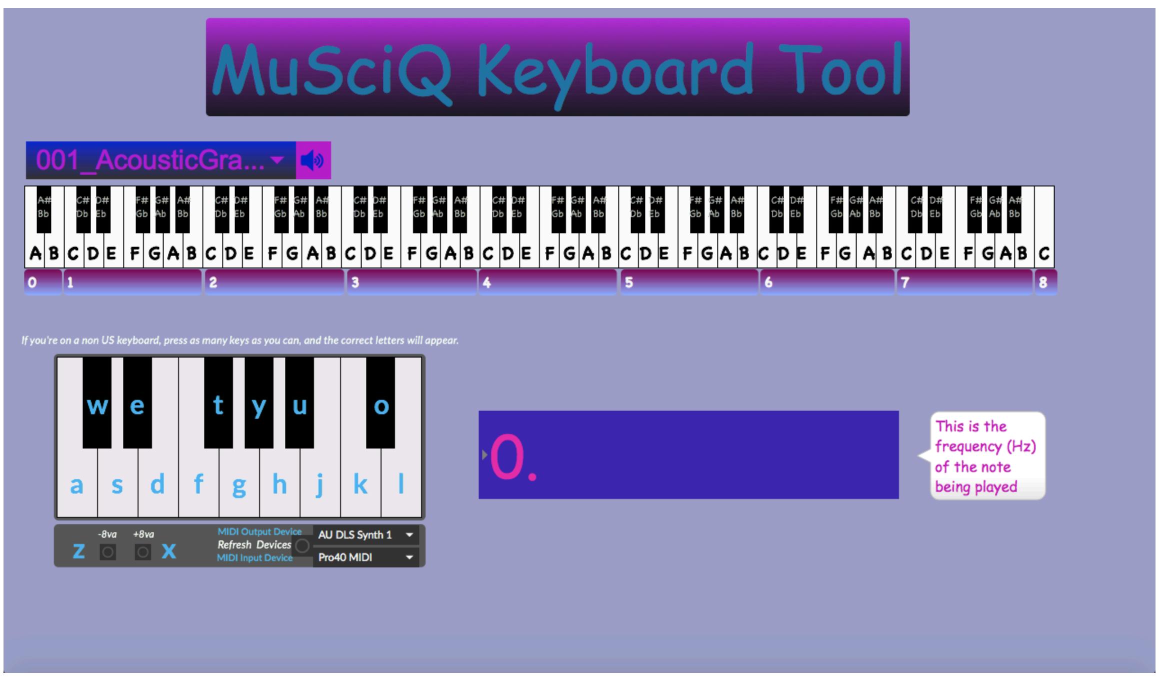


Figure 3. MuSciQ keyboard Tool Interface

Auxiliary Tools

In addition to the workbook and application, there were other tools that were used during the instruction. To reinforce some of the musical concepts, the researcher used Presonus Studio One and Reason Studios. Each application contains enhanced audio-related functions known as plugins. At times, rhythm and frequency related plugins helped draw connections between what was being taught in the workbook and how it applied in a more practical sense. For example, after students derived the melodies, the spectrogram plugin in Studio One was used by the researcher to help students verify that their derived frequency was consistent with what was present on the spectrogram. Additionally, DAWs contain time grids so notes and rhythms can be observed visually in real time. Some of the songs were further explored in both DAWs. For example, MIDI notes were used in the editing window to explore the concept of duration.

Research Participants

Twelve fourth-grade students (male=8, female=4) attending a preK-5 co-educational school participated in the study. These students were selected because they fit within the target academic group of grades 3-5. No cultural demographic information was collected, however according to the school head, all of the twelve students identified as African-American/Black. Each student had less than a year of musical experience because they started playing recorder within the same year. Each student was asked to complete a pre- and post-math assessment, pre- and post-Math Self- Efficacy and Anxiety Questionnaires (MSEAQ), pre- and post-Beliefs, Engagement, Math Motivation Scale (BEAMMS) assessment, and the Technology Acceptance Model (TAM) assessment.

Two adults helped monitor students during the study. One was a schoolteacher, and the other was the Head of School. They were both provided with a complete overview of the curriculum, and they also observed the classes on a regular basis. They were also given the Technology Acceptance Model assessment at the end of the study. Each participant was assigned a number to protect individual identities and confidentiality.

Research Setting

The instruction was conducted remotely on Zoom. Initially the curriculum was designed to be conducted in a classroom setting, however parts of the study were adjusted to adhere to COVID-19 protocols. Canvas® learning management system was used to communicate and disburse materials such as the MuSciQ App, MP3s, and extra copies of the MuSciQ workbook, and consent/assent forms. All students were given a username and password, provided by Indiana University. Workbooks were printed and given to each student by school administrators. For the first half of the curriculum, students participated at home on their computer/mobile devices. For the second part of the curriculum, some students returned to school, while others remained at home. In both scenarios, all students had individual access to Zoom. To reduce classroom disruptions, students attending school on site were given personalized headsets.

Data collection

The Indiana University Institutional Review Board approved all the research that was conducted in the study. The primary data collected included standardized measures of math self-efficacy, math anxiety, math motivation, math performance, and technology acceptance. Students were given pre math measures before the curriculum and were given post math measures once the curriculum was complete. The Technology Acceptance Model was given after the curriculum was complete. The MSEAQ, BEAMMS, and TAM were created and disbursed through Qualtrics. The math assessment was sent to students as a PDF in Canvas®. Students were responsible for printing and returning the assessments to their teacher or administrator, who then returned the assessments to the researcher. The entire study was conducted over one academic Spring semester. There was a total of fifteen sessions, each lasting for one hour. Data analysis and written findings were completed within six months of data collection.

Analytic Plan

T-test scores ($p<.05$) were used to determine any statistically significant differences in pre- and post- measures between math self-efficacy, math anxiety, and technology acceptance. In this case a t-test was appropriate because it was used to compare two sample means where there is a one-to-one correspondence (McCrum-Gardner, 2008).

. Cohen's D was calculated to determine effect size (Cohen, 1992). Effect sizes are important in this study because they present the magnitude of the effect in a standardized metric (Lakens, 2013). In addition to statistical significance, the magnitude of the effect also important, especially given the small sample size. Internal consistency of each measure was measured using Cronbach's alpha. Intercorrelations between math measures were calculated using Pearson's R. Pearson's R is most appropriate for variables measured on a continuous scale (McCrum-Gardner, 2008). Averages of each item in the Technology Acceptance Model were assessed for both teachers and students. Descriptive statistics of each item of the Technology acceptance model were calculated.

Because the BEAMMS included non-parametrical data, all statistical procedures that included the BEAMMS utilized the Wilcoxon signed-rank test to determine any statistical significances (McCrum-Gardner, 2008). Spearman's Rho was used to determine correlations involving the BEAMMS and other measures in the study. Spearman's Rho was appropriate in this case because the relationship between numbers in the scale are not linear (Puth et al., 2015).

CHAPTER 4: RESULTS

In this chapter, quantitative and qualitative results of this study are reported. Internal consistency of math anxiety, math motivation, and math self-efficacy were calculated using Cronbach's Alpha. T-tests were performed on the pre- and post-mean scores for math self-efficacy and math anxiety, while the Wilcoxon signed ranked test was used for math motivation. Correlations for anxiety and self-efficacy were determined using Pearson's R, while Spearman's R was used for any calculations involving motivation. Results for anxiety, self-efficacy, and motivation were separated by gender. Results for technology acceptance are represented as frequency tables. Lastly, A qualitative questionnaire provides additional insight from the perspective of students, teachers, and administrators.

Cronbach's Alpha, represented in Table 1, was run on each of the pre- and post-constructs to determine internal consistency. All construct alphas were within acceptable range (Cortina, 1993).

Table 1. Cronbach's Alpha for Pre and Post Assessments

	Pre	**Post**
MSEAQ (Self-Efficacy)	.97	.96
MSEAQ (Math Anxiety)	.85	.84
BEAMMS (Motivation)	.91	.70

Note: For MSEAQ, there are two subscales.

Table 2 provides the pre- and post-means for math self-efficacy, math anxiety, and math motivation. Scores for math anxiety were reversed, meaning higher math anxiety scores indicate lower math anxiety. Although there were twelve students total, only three completed both the pre- and post-assessments, therefore mean scores were calculated for three students. The maximum possible scores for self-efficacy, anxiety, motivation, and performance were 70, 75, 10, and 44, respectively.

Table 2. Pre and Post Assessment Means for All Measures

	N	Mean	SD	SEM
MSEAQ (Self- Efficacy) Pre	12	60.17	12.28	3.55
MSEAQ (Self- Efficacy) Post	12	63.17	9.93	2.87
MSEAQ (Math-Anxiety) Pre	12	59.75	9.83	2.84
MSEAQ (Math-Anxiety) Post	12	66.08	8.99	2.60
BEAMMS (Motivation) Pre	12	7.58	3.15	.91
BEAMMS (Motivation) Post	12	9.17	1.34	.39
Math Performance Pre	3	34.67	8.02	4.63
Math Performance Post	3	38.33	3.06	1.76

Note: Math anxiety scores were reverse coded.

A paired sample t-test (Table 3), was performed to compare pre- and post- scores for math anxiety, math self-efficacy, and math performance. Post math anxiety scores (M=66.08, SD= 8.99) were significantly different than pre- math anxiety (M=59.75, SD= 9.83) scores. The effect size for math anxiety scores (d=-.998) was found to exceed Cohen's convention for a large effect (Cohen, 2013). While there was no significant change in math self-efficacy or math performance scores, math performance did increase with a medium effect size (d=-.72).

Table 3. Paired Sample t-test results for Self-Efficacy, Anxiety, and Performance (All)

				95 % Confidence Interval Difference					
	Mean Diff.	**SD**	**SEM**	**Lower**	**Upper**	**t**	**df**	**Sig (2 tailed)**	**Cohen's *d***
MSEAQ (Self-Efficacy) Pre-Post	3.00	7.12	2.06	-7.53	1.53	-1.46	11	.17	-.42
MSEAQ (Anxiety) Pre-Post	6.33	6.34	1.83	-10.36	-2.30	-3.46	11	.005	-.998
Math Performance	.37	5.13	.33	-2.10	.77	-2.00	2	.18	-.72

A Wilcoxon Signed Rank test was performed in Table 4 to compare results between pre- and post- math motivation scores. The BEAMMS is a dichotomous 0 and 1 categorical scale, meaning a non-parametrical analysis was most appropriate (Woolson, 2007). The test revealed significant differences between pre- math motivations scores and post-math motivation scores. Consistent with Cohen's (1992) statistical power analysis literature, a medium effect size was observed for math motivation.

Table 4. Wilcoxon Signed Rank Test for Motivation (All)

	Mean	SD	Min	Max	Z	Asymp. Sig (2 tailed)	r
BEAMMS (Motivation) Pre	7.58	3.15	1.00	10	-2.39	.017	-.49
BEAMMS (Motivation) Post	9.17	1.34	6.00	10			

Note: $p<.05^*$; $p<.01^{**}$

Table 5 shows the mean scores for self-efficacy, anxiety, and motivation for males.

Table 5. Male Pre- and Post- Assessment Means for math measures (N = 8)

	Mean	SD	SEM
MSEAQ (Self- Efficacy) Pre	66.75	3.66	1.30
MSEAQ (Self- Efficacy) Post	68.82	1.99	.71
MSEAQ (Math-Anxiety) Pre	63.25	9.41	3.33
MSEAQ (Math-Anxiety) Post	69.63	5.24	1.85
BEAMMS (Motivation) Pre	9.25	1.17	.41
BEAMMS (Motivation) Post	9.75	.46	.16

Post math anxiety scores were significantly higher (better) than pre- math anxiety scores (Tables 5 & 6). The effect size for math anxiety scores exceeded Cohen's convention for a large effect size (Cohen, 2013). While not significant, math self-efficacy scores improved with a medium effect size (d = -0.52).

Table 6. Male Paired Sample t-test Results for Self-Efficacy and Anxiety

				95 % Confidence Interval Difference					
	M	***SD***	**SEM**	**Lower**	**Upper**	***t***	**df**	***p***	**Cohen's *d***
MSEAQ (Self-Efficacy) Pre-Post	-1.88	3.64	1.288	-4.92	1.17	-1.46	7	.19	-.52
MSEAQ (Anxiety) Pre-Post	-6.37	5.125	1.812	-10.66	-2.10	-3.52	7	.010	-1.24

Because the BEAMMS is a dichotomous scale, a Wilcoxon Signed Rank test was performed to compare results between pre- and post- math motivation scores for males (Woolson, 2007). Table 7 revealed nonsignificant differences between pre- math motivations scores and post-math motivation. A medium effect size was observed for math motivation (*r*=-.33).

Table 7. Male Wilcoxon Signed Rank Test for Motivation

	Mean	**Standard Deviation**	**Min**	**Max**	**Z**	**Asymp. Sig (2 tailed)**	**r**
BEAMMS (Motivation) Pre	9.25	1.165	7	10	-1.633	.102	-0.33
BEAMMS (Motivation) Post	9.75	.463	9	10			

Table 8 provides the pre- and post-means for female math self-efficacy, math anxiety, and math motivation.

Table 8. Female Pre- and Post- Assessment Means for all measures

	Mean	N	SD	SEM
MSEAQ (Self- Efficacy) Pre	66.75	4	3.66	1.29
MSEAQ (Self- Efficacy) Post	68.82	4	1.99	0.71
MSEAQ (Math-Anxiety) Pre	47.00	4	13.24	6.62
MSEAQ (Math-Anxiety) Post	52.25	4	10.69	5.34
BEAMMS (Motivation) Pre	4.25	4	3.30	1.65
BEAMMS (Motivation) Post	8.00	4	1.83	0.91

Table 9 reports the comparison pre- and post- scores for math anxiety and math self-efficacy for females. The t-test reveals no significant change in math anxiety or math self-efficacy. However, a medium effect size was observed for both math anxiety (d=-.67) and math self-efficacy (d=-.44).

Table 9. Female Paired Sample t-test Results for Self-Efficacy, Anxiety, and Motivation

	Mean	SD	SEM	95 % CI		t	df	Sig(2-tailed)	Cohen's d
				Lower	Upper				
MSEAQ (Self-Efficacy) Pre-Post	-5.25	12.03	6.02	-24.40	13.90	-0.87	3	.45	-.44
MSEAQ (Anxiety) Pre-Post	-6.25	9.29	4.64	-21.02	8.52	-1.35	3	.27	-.67

A Wilcoxon signed rank test for females, represented in Table 10, showed no significant change in math motivation. A medium effect size, however, was observed (r=-.38).

Table 10. Female Wilcoxon Signed Rank Test for Motivation

	Mean	SD	Min	Max	Z	Asymp. Sig (2 tailed)	r
BEAMMS (Motivation) Pre	4.25	3.30	1	8	-1.841	.066	-0.38
BEAMMS (Motivation) Post	8.00	1.83	6	10			

In Table 11, technology acceptance means for students and teachers are shown. They are also divided by individual constructs, perceived usefulness, and perceived ease of use. There was a total of twelve students who completed the technology acceptance survey along with two teachers.

Table 11. Technology Acceptance Means for students and teachers

	N	Mean	SD
Technology Acceptance (Students)	12	70.083	8.660
Perceived Usefulness (Students)	12	34.500	4.602
Perceived Ease of Use (Students)	12	35.58	5.177
Technology Acceptance (Teachers)	2	71.50	6.363
Perceived Usefulness (Techers)	2	35.50	4.949
Perceived Ease of Use (Teachers)	2	36.00	1.414

Table 12 shows the combined averages for overall technology acceptance between students and teachers/administrators. The model is a Likert scale ranging from "extremely disagree" (1) 1 to "extremely agree" (7). The Technology acceptance model mean average for students was 5.83 and the average for teachers was 5.95. The usefulness subconstruct was 5.75 for students and 5.92 for teachers. Lastly, the ease of use sub-construct was 5.93 for students and 6 for teachers.

Table 12. Technology Acceptance Model Combined Averages for Students and Teacher

	N	Min	Max	Mean	SD
TAM (Students)	14	5.08	6.17	5.83	.36
TAM (Teachers)	14	4.00	6.50	5.95	.66
Usefulness (Students)	14	5.08	6.08	5.75	.38
Usefulness (Teachers)	14	4.00	6.50	5.92	.97
Ease of Use (Students)	14	5.25	6.17	5.93	.34
Ease of Use (Teachers)	14	6.00	6.00	6.00	0

Spearman's r was calculated in Table 13 to report the correlational rank of pre- and post-motivation scores to pre- and post-self-efficacy scores. There was a significant positive correlation between pre motivation and pre-self-efficacy. Post motivation and post self-efficacy demonstrated a significant positive correlation.

Table 13. Spearman's Correlation for Motivation and Self Efficacy

	Motivation Pre	Motivation Post	Self-Efficacy Pre
Motivation Post	.79**		
Self-efficacy Pre	.72**	.43	
Self-Efficacy Post	.92**	.68*	.77**

Note: p<.05*; p<.01**

Table 14 shows correlational values for motivation and anxiety using Spearman's correlation. There were no significant correlations found between pre motivation and pre anxiety scores.

Table 14. Spearman's Correlation for Motivation and Anxiety

	Motivation Pre	Motivation Post	Anxiety Pre
Motivation Post	.793**		
Anxiety Pre	.494	.308	
Anxiety Post	.543	.166	.891**

Note: p<.05*; p<.01**

The relationship between motivation and technology acceptance is represented by Spearman's *r* in Table 15. There was a significant positive relationship found between post motivation and technology acceptance. A significant positive correlation between post motivation and perceived usefulness was also found.

Table 15. Spearman's Correlation for Motivation and Technology Acceptance

	Motivation Pre	**Motivation Post**
Technology Acceptance	.505	.620*
Perceived Usefulness	.671*	.635*
Perceived Ease of Use	.158	.346

Note: p<.05*; p<.01**

Pearson R, shown in Table 16, was used to determine correlations between anxiety and self-efficacy. Because math anxiety items are reverse scored, positive correlations are shown, indicating correlations in improvement. In pre- measures, there was a significant correlation found between self-efficacy and anxiety scores; however, that relationship was not found in the post- correlational measures between self-efficacy and anxiety.

Table 16. Pearson's Correlation for Self- Efficacy and Anxiety

	Self-Efficacy Pre	**Self-Efficacy-Post**	**Anxiety-Pre**
Self- Efficacy Post	.815**		
Anxiety Pre	.610*	.544	
Anxiety Post	.758**	.399	.776**

Note: p<.05*; p<.01**

There were significant positive correlations found between self-efficacy and technology acceptance (Table 17). Each subconstruct of technology acceptance demonstrated significant positive correlations with self- efficacy.

Table 17. Pearson's Correlation for Self-Efficacy and Technology Acceptance

	Self-Efficacy Pre	Self-Efficacy Post
Technology Acceptance	.584*	.836**
Perceived Usefulness	.588	.696*
Perceived Ease of Use	.481	.779**

Note: p<.05*; p<.01**

In Table 18 correlational values for anxiety and technology acceptance were assessed. The results indicate no significant relationship between anxiety and technology acceptance.

Table 18. Pearson's Correlation for Anxiety and Technology Acceptance

	Anxiety Pre	Anxiety Post
Technology Acceptance	.429	.135
Perceived Usefulness	.262	.190
Perceived Ease of Use	.484	.057

Table 19 shows comparative means for each math-anxiety item. The results reveal significant changes in score for some items (i.e., Items 14, 15, & 22). A large effect size was observed for all individual math anxiety items except item 25, which showed a small effect size (d=.39).

Table 19. Math Anxiety Pre-Post t- Test for Individual Items

		Mean	SD	SEM	95% CI		t	df	Sig (2-tailed)	Cohen's d
					Lower	Upper				
2	**I get tense when I prepare for a math test.**	-.42	-.80	.23	-.92	.09	-1.82	11	.10	.80
3	**I get nervous when I have to use math outside of school.**	-.33	1.16	.33	-1.07	.40	-1.00	11	.34	1.16
5	**I worry that I will not be able to use math when I**	-.17	1.12	.32	.88	.54	-.52	11	.62	1.12

	get a job one day.									
6	**I worry that I will not be able to get a good grade in my math class.**	.17	1.34	.39	-.68	1.02	.43	11	.67	1.34
8	**I worry that I will not be able to do well on a math test.**	-.58	1.51	.43	-1.54	.37	-1.34	11	.20	1.51
11	**I feel stressed when listening to math instructors in class.**	-.58	1.83	.53	-1.75	.58	-1.10	11	.29	1.83
14	**I get nervous when asking questions in class.**	-1.33	1.37	.40	-2.20	-.46	-3.37	11	.01	1.37
15	**Working on math homework is stressful for me.**	-1.00	1.48	.426	-1.93	-.061	-2.35	11	.040	1.48
17	**I worry that I do not know enough math to do well in future math classes.**	-.25	1.96	.57	-1.50	1.00	-.44	11	.67	1.96
18	**I worry that I will not be able to complete every assignment in a math class.**	-.58	1.24	.36	-1.37	.21	-1.63	11	.13	1.24
22	**I worry I will not be able to understand the math.**	-.75	.97	.28	-1.36	-.14	-2.69	11	.02	.97
24	**I worry that I will not be able to get an "A" in my math class.**	.25	1.49	.43	-.69	1.19	.58	11	.57	1.49
25	**I worry that I will not be able to learn well in my math class.**	-.17	.39	.11	-.41	.08	-1.48	11	.166	.39
26	**I get nervous when taking a math test.**	-.33	1.61	.47	-1.36	.69	-.72	11	.49	1.61

27	**I am afraid to give an incorrect answer during my mathematics class.**	-.25	1.96	.56	-1.50	1.00	-.44	11	.67	1.96

Table 20 shows comparative means for each math self-efficacy item. The results reveal significant changes in score for some items (i.e., Items 19, & 23). A large effect size was observed for several math self-efficacy items (i.e., Items 1, 9, 10, 21, 23, 28, & 29). The remaining items showed medium and small effect sizes.

Table 20. Math Self-Efficacy t-Test for Individual Items

		Mean	**SD**	**SEM**	**95% CI**		**t**	**df**	**Sig (2-tailed)**	**Cohen's d**
					Lower	**Upper**				
1	**I feel confident enough to ask questions in my math class.**	.00	.853	.25	-.54	.54	.00	11	1.00	.85
4	**I believe I can do well on a math test.**	-.25	.75	.22	-.73	.23	-1.15	11	.28	.75
7	**I believe I can complete all of the assignments in a math class.**	.08	.52	.15	-.24	.41	.56	11	.59	.52
9	**I believe I am the kind of person who is good at math.**	.08	1.38	.40	-.79	.96	.21	11	.84	1.38
10	**I believe I will be able to use math in my future career when needed.**	-.42	1.17	.34	-1.16	.32	-1.24	11	.24	1.17
12	**I believe I can understand the content in a math course.**	-.17	.58	.17	-.53	.20	-1.00	11	.34	.58
13	**I believe I can get an "A" when I am in a math course.**	-.083	.52	.150	-.41	.24	-.56	11	.59	-.52

16	**I believe I can learn well in a math course.**	-.33	.65	.18	-.74	.081	-1.77	11	.10	.65
19	**I feel confident when taking a math test.**	-.25	.45	.13	-.54	.04	-1.92	11	.04	.45
20	**I believe I am the type of person who can do math.**	-.25	.62	.18	-.65	.15	-1.39	11	.10	.62
21	**I feel that I will be able to do well in future math classes.**	-.33	.89	.26	-.90	.23	-1.30	11	.10	.89
23	**I believe I can do the mathematics in a math class.**	-.42	.90	.26	-1.00	.155	-1.60	11	.07	.90
28	**I believe I can think like a mathematician**	-.33	1.435	.41	-1.25	.58	-.80	11	.22	1.44
29	**I feel confident when using math outside of school.**	-.33	.89	.26	-.90	.23	-1.30	11	.11	.89

Table 21 shows the frequencies for each item of math motivation. An increase in positive responses was reported for all items after MuSciQ was introduced.

Table 21. Student BEAMMS Item Frequency Table

		PRE		POST	
		Positive	**Negative**	**Positive**	**Negative**
1	**I like doing math/I do not like doing math.**	10	2	12	0
2	**Doing math makes me sad/Doing math makes me happy.**	11	1	12	0
3	**I feel good when I do my math work/I feel bad when I do my math work.**	10	2	11	1
4	**I like spending my energy doing math/I do not like**	10	2	11	1

	spending my energy doing math.				
5	**When I do math I would rather be doing other things/Math is the only thing I want to do.**	6	6	9	3
6	**Math is easy for me/Math is hard for me.**	7	5	9	3
7	**Math goes by pretty fast/Math takes too long to do.**	8	4	11	1
8	**I get bored when I do math/I get excited when I do math.**	8	4	12	0
9	**I do not care how well I do in math . Math is not Important/I really want to do well in math. Math is important.**	11	1	12	0
10	**I choose to do math because I like it/If I had a choice I would not do math.**	10	2	11	1

Table 22 shows the frequencies for each item of the Technology Acceptance Model. Most respondents (students and teachers) agreed that the MuSciQ was Useful and Easy to Use. A small proportion of respondents disagreed with the benefits of MuSciQ in improving schoolwork (i.e., Items 5, 6 & 7).

Table 22. Combined Technology Acceptance Model Frequency Table

	Extremely Agree	**Agree**	**Slightly Agree**	**Neither**	**Slightly Disagree**	**Disagree**	**Extremely Disagree**
1. Using MuSciQ in school would help me accomplish tasks more quickly.	4	8	2	0	0	0	0
2. Using MuSciQ would improve my school performance	5	3	2	4	0	0	0

3. Using MuSciQ at school would increase my productivity.	3	8	1	2	0	0	0
4. Using MuSciQ at school would increase my effectiveness during school.	4	6	3	1	0	0	0
5. Using MuSciQ at school would make it easier to do my schoolwork.	4	1	5	1	0	3	0
6. I would find MuSciQ useful at school.	8	3	3	0	0	1	0
7. Learning to operate MuSciQ would be easy for me	4	4	3	1	0	2	0
8. I would find it easy to get MuSciQ to do what I want it to do.	5	7		2	0	0	0
9. My interaction with MuSciQ would be clear and understandable	6	6	1	0	0	1	0
10. I would find MuSciQ to be flexible to interact with	6	5	2	1	0	0	0
11. It would be easy for me to become skillful at using MuSciQ	3	8	3	0	0	0	0
12. I would find MuSciQ easy to use	3	8	3	0	0	0	0

Qualitative feedback of the MuSciQ curriculum was collected from both students and teachers/administrators, shown in Tables 23 and 24. The qualitative survey asked each person to describe what they liked and disliked about the MuSciQ curriculum, along with any additional comments.

Table 23. Student Qualitative Feedback

ID	What did you like about MuSciQ Curriculum?	What did you Dislike about MuSciQ Curriculum?	Additional Comments
010	It is easy to understand and I like the fact that is fun	nothing really	
011	It's on Wednesdays and Fridays and it's like a feel-good class.	Actually nothing.	
004	It was an extremely fun experience, I'd wish we would have this longer than we had, other than that, I enjoyed it.	Nothing, honestly.	I wish we could take this class longer, thank you Mr. Alan!
007	I have an awesome teacher and I like that he is always challenging us because he wants to see what we know	Nothing	I love my teacher
001	The math or listening to new music	I don't know	I think that this program would be extremely useful for young music learner
003	That it is fun and learning new things	Not a lot it just that I wanted to have more MusicIQ	
002	I like how Your get to have workbook and listening to music and math	I like everything	
005	The notes and frequency	nothing	
006	I liked about MuSiciQ curriculum is learning new music	I don't dislike anything about MuSiciQ	
009	IDK	IDK	
012	I get to learn more and more about music	nothing	
008	It is fun	Nothing	

Table 24. Teacher Qualitative Feedback

ID	What did you like bout MuSciQ Curriculum?	What did you Dislike about MuSciQ Curriculum?
013	That it married math and music, making math more understandable for the students while improving music knowledge.	Nothing
014	Students learned about different musicians. The beats made it fun to learn. It taught frequency.	Nothing. The students really enjoyed the entire program.

CHAPTER 5: DISCUSSION

Introduction

MuSciQ was the curriculum used in this study to help determine how a musical curriculum for math might impact math constructs. In addition to the aims of the study, MuSciQ was developed with an intent to include culturally responsive components to address both academic and cultural shortcomings of traditionally based approaches. This discussion will contextualize the results of the study and examine more carefully the aspects of the curriculum.

MuSciQ as a Multidisciplinary Approach to Teaching

Fields of study are not discrete entities—that is, they almost always overlap with other disciplines (Youngblood, 2007). *Multidisciplinary* is a term used to describe the cooperation of two or more disciplines being utilized in new ways to consider multifaceted problems (Youngblood, 2007). Although math and music are connected, they are not usually taught as interconnected fields. One of the tangential goals of MuSciQ was to implement a multidisciplinary approach to teaching.

MuSciQ as a Culturally Responsive Approach to Learning

As it relates to mathematics, learning disparities still exist amongst marginalized groups of students (Flores, 2007; Morton, 2014). There has been a lack of research surrounding these groups to examine their mathematical thinking (Berry et al., 2013; Morton, 2014). MuSciQ considered the inequities that exist in both math and music education by including components of CRP in a multidisciplinary context. While the primary aim of the study was to understand the impact a musical curriculum for math may have on math- related constructs, The researcher’s aim was to use the curriculum to acknowledge and address shortcomings that exist in both math and music education communities.

Math Anxiety

Although there were four different math-related constructs within the study, the math anxiety was a starting point that connected the other constructs—motivation, performance, and self-efficacy. This part of the discussion will help clarify and expound upon the results surrounding each construct. Due to the under-targeted sample size, effect sizes are discussed in addition to comparison test scores in order to help contextualize significances. Effect sizes are important, especially in empirically- based studies, because they present the magnitude of the effect in a standardized metric, making it independent from the metric used to measure the construct (Lakens, 2013). This allows researchers to report practical significance in addition to statistical significance (Lakens, 2013).

Reduced math anxiety was predicted in hypothesis 1. As expected, the paired sample t-test in table 4 showed a statistically significant increase in math anxiety scores with a large effect size. When split by gender, t-test results revealed significant improvement in math anxiety scores for males only (Table 7), with a large effect size (d=-1.24). One potential reason for significant improvement in males and not females may be related to teacher and/or student gender. Beilock et al (2010) showed that female teacher's math anxieties had a direct impact on girls' math anxiety, but not boys. Beilock et al. (2010) also discusses the difficulty of knowing the impact male teachers would make on math anxiety in boys because of the lack of male elementary school teachers. It is possible that the classroom student-teacher gender dynamic may have contributed to the outcomes for math anxiety. Future research could further explore the role and interactions between teacher and student gender.

"I get nervous when asking questions in class"

Three out 15 math anxiety questions showed significant improvement after the curriculum was introduced. Item 14 of the MSEAQ asked if students get nervous when they go to class. A t-test revealed a significant improvement (lower anxiety). Research surrounding math anxiety suggests that reduction in math anxiety can be a result of increased understanding of content (Ramirez, Shaw, et al. 2018). It is possible that as students gained more understanding of the concepts presented in MuSciQ they were less nervous about asking questions. Qualitative feedback revealed that students enjoyed the class (Table 23). One student described it as a "feel good class". Thus, as MuSciQ curriculum progressed students became more comfortable with the teacher and the environment, making students less anxious about asking questions.

"Working on math homework is stressful for me."

Item 15 showed significant improvement, indicating students found working on homework less stressful. During the curriculum, students were given assignments to work on outside of class time. The assignments required students to use math concepts to identify a melody to a new song. The thought of math homework within the context of MuSciQ was likely seen as less stressful. One reason students have found math, and even math homework to be unnecessarily challenging is because it lacks contextualization (Reyes et al., 2019). MuSciQ was, in part, likely viewed as useful because it helped contextualize math concepts into "real world" applications, possibly making the idea of homework less stressful.

It is also possible that students' grade level math classes also contributed to the overall improvement in the math anxiety item. Students were still participating in their grade-level math classes while they were participating in MuSciQ. It is hard to know how the other math classes may have played a role.

"I worry I will not be able to understand the math."

Item 22 asked students whether they worried about their ability to understand math. There was a significant improvement in this item indicating less worry. There are only math performance scores for 3 students, and they revealed non-significant increase in scores after the curriculum. Because of the small class size, the researcher was able to take time and explain math concepts and activities that were connected to the curriculum. It is possible that students worried less about the thought of understanding math because a large portion of the curriculum went to teaching and thoroughly explaining math concepts in the workbook. Future studies with a larger number of students will assist in determining whether or not this assertion is accurate.

Math Self-Efficacy

Math self-efficacy is defined as one's own perceptions about his or her ability to perform in mathematics (Bahr & Christensen, 2000). In this study, there was a moderate, insignificant increase in self-efficacy. There are several possible reasons for the lack of significant results, such as inadequate sample size or that self-efficacy requires additional time to influence. Supportive home and classroom environment play an important role in an individual's self-efficacy (Bradley & Corwyn, 2001; Schunk & Meece, 2006). The students who participated in this study had supportive school and home environments. Thus it is possible that self-efficacy scores reflected home and school environment in addition to the introduction of the curriculum. If self-efficacy was already established at home and school, it is possible that the curriculum, given the short timeline and online delivery, was not powerful enough for a statistically significant change. Students also started with relatively high levels of math self-efficacy. It is possible that there were ceiling effects, making it difficult to obtain significant results.

"I feel confident when taking a math test."

There was a significant improvement in students' confidence about taking math tests post MuSciQ. There was a strong correlation between technology acceptance and math-self efficacy (Table 17). Thus, as the students found the technology easy and useful, it is possible that as students mastered the technology and math concepts, they gained confidence about their abilities to take math tests, including the MuSciQ math assessment. It is also possible that their grade level math class played a role in their ability to perform in math.

Math Motivation

The Beliefs, Engagement, Attitudes, and Math Motivation Scale (BEAMMS) was used to determine math motivation. A significant increase in math motivation was found in combined groups, while no significant changes were found when the groups were split by gender. This was expected because the components of MuSciQ were designed with the intent to help students to want to learn. As a group, males began the study with relatively high math motivation. It is possible that ceiling effects for the BEAMMS made it difficult to obtain any significant changes in males. As for females, according to the Wilcoxon signed ranked test, the small number (N=4) may have contributed to the lack of statistical significance.

Robb (2000) highlights that when musical environments are created, consideration must be put into how individuals acquire new skills. According to motivational theorists, individuals are motivated by the need for competence, autonomy, and relatedness to others (Connell & Wellborn, 1991). Students were given several opportunities to choose musical components, giving them some level of autonomy in the process. For example, during one of the MuSciQ practice activities, students were asked to create their own affirmations. As a class they created the affirmation “we are unstoppable”. Next, they were asked to fit the affirmation into two bars of 4/4 time signature. They each developed their own rhythm and voted on the one they liked the best. Lastly, they were asked to identify where each syllable of the affirmation was placed in each bar. Figure 4 shows the rhythm they created along with the assisted loop created by the researcher.

The autonomy they experienced to develop and transcribe their own class affirmation, while simultaneously interacting with their classmates and the researcher, may have contributed to the overall significant increase in motivation, reduced math anxiety, and acceptance of MuSciQ represented in the results. Also there was a strong correlation between technology acceptance and motivation after the curriculum was introduced. Activities like this one may have contributed to the strong correlations found in the results.

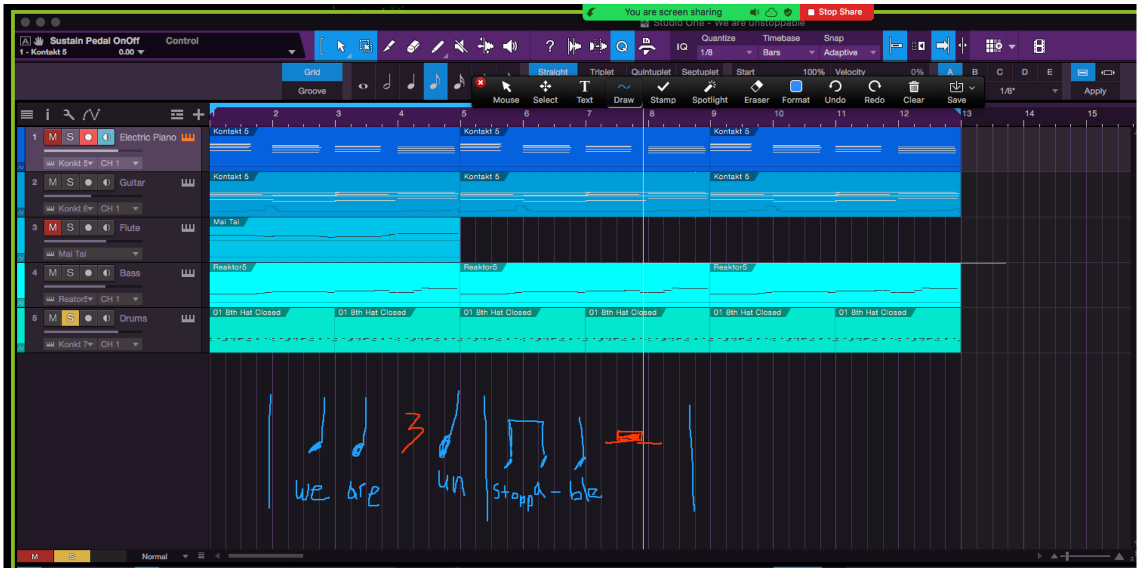


Figure 4. An example of an in-class activity, where students were created and transcribed their own musical affirmation.

Math Motivation Individual Items

While students endorsed more positive responses for each math motivation items after the curriculum was introduced, the largest shift occurred in two items. Item 1 and item 8 highlighted students' feelings about doing math. Before MuSciQ, two students responded that they did not like math (Item 1) and four students responded that they get bored when they do math (Item 8). After the curriculum all students reported that they liked doing math and they get excited when they do math. These results are consistent with research by Ramirez, Shaw, et al. (2018) demonstrating that individual's account of their experiences with math can change in positive directions.

Math Performance

Math performance was measured by a set of eleven questions, each one addressing a concept covered in MuSciQ curriculum. All twelve students completed the pre-post MSEAQ and pre-post BEAMMS, which was administered electronically online. However, the pre- and post-math performance measure was distributed on paper, meaning students had to physically turn it in. Of the students who completed the assessment, some did not complete all the confidence measures, limiting the number of statistical analyses that could be performed. Although the combined group showed non-significant improvement in math performance, no statistical results were determined for confidence. This further reiterates the need for all assessments to be administered electronically or in person.

The last item in the pre- and post-math assessment was directly connected to the subject of frequency and ratios, which was covered in the MuSciQ curriculum. In the assessment, a value was given for the variable x. Students were asked to compare two ratios multiplied by x and determine if one ratio was “greater than”, “less than”, or “equal to” the other. Figure 5 shows how a student responded and how the curriculum directly applied to the assessment. The ratios in the assessment are the same as the frequency ratios used in the curriculum. In the pre- assessment, the student attempted to use long-hand division to determine which ratio was greater. Although the student chose the correct answer, it is not clear how the student derived the answer. However, after learning the frequency ratios from the curriculum, the same student was able to use basic reasoning skills to determine the answer for the post assessment. Although no explanation was given on the first assessment, Figure 5 shows the student was able to give an explanation based on the understanding of frequency ratios and multiplication, stating that when a smaller and larger number are multiplied by the same number, the larger number will be greater. Showing work and explaining answers is seen to help students concretely represent their thinking (Stearns, 2020). Additionally, the student’s confidence level went from a 5 in the pre-assessment to a 6 in the post-assessment. Although the student chose the correct answer both times, the post assessment shows how the curriculum may have played a role in the student's response. While teaching the curriculum there were similar examples that were explained thoroughly. It is likely that although the student knew how to perform the problem before the introduction of MuSciQ, specific language was developed during the curriculum to explain the answer.

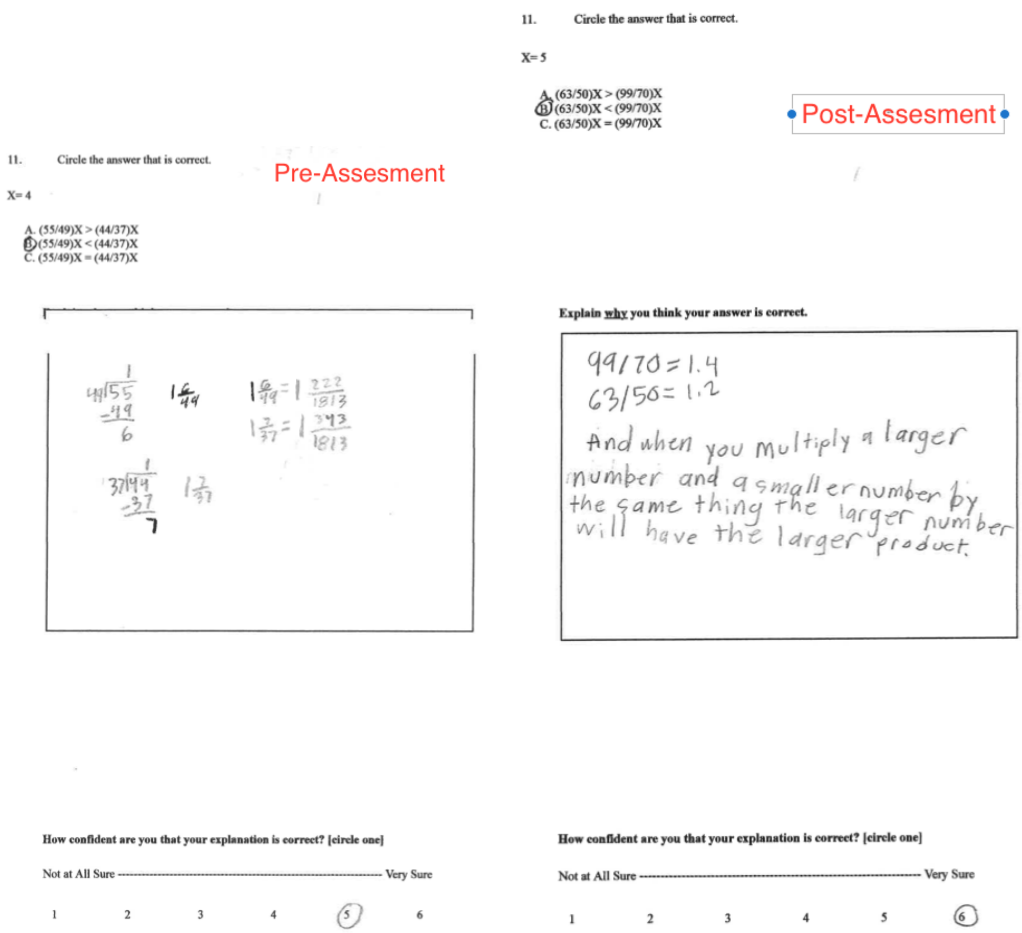


Figure 5. Student response for Item 11 on the pre- and post- assessments

Figure 6 shows an example exercise from the curriculum and how it connected directly to item 11 on the pre and post math assessment. The ratio multiplied by the given frequency revealed the new frequency. In the last section of the exercise, students had to determine whether the new value was greater than, less than or equal to the given frequency, G=391.99 Hz.

G=391.99 HZ

Word	Interval from G	Number of half Steps from G	Note	Ratio	Frequency	>, <, or = G
I'm	Major 3rd	4		(63/50)G		

Figure 6. Shows a problem given as a part of the MuSciQ curriculum.

Figure 7 shows a student response from item 3 on the pre and post math assessment. In both examples, the student answered correctly and explained the answer in an algebraic logical fashion. Also in both examples, the answers could have been explained using basic understanding of note durations in a 4/4-time signature. For example, in the pre-assessment, it could have been represented in a way where a half note and an eighth note were given in a measure, and x represented what was left in the measure- the equivalent of three eight notes. Regardless of whether they got the answer right or wrong, no student took a musical approach to item 3. This reveals opportunities in the future to further connect music and math problem sets so that students are more aware of the option to explain their answers using their musical understanding in addition to more traditional math approaches.

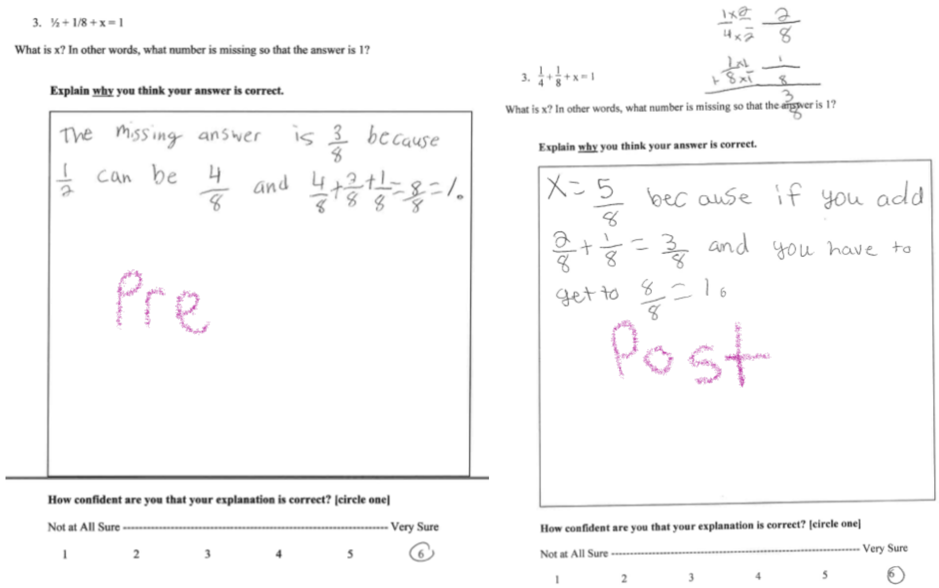


Figure 7. Student response for Item 3 on the pre- and post- assessments

Technology Acceptance

Technology acceptance was measured using the Technology Acceptance Model. The model is broken down into two sub constructs--perceived usefulness and perceived ease of use.

"Using MuSciQ in school would help me learn more quickly than other methods."

All fourteen respondents agreed to some extent that the MuSciQ curriculum would help them learn more quickly than other methods. These results are consistent with the qualitative data suggesting that the curriculum was enjoyable for most students (Table 19). These results are also consistent with literature that connects fun and enjoyment as a natural and important part of the learning process for children (Lucardie, 2014). Moreover, games are thought to be an ideal vehicle for teaching due to their ability to connect children, play, and the desire to have fun (Hromek & Roffey, 2009). Although the MuSciQ curriculum was not initially considered a game, it did have game-like components, as shown in the exercises, where students were given the opportunity to use bits of information to complete and perform a melody.

"Using MuSciQ in school would improve my school performance."

Most students connected the MuSciQ curriculum to improved performance in school (Item 2); however, there were four students that scored neutral, meaning they did not agree or disagree with the statement. Ideally, a future goal of the MuSciQ curriculum would be to further connect positive MuSciQ experiences to traditional math experiences. This could be accomplished by finding more ways to contextualize traditional math approaches through the MuSciQ curriculum. In future studies it might also be beneficial to gain insight on how students compare based on their ability to connect two fields in a multidisciplinary fashion.

"Using MuSciQ in school would increase my productivity/help me be more effective in school."

Students answered similarly when asked if MuSciQ would increase productivity and help be more effective in school (Items 3 & 4). The TAM was originally designed to understand technology acceptance in work-related fields. Eventually the model was used to fit the technological advances within the education community (Granić & Marangunić, 2019). This may be relevant as productivity and efficacy in the workplace may look different than in school settings. Productivity and efficacy in the workplace are usually measurable outcomes, whereas productivity and efficacy in school are perhaps more ambiguous. It is possible that some students did not have a perceived understanding of both terms. In the future, if this model is used, attention should be placed on operative definitions for productivity and efficacy as they relate to the school setting.

"Using MuSciQ at school would make it easier to do my schoolwork/I would find MuSciQ useful at school."

While most students believed that MuSciQ would be useful at school and it would make it easier to do schoolwork, there were also some students that disagreed with both statements (Items 5 & 6). The MuSciQ curriculum was not a replacement class, but an auxiliary class. Students participated in MuSciQ in addition to their other classes and some students may have thought it was challenging to manage both. That understanding may have led some students to disagree.

Correlational Analysis

Tables 13-18 highlight correlations between study outcomes. Table 13 demonstrated there was a significant positive relationship between math motivation and math self-efficacy before and after the curriculum was introduced. This was expected because in math, students who have high expectancy in their abilities are more likely to demonstrate more persistence within a task, even if it becomes challenging (May, 2009). Several studies point to higher levels of self-efficacy positively correlating to motivation (Pajares & Graham, 1999; Pajares & Kranzler, 1995; Zeldin et al., 2008).

Table 14 showed no significant correlations between motivation and anxiety. Previous studies highlight significant, positive relationships between motivation and anxiety (Chiu & Henry, 1990; Meece et al., 1990). Wang et al. (2018), however, highlights multifaceted, non-linear relationships between anxiety and motivation. It is possible in this study that there were more complex significant factors at play that were not specifically observed in the study. Similarly, there was no significant correlation between anxiety and technology acceptance (Table 18). It is possible that a person can accept the technology independently from the anxiety they may feel towards what the technology targets. In other words, MuSciQ was most likely perceived as something totally different from other math classes. As a result, there may have been little to no connection between their feelings of anxiety towards math at trait level, and their acceptance of the curriculum.

There were significant positive correlations between technology acceptance and motivation (Table 15). This was also true for the perceived usefulness construct of the TAM. Some studies highlight correlations between motivation and achievement (Wang et al., 2018). Other connected discipline areas such as physics have highlighted positive relationships between perceived usefulness and achievement in students (Zhai & Shi, 2020). Although few studies highlight the relationships between acceptance and motivation, the theoretical framework for math anxiety points to connections between anxiety, motivation, self-efficacy, and achievement. It is possible that if components of technology acceptance positively correlate to math constructs such as achievement, they can also positively impact motivation in a similar fashion.

As expected, there was a significant relationship between math anxiety (reversed scored) and math self-efficacy, revealing a negative correlation between the two. After the curriculum was introduced, Pearson's r showed the relationship was strengthened by 0.166. Literature suggests those who do not believe that they are able perform well in math will often avoid it (Ashcraft, 2002; May, 2009). A possible explanation is those who believe they are good at math may have less anxiety at the trait level.

Limitations and Challenges

There were some limitations and challenges in this study. The biggest adjustment during this study was converting a curriculum that was designed to be in-person, to an online curriculum. The original research design was developed before the pandemic and was adjusted during the pandemic to adhere to COVID-19 protocols. This section will discuss some of the challenges of the overall study, many of which were directly connected to the adjustments made due to the pandemic.

Recruitment Challenges

There were in-school and after-school programs in Indianapolis that agreed to participate in the study; however, administrators expressed reluctance due to the learning loss students were already facing during the pandemic. Their concerns were consistent with research that highlights pandemic learning challenges and perceived concerns from parents, teachers, and administrators (Dorn et al., 2020; Horowitze & Igielnik, 2020). Understandably, the schools in Indianapolis who originally agreed to be part of the study cancelled because the curriculum was considered an additional workload. Given the circumstances, recruitment became more of a challenge than originally anticipated. Additionally, recruiting challenges delayed the overall research timeline by about eight months. Ultimately a school in Columbus, Ohio agreed to be a part of the study.

Study Design

Statistical power depends on significance criteria, sample size and effect size (Cohen, 1992). The target number of students for the study was thirty-four; however, due to changes in recruitment, the total number of students in the study was twelve. Consequently, the statistical strength of this study was limited due to the small sample size. In future studies, continued focus will be given to recruiting more subjects that meet research criteria. Also, there was no control group in this study, therefore differences between pre- and post-data were analyzed not to determine efficacy, but to understand how the curriculum may have contributed. To determine the efficacy of the curriculum in future studies, a control group will need to be included.

Another limitation was, in addition to MuSciQ, students were still taking their fourth grade-level math class. For this reason, was difficult to separate the progress made during MuSciQ versus the progress made in their grade-level class. In fact, the researcher was unaware of what concepts were being taught in the grade-level class. For future studies future, in addition to a control group, effort should go towards making sure the content of MuSciQ does not overlap with grade-level class content.

Math Assessment

Measures for math anxiety, math motivation and math self-efficacy assessments were all delivered through Qualtrics with 100 percent completion for both pre- and post-assessments. The math assessment was also delivered as a PDF through Canvas, but students were required to print and submit a hardcopy of the assessment to their teacher or administrator. The researcher walked through the directions of the Qualtrics surveys and the math assessment. At the start of the study, all students were still at home due to pandemic protocols. As a result, only five students completed the pre assessment. Although some returned to school in the middle of the study, only eight students completed the post-assessment. Between both groups only three students completed the pre- and post-assessment. As a result, there were statistical procedures that could not be performed for math performance. For example, correlations between math performance and math self- efficacy, math performance and math motivation, and math performance and math anxiety were not performed. In future studies, if the study is online-only, the math performance assessment should also be accessible to complete electronically.

Curriculum Challenges

MuSciQ was designed to be an in-class only curriculum. To adjust to pandemic protocols and challenges, the entire curriculum was converted to an online platform. Some adjustments proved to be more fitting. For example, as mentioned previously, most of the math measures were delivered through Qualtrics, which resulted in a higher completion rate. There were other aspects, however, that made the experience more challenging. Monitoring the workbook progress of students was difficult because of the remote dynamic. Also, the curriculum started with students at home, and not in their classroom. Most students did not have print and copy access to turn in assignments, and if they did, the task of printing and copying assignments became another hassle. To help resolve the issue, documents were made available at the students' school for them to pick up. However, there was no easy way to collect homework assignments. Adjustments were made by covering homework assignments in class. Overall progress was monitored during each class by intentionally engaging students and assessing their understanding. This method helped ensure the curriculum was paced correctly. About midway through the curriculum, some students returned to school. Although the entire curriculum was still online, having a more controlled environment for some students to learn made a noticeable difference. The students appeared to be more focused, and the classroom assistant was able to manage classroom behavior more directly.

Canvas

Canvas was the default platform used to communicate general information to students. Because all students were fourth graders and outside of the Indiana University network, guest accounts were created. The process of getting the accounts created and teaching students how to use *Canvas* took about four full classes, which overlapped with the curriculum timeline. To address the overlap, a two-week extension was given by the school head. In the future, consideration of more familiar student platforms will be made or more time will be allotted to set up and learn the chosen platform.

MuSciQ Keyboard Tool

The MuSciQ Application was created in *MaxMSP* and was made available for Mac and PC users. Most of the students used Chromebooks, which meant they were not able to use the application. They were still able to complete the in-class assignments; however, performance became more challenging if they did not have a keyboard at home. For the students who did not have access to the MuSciQ keyboard or a hardware keyboard, an online virtual piano was provided. Additionally, because most of the songs had lyrics, many of the students were more interested in learning the songs both vocally and instrumentally, which was an unanticipated observation.

Zoom Environment

Although the *Zoom* environment proved to be a powerful teaching tool, there were also limitations. There were times in the study where students' internet connections were not stable which made it challenging to understand students' questions or responses. The connection issues made it challenging to cover entire lesson plans. *Zoom* also has an "annotation" feature, but it was also limited. The feature was useful for writing down short notes and points, but it was not useful for writing longer musical phrases. Because students were in their own environments, at times the background noise was difficult to manage, specifically when students were selected to ask or answer questions. These issues are consistent with documented challenges other teachers face while using *Zoom* (Oliveira Dias et al., 2020).

A secondary component of the curriculum was musical performance. One of the limitations of *Zoom* was the inability to adequately observe students' ability to perform the music they learned. It was difficult to determine if they were playing or singing the notes correctly. According to (Philippe et al., 2020), music learning involves belonging, collaboration, and affiliation. This was true in the *Zoom* environment; however, traditional group performance expectations were not realistic.

In addition to the study being performed remotely and in the middle of a pandemic, there were times where all the students were at home instead of in class. This posed additional challenges. For example, in the beginning of the study, there was no assistant in-person teacher in to make sure students were paying attention or completing their work. There was an additional teacher present in some zoom session, but the absence of one-on-one contact made it difficult to ensure students were focused at all times. Parents played a critical role in both the technical and hands on support. As previously mentioned, most parents "bought in" to the overall aims of the study. There were instances where students were experiencing technical difficulties over Zoom, and parents were quick to help. In some cases, parents overheard the researcher addressing a behavioral issue with their child and they were quick to come in the room and correct their child's behavior to help maintain a productive learning environment. Without both technical and hands-on parental support, it is unlikely that any of the students would have been able to complete the study.

Scalability

Although it was not a limitation in this study, scalability is something to be considered for future studies. Currently, MuSciQ is designed to be used primarily by the creator. One of the future goals of MuSciQ is broader impact. In the future, both math teachers and music teachers will need training and access to MuSciQ contents. By doing this, it will also help gain a better perspective, from a research perspective, about whether similar results can be achieved if someone else is teaching the curriculum.

Qualitative feedback

In addition to the Technology Acceptance Model results, the qualitative feedback verified that MuSciQ curriculum was an acceptable form of technology amongst students and teachers. This section will highlight some of the comments given by students and teachers/administrators. As noted in the methodology, each student and teacher was given an ID ranging from 001 to 014 to protect their identity.

"What did you like about MuSciQ?"

Both students and teachers shared that MuSciQ was an overall enjoyable experience. In addition to several students mentioning the curriculum being fun, some students mentioned that they learned something new. Interestingly, some students emphasized they enjoyed being able to learn about music rather than math. No student commented that they did not like math, but several commented that they enjoyed the music component. This feedback is valuable, especially for future studies. If students enjoy MuSciQ and it is shown to have positive outcomes, it may help other teachers see the benefits in future studies.

The curriculum has an embedded math component, meaning when students were enjoying and learning the music, they were simultaneously learning a math concept. Interdisciplinary approaches are known to provide benefits that convert to lifelong skills that contribute to learning (Jones, 2010). In this case students highlighted the music component but were exposed to both music and math. Teachers/administrators also acknowledge the interdisciplinary component of the curriculum. 013 stated "…it married math and music, making math more understandable for the students while improving music knowledge". If teachers and administrators see the value in MuSciQ not only in terms of math outcomes, but also music, it may create more opportunities for MuSciQ to be used.

Academic Standards

MuSciQ targeted several Department of Education Academic Standards (Education, 2020). This section will discuss some of the standards.

Students makes sense of problems and perseveres in solving them

According to Education (2020), mathematically proficient students look for the meaning of the problem along with an entry point to the solution. This includes analyzing givens, constraints, relationships, and goals. In the MuSciQ curriculum, students were assigned musically based problem sets that required students to analyze what was provided and, in some cases, manipulate sets to derive an answer. Additionally, they were able to check their work by using both math based and music-based methods. Figure 8 shows an example of how students are required to analyze what is given in order to provide a series of answers

F#=369.994 HZ

Word	Interval	Number of Steps from F#	Note	Ratio	Frequency	>, <, or =
Make		4				F#4

Figure 8. Shows a series of problems to be derived from one given.

MuSciQ was designed, in part, to help students perform better in math. The musical component was designed, in part, to help students persevere long enough to find a solution.

Students look for and express regularity in repeated reasoning

Math proficient students recognize repeated calculations and look for general methods of shortcuts (Education, 2020). The curriculum incorporated a large amount of repetition. As students became more familiar with interval ratios of specific musical intervals, some students began to memorize the ratio in decimal form, with the purpose of calculating answers faster. There were also instances in the curriculum where students had to determine the frequency of a note that was lower than the original note. To do this, the reciprocal of the higher interval was used. For example, figure 9 shows the ratio to determine a minor third interval above another note is 44/37 and the decimals were provided in the frequency chart. The ratio to determine a major third below another note, however, is 37/44, the reciprocal. That decimal was not provided; however, some students calculated the reciprocal values of all the intervals to save time when trying to determine the new note and frequency.

G = 391.99 Hz						
Word	**Interval from G**	**Number of half-steps**	**Note**	**Ratio**	**Frequency**	**<, >, or = G**
“do”	Minor third (down)	3 down	E	**(37/44)(G)** (37/44)(391.99) Hz)	Frequency E= 329.63 Hz	< G

Figure 9. Determining an interval of a note below the given note using the reciprocal of the interval ratio.

Algebraic Thinking Standards

Algebraic thinking standards involve solving real-world problems involving addition and subtraction of multidigit whole numbers (Education, 2020). MuSciQ song number five incorporated several addition and subtraction problems to derive new notes and frequencies. The activity for this song was different from the others in that the rhythm and activity sheet were combined in a trivia fashion. In alignment with algebraic thinking standard two, Students were also required to apply inverse relationships between multiplication and division when working with frequency ratios. Lastly, addressing algebraic thinking standard six, students were required to find a second number (and note) when the first number (and note) is provided.

Measurement Standards

Fourth grade measurement standards were applied in both the rhythm and melody activities of the curriculum (Education, 2020). Interval distances were determined by counting half steps from one note to another. Although line plots were not used in the curriculum, the rhythm activities consisted of accounting for and identifying each beat and shading in the portion of a sequence to identify both placement and duration of the notes. The sequence was sixteen boxes long, like a step sequencer. This activity was like identifying a number on a number line, however there was an extra layer of complexity because students were required to shade in the correct number of boxes to account for the duration of the given note. For example, if the note was a half note placed on beat two, then the student would shade in boxes 5-12. In some ways these exercises were unique because they were not simply using one discipline to teach another. Instead, both disciplines, music and math, were equally distributed between the problem sets and applications. Figure 10 shows an example problem.

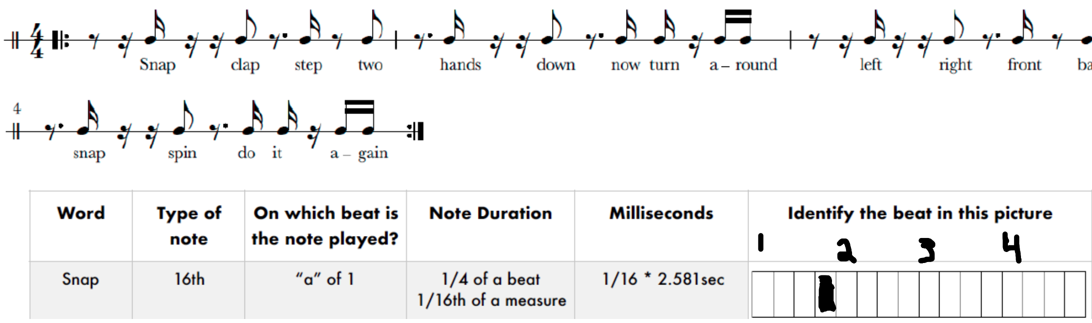


Figure 10. An example of the sequence of questions for one word in the song.

Table 25 highlights some of the third, fourth, and fifth grade national Common Core Standards along with the MuSciQ curriculum application (*Mathematics Standards*, 2022).

Table 25. Common Core Standards and the correlating MuSciQ application.

Standard	**Description**	**MuSciQ Application**
CCSS.MATH.CONTENT.3.OA.B.6	Understand division as an unknown-factor problem.	Students were asked to determine the original frequency of a note, given the new frequency and the interval from the original.
CCSS.MATH.CONTENT.3.OA.D.9	Identify arithmetic patterns (including patterns in the addition table or multiplication table), and explain them using properties of operations.	In the MuSciQ app, students were able to identify different patterns. For example, an octave of an original note will always be two times the frequency of the original note.
CCSS.MATH.CONTENT.3.NF.A.2.B	Represent a fraction *a*/*b* on a number line diagram by marking off a lengths 1/*b* from 0. Recognize that the resulting interval has size *a*/*b* and that its endpoint locates the number *a*/*b* on the number line.	The curriculum used a step sequencer, which was like a number line, to identify points within one whole measure, using musical subdivisions.

CCSS.MATH.CONTENT.4.NF.A.2	Compare two fractions with different numerators and different denominators, e.g., by creating common denominators or numerators, or by comparing to a benchmark fraction such as 1/2. Recognize that comparisons are valid only when the two fractions refer to the same whole. Record the results of comparisons with symbols >, =, or <, and justify the conclusions, e.g., by using a visual fraction model.	Comparing ratios of musical intervals were a key part of the MuSciQ curriculum. In the melodic portion of the curriculum, students had to compare ratios while determining new frequencies of notes.
CCSS.MATH.CONTENT.4.NF.B.3.B	Decompose a fraction into a sum of fractions with the same denominator in more than one way, recording each decomposition by an equation. Justify decompositions, e.g., by using a visual fraction model.	Students were taught how to subdivide rhythms, especially within a whole measure. For example, if only a whole note was provided in a bar of 4/4 time signature, students had to determine what options were left to complete the measure. 1 = 4/4 = ¼ + ¼ + ¼ + ¼
CCSS.MATH.CONTENT.4.NF.B.3.B	Decompose a fraction into a sum of fractions with the same denominator in more than one way, recording each decomposition by an equation. Justify decompositions, e.g., by using a visual fraction model.	Students were taught how to subdivide rhythms, especially within a whole measure. For example, if only a whole note was provided in a bar of 4/4 time signature, students had to determine what options were left to complete the measure. 1 = 4/4 = ¼ + ¼ + ¼ + ¼
CCSS.MATH.CONTENT.5.NF.B.4.A	Interpret the product $(a/b) \times q$ as a parts of a partition of q into b equal parts; equivalently, as the result of a sequence of operations $a \times q \div b$	When determining new frequencies, visual fraction models were used to multiply old frequencies by the given ratio to derive a new frequency.
CCSS.MATH.CONTENT.5.NF.B.5.B	Explaining why multiplying a given number by a fraction greater than 1 results in a product greater than the given number (recognizing multiplication by whole numbers greater than 1 as a familiar case); explaining why multiplying a given number by a fraction less than 1 results in a product smaller than the given number; and relating the principle of fraction equivalence $a/b = (n \times a)/(n \times b)$ to the effect of multiplying a/b by 1.	In the melodic portion of the curriculum, students multiplied fractions (some were greater than 1 and some were less than 1) with an understanding that fractions less than 1 resulted in a smaller frequency and fractions more than 1 resulted in a higher frequency.

Summary

The focus of this chapter was to expound on the findings of the study. In doing so, there were some observed strengths and limitations. A strength of this study was MuSciQ incorporated aspects of Culturally Responsive Pedagogy. Both personal observation and qualitative feedback revealed that most students and teachers in the study were positively impacted by MuSciQ. The results are promising for future studies because results point to MuSciQ as an acceptable platform that can potentially help reduce math anxiety while increasing self-efficacy, motivation, and performance. As MuSciQ continues to develop, more effort can be placed on exploring ways that MuSciQ can strategically target more standards.

One of the most challenging aspects of the study was converting an in-person curriculum to an online format. However, in doing so it helped identify what worked well and what needed to be improved for the study. It also helped reveal the need for a hybrid MuSciQ platform. Throughout the pandemic, learning loss has been an issue in classroom settings (Anderson & Hira, 2020). Platforms like MuSciQ can be beneficial if they help mitigate learning loss. If the limitations of the study can be addressed adequately, the potential for MuSciQ to improve and continue to be an acceptable and effective platform are promising.

CHAPTER 6: CONCLUSION

Introduction

The intent of this research was:

1. To determine how a musical curriculum for math would impact math anxiety, math performance, math self-efficacy and math motivation.
2. To better understand any correlations that exist between math variables.
3. To determine the acceptability of the curriculum using the Technology Acceptance Model.

Results showed that after the curriculum was introduced, significant reductions in math anxiety were observed, along with significant increases in math motivation. Additionally, there were significant correlations between variables. Beyond research aims, there were tangential findings and implications for future research. The following section will connect all findings to future studies and implications for teachers, the field of music technology, education policy stakeholders, and students.

Implications for teachers

Implications of this study point teachers to additional methods for teaching and motivating students to learn. Some teachers suffer from math anxiety, and a curriculum like MuSciQ presents opportunities for both music and math teachers to work together in supportive, collaborative, and non-traditional ways (Beilock et al., 2010). Also, teachers can potentially use the curriculum as a supplemental tool throughout the year not just for competency, but as an overall motivational and anxiety reducing intervention.

Math anxiety is thought to be a trait level anxiety, meaning it is connected to a person's cumulative experiences, not simply momentary feelings (Ramirez, Shaw, et al., 2018). Although some of the questions in the MSEAQ were situationally based scenarios, it is likely that students answered the questions based on their overall experiences with math. After the curriculum was introduced, the outcome was a significant change in math anxiety scores. If the results of this study can be replicated, there are implications of how a curriculum like MuSciQ can be used by teachers to longitudinally shift students' interpretation accounts of their trait level experiences with math.

Lastly, teachers can potentially use the curriculum in conjunction with parents and other adults. Music connects people (O'Rourke et al., 2021). A music-based math curriculum may be a useful tool to help teachers motivate parents to be and stay actively engaged with students' pursuits outside of school.

Implications for students

The MuSciQ curriculum has implications for students. In addition to the reduced competency and disruption account, Ramirez, Shaw, et al. (2018) introduced the interpretation account, which suggests that individual's responses are a direct reflection of how students interpret their experiences. The curriculum may be useful in helping students positively appraise their ongoing experiences with math, despite their momentary outcomes.

In the study, students provided qualitative feedback emphasizing their interest in learning about music. Perhaps the most powerful aspect of the curriculum is when they learned about music, they also learned about math. One of the unique components of the curriculum is it strategically integrated both subjects. MuSciQ was developed, in part, to help contextualize abstract math concepts and operations. Contextualization is a key component in engaging students to learn because it makes learning more meaningful and relevant to students' lives (Reyes et al., 2019). Platforms like MuSciQ, that are intentional about contextualizing learning, may ultimately have a greater impact on student achievement.

Implications for Music Technology

"Music Teaches us Math"

One of the key takeaways from this study is something that has been known in the music community for some time- when you learn music, you inherently also learn math (Jones & Pearson Jr, 2013). This statement can also be applied to music technology, as it also has embedded mathematical applications tied to it. Similar to MuSciQ, there are opportunities for music technologists to build activities that teach what is already being used in the field. For example, a large focus of music technology is performance- that is, how technology can be used as a tool to aid in performance and production. Technology used in telematic performances, for example, often requires a foundational understanding of computer science, engineering, math and other STEM fields. If similar, downsized projects can be simulated for younger students, it will allow creative opportunities to apply what they are learning in the classroom. This is an example of how contextualization can make learning experience more meaningful (Barton & Riddle, 2022). In addition to performance, the same applications can be applied to other areas of music technology such as recording/production, hardware development, electronic instrument development, acoustic instrument development, virtual instrument development, building digital system processors and more.

Another benefit of music technology in grade level classrooms is it offers more opportunities for students to collaborate in organic ways while learning. Collaboration affords students a more complete and enhanced learning experience while giving them the opportunity to meaningfully contribute in a way that displays their strengths within a group (Cane, 2009).

Lastly and most importantly, because learning disparities still exist amongst marginalized groups of students, MuSciQ and similar platforms can be used to serve and learn more about those populations (Berry et al., 2013; Flores, 2007; Morton, 2014). With a culturally responsive approach to teaching, continued effort can be placed towards providing opportunities and learning more about these diverse populations so that the music and curriculum reflect the preferences and values of the communities to which they belong.

"Math Teaches us Music"

As a part of a music education panel, music educator Wynton Marsalis commented about the state of the arts in America saying:

> …why is it always the feeling that the arts is the last thing to think of…many times we justify training in the arts to say it helps people with math or it helps them with sciences…music is super math. Math helps people with music…(*Wynton On Music Struggles*, 2022)

The statement "music helps people with math" is a more common statement. However, the statement "math helps people with music" could be considered controversial because it challenges the idea that areas like music technology exist primarily to serve other academic areas such as math. The statement that "music is a super math" may have been a use of hyperbole, but it strongly hints towards the idea that music is just as important as other subjects. Moreover, areas like math, physics, and engineering can lead individuals to areas like music technology.

Although platforms like MuSciQ use music technology to teach math, a long-term goal can be to help change the narrative surrounding the meaningfulness of music technology independent from other fields like STEM- that is, music technology is only meaningful when it can be applied to other areas. There have been underlying concerns from members in arts communities that funding is limited (Kassner, 1998; Keast, 2011). For this reason, connecting music technology with other fields can certainly help in terms of funding, but effort should also go towards areas of music technology that are not directly connected to other fields. With the broader picture in mind, platforms like MuSciQ can help. With MuSciQ, although effort is placed in integrating music and math, those who use the curriculum can observe over time how students develop, not only with math, but with music also. In the future, the takeaway should be music can help with math; math can help with music; and they can both be exclusively independent from one another.

Implications for Interdisciplinary Music Technology Initiatives

There are several music, technology, and math platforms, but few studies explain how effective the platforms are. There is a need for empirically based data to better understand existing platforms and future platforms. Understanding the efficacy of these platforms will likely impact future funding. In the past decade, schools and school districts have focused on incorporating STEM initiatives in their schools (DeJarnette, 2012). With a clear understanding of the connections between math and music technology, more music technology-based math interventions can be implemented at the grade school level to help students learn both subjects. Future studies involving MuSciQ can contribute to collecting data to understand what works, what doesn't, and what can be replicated. Replication is important because knowledge is corrigible (Lamal, 1990).

Recommendations for Future Research

Based on the results of this study there are opportunities for future research. There were several limitations in the study that should be addressed. First, a more in-depth study must include more students and control groups, with the purpose of further understanding the efficacy of the curriculum. The results also point to MuSciQ as being an acceptable platform for teachers and students. In the future, developing applications and methods that are more easily accessible for students may further strengthen results.

A longitudinal study should also be considered. Understanding how math anxiety, math self-efficacy, math motivation, and math performance change over time may provide insight into areas of retention in math for students. Lastly, methods for online and in-person instruction should be equally considered. With external circumstances that are unpredictable, effort should be placed on a flexible model that can stand alone and be adjusted seamlessly if needed.

Final Considerations

Music is important because it can influence how people feel and act, allowing individuals to define themselves in relation to other people, social networks, and cultures in which they live (North et al., 2000; "Qualifications and Curriculum Authority," 1999). Music technology is unique because in many ways it accomplishes the objectives while also using a systematic study of tools and techniques used for music production, performance, education, and research (Rees, 2012). Music technology impacts several areas of society in vastly different ways, while maintaining one common theme--people. Whether it is directly or peripherally, impact in the field is almost always connected to people.

Before MuSciQ was fully developed, students, specifically those in marginalized communities, were the target group. The original question was "how can music technology be used to serve marginalized groups?" Later, the complete project for MuSciQ was developed. Some of the most impactful projects, ideas, and inventions come from learning how to best serve people because they strategically speak to a broader need.

According to Manzo (2016), music technology can solve problems and make life easier for performers. However, I don't think it should only be limited to performers. Future research must consider how music technology functions in society by solving problems. It is also important to note that answers will develop outside of academia; consequently, efficacy and impact may take on non-traditional interpretations, and that is okay. Music technologists in the academic community play a pivotal role in terms of partnerships and collaboration because often, they can connect people from both academic and non-academic communities. Whether it's STEM, music performance, visual art, medicine, or sociology, there are more opportunities for multidisciplinary collaborations with other fields. Moreover, music technologists in the academic community play a key role in contributing to the scholarly literature of future developments.

MuSciQ will continue to grow as a platform that uses music technology as a tool to help students learn math. By including the cultural characteristics, experiences, and perspectives of its audience, MuSciQ will continue to use culturally responsive approaches to teach in the most effective ways. As the platform develops and the limitations of this study are addressed, it is expected that MuSciQ will be an effective way for students to learn math and music.

APPENDICES

APPENDIX A: Letter of Support

Dear Alan,

I write on behalf of ***************, an independent private school serving the needs of preschool-4th graders, accredited by the ****************. We are in support of a partnership between **************** and MuSciQ™. Thank you for introducing MuSciQ to us! We strongly support your request to test your curriculum as a tool to help teach mathematics and music to elementary students at ****************. The overarching goal of this innovative curriculum aligns with our mission to provide a meaningful experience and stretch the intellectual reach to our students as we assist them in exceeding grade-level academic standards in math. The intentional delivery of math concepts such as fractions, arithmetic, intervals, and algebraic thinking via musical tasks and concepts will likely be highly acceptable to our students.

Through this letter, we understand that tangible support will come in the form of classroom space to deliver the curriculum and assistance in recruiting 3rd, 4th, and 5th grade students to participate.
We further understand that you will take responsibility for collecting the needed data before and after delivering the curriculum per the Internal Review Board approved curriculum. We also understand that the results will be used in a human subjects approved research study by Indiana University.

The **************** community looks forward to working with you and utilizing the MuSciQ™ curriculum to help to strengthen our math program, but to support our desire to give our students the foundation to position them for success as they make a difference in their communities, states, and the world in the years to come.

Sincerely,

****

APPENDIX B: Informed Consent

INDIANA UNIVERSITY INFORMED CONSENT STATEMENT FOR RESEARCH

A Musical Curriculum for Math

ABOUT THIS RESEARCH

You are being asked for consent for your children to participate in a research study. Scientists do research to answer important questions which might help change or improve the way we do things in the future.

This consent form will give you information about the study to help you decide whether you want your children to participate. Please read this form, and ask any questions you have, before agreeing to be in the study.

TAKING PART IN THIS STUDY IS VOLUNTARY

You may choose not to take part in the study or may choose to leave the study at any time. Deciding not to participate, or deciding to leave the study later, will not result in any penalty or loss of benefits to which you are entitled and will not affect your relationship with Indiana University

WHY IS THIS STUDY BEING DONE?

The purpose of this study is to understand how a musical curriculum may play a role in math related variables

Your child was selected because he or she is a current elementary school student.

The study is being conducted by

Dr. Debra Burns, PhD, MT-BC
Alan B. Tyson II

HOW MANY PEOPLE WILL TAKE PART?

If you agree to participate, you will be one of 12 participants taking part in this study.

WHAT WILL HAPPEN DURING THE STUDY?

If you agree to be in the study, your child will do the following things:

1. **Learn how to derive songs using math and music theory.**
2. **Take a short math assessment**
3. **Provide basic demographic info**
4. **Take a Math Self Efficacy and Anxiety Questionnaire**
5. **Complete a Beliefs, Engagement, and Attitude Motivation Scale (BEAMMS)**

HERE IS SOME MORE INFORMATION ABOUT THE STUDY

- The name of the curriculum is called MuSciQ
- The study will take place either online via zoom and Canvas or it will take place in person. This will all depend on school policy and regulations at the time the research is conducted.
- It will be three days a week, for approximately 1 hour and 30 minutes
- The study will last for 4-8 weeks

WHAT ARE THE RISKS OF TAKING PART IN THE STUDY?

The risks of this study are minimal. Some minimal risks may include:

- Feeling uncomfortable while answering questions
- Potential loss of confidentiality

In order to minimize risk, All data and/or measures will be collected/administered on site or on a virtual learning platform called canvas.. A designated folder will be used to store information from respective sheets. No one other than research personnel will have access to the data.

Please keep in mind that while completing the survey, students may tell the researcher that they feel uncomfortable or that they do not want to answer a particular question.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THE STUDY?

The benefits to participation in the study that are reasonable to expect:

1. **Increased piano and music theory related proficiency**
2. **Increased math proficiency**
3. **Greater appreciation for both math and music**
4. **Opportunity to collaborate with other students**

HOW WILL MY INFORMATION BE PROTECTED?

Efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. No information which could identify you will be shared in publications about this study.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board or its designees, and state or federal agencies who may need to access the research records (as allowed by law).

WILL MY INFORMATION BE USED FOR RESEARCH IN THE FUTURE?

Information for this study may be used for future research studies or shared with other researchers for future research. **If this happens, information which could identify you will be removed before any information or specimens are shared.** Since identifying information will be removed, we will not ask for your additional consent.

WILL I BE PAID FOR PARTICIPATION?

Neither you nor your child will be paid for participating in this study.

WHO WILL PAY FOR MY TREATMENT IF I AM INJURED?

In the event of physical injury resulting from your participation in this study, necessary medical treatment will be provided to you and billed as part of your medical expenses. Costs not covered by your health care insurer will be your responsibility. Also, it is your responsibility to determine the extent of your health care coverage. There is no program in place for other monetary compensation for such injuries. However, you are not giving up any legal rights or benefits to which you are otherwise entitled. If you are participating in research that is not conducted at a medical facility, you will be responsible for seeking medical care and for the expenses associated with any care received.

WHO SHOULD I CALL WITH QUESTIONS OR PROBLEMS?

For questions about the study, contact the researcher:

Dr. Debra Burns, PhD, MT-BC
Alan B. Tyson II, PhD Student

For questions about your rights as a research participant, to discuss problems, complaints, or concerns about a research study, or to obtain information or to offer input, please contact the IU Human Subjects Office at 800-696-2949 or at irb@iu.edu.

CAN I WITHDRAW FROM THE STUDY?

If your children decide to participate in this study, you or your children can change your mind and decide to leave the study at any time in the future. The study team will help you withdraw from the study safely.

PARTICIPANT'S CONSENT
In consideration of all of the above, I give my consent for my child to participate in this research study. I will be given a copy of this informed consent document to keep for my records. I agree for my child to take part in this study.

Participant's Printed Name:________________________________

Participant's Signature:____**Date**:_______

Printed Name of Person Obtaining Consent:_____________________________

Signature of Person Obtaining Consent:___________________________**Date**: ______

Printed Name of Parent:___________________________________

Signature of Parent:____**Date**: ______

APPENDIX C: Student Assent Form

Indiana University Assent to Participate in Research

A Musical Curriculum for Math

We are doing a research study. A research study is a special way to learn about something. We are doing this research study because we are trying to find out more about the role that music may have in learning other subjects such as math. We would like to ask you to be in this research study.

Why am I being asked to be in this research study?

You are being asked to be in this research study because you are a 3rd, 4th, or 5th grader who is currently enrolled in a school.

What will happen during this research study?

We want to tell you about some things that might happen if you are in the study. This study will take place online and/or in person. We think it will last for 4-8 weeks, 2 to 3 times a week for approximately 1 hour 30 minutes.

If you want to be in this study, here are the things that we will ask you to do.

1. **Learn how to derive songs using math and music theory.**
2. **Take a short math assessment**
3. **Provide basic demographic info**
4. **Complete Math Self Efficacy and Anxiety Questionnaire (MSEAQ)**
5. **Complete a Beliefs, Engagement, and Attitude Motivation Scale (BEAMMS)**

Are there any bad things that might happen during the research study?

Sometimes bad things happen to people who are in research studies. These bad things are called “risks.” The risks of being in this study are minimal.

Are there any good things that might happen during the research study?

Sometimes good things happen to people who are in research studies. These good things are called “benefits.” The benefits of being in this study might be

1. **Gaining a better understanding of music theory.**
2. **Getting better at math and math related concepts**
3. **Gaining a better appreciation for math.**

We don’t know for sure if you will have any benefits. We hope to learn something that will help other people some day.

Will I get money or payment for being in this research study?

You will not get any money for being in this research study.

Who can I ask if I have any questions?

If you have any questions about this study, you can ask your parents or guardians or the researcher. Also, if you have any questions that you didn't think of now, you can ask later.

What if I don't want to be in the study?

If you don't want to be in this study, you don't have to. It's up to you. If you say you want to be in it and then change your mind, that's OK. All you have to do is tell us that you don't want to be in it anymore. No one will be mad at you or upset with you if you don't want to be in it.

My choice:

If I write my name on the line below, it means that I agree to be in this research study.

________________________________ ________________
Subject's signature Date

____
Subject's printed name

________________________________ _________________
Signature of person obtaining assent Date

____
Name of person obtaining assent

APPENDIX D: PERMISSION TO USE THE MSEAQ

Hi Dr. [redacted]

I hope this email finds you well. My name is Alan Tyson and I am a PhD Student in Music Technology at IUPUI. My research focus is understanding how a musical curriculum for math will impact interacting variables including math anxiety, math self-efficacy, math motivation and math performance in 3rd, 4th, and 5th graders.

Your dissertation has been a point of reference throughout my graduate career. I am very familiar with your work and the MSEAQ measure you developed. I would like to ask permission to use the questionnaire for the students I will be working with. I understand that the MSEAQ was originally designed for college students. I've talked with individuals on my committee, two of whom work with elementary school students, and we believe that the language of the scale is fitting for 3rd, 4th, and 5th graders. There may be a few modifications that need to be made in order to help the students grasp the language (for example, changing "mathematics" to "math"; or changing "future career" to "job").

If using the MSEAQ as a measure for my dissertation is a possibility, please let me know.

I truly appreciate your time and I look forward to hearing from you!

Sincerely,

Alan

Alan B. Tyson II
PhD Student, Music Technology
Indiana University-Purdue University Indianapolis
Purdue School of Engineering and Technology
Department of Music and Arts Technology
[redacted]
altyson@iu.edu

[redacted] [redacted]
to me

This message was sent from a non-IU address. Please exercise caution when clicking links or opening attachments from external sources.

Hi Alan

Your research sounds very interesting. You may use the questionnaire as you see fit. Good luck with your work!

[redacted]

APPENDIX E: PERMISSION TO USE THE BEAMMS

Hi Dr. [redacted]

I hope this email finds you well. My name is Alan Tyson and I am a PhD Student in Music Technology at IUPUI. My research focus is understanding how a musical curriculum for math will impact interacting variables including math anxiety, math self-efficacy, math motivation and math performance in 3rd, 4th, and 5th graders.

Your research has been a point of reference throughout my graduate career. I am very familiar with your work and the BEAMMS measure you developed. I would like to ask permission to use the scale as means to measure math motivation for the students I will be working with.

If using the BEAMMS for my dissertation is a possibility, please let me know.

I truly appreciate your time and I look forward to hearing from you!

Sincerely,

Alan

Alan B. Tyson II
PhD Student, Music Technology
Indiana University-Purdue University Indianapolis
Purdue School of Engineering and Technology
Department of Music and Arts Technology
[redacted]
altyson@iu.edu

[redacted] [redacted]

to me

This message was sent from a non-IU address. Please exercise caution when clicking links or opening attachments from external sources.

Hi Alan,

I hope you are well. I am well. **Yes**, you have my permission to use the BEAMMS. Good luck with you research! Take Care, [redacted]

APPENDIX F: MSEAQ

MATH SELF-EFFICACY AND ANXIETY QUESTIONAIRRE

	Never	Not Often	Sometimes	Often	Usually
1. I feel confident enough to ask questions in my math class.					
2. I get tense when I prepare for a math test.					
3. I get nervous when I have to use math outside of school.					
4. I believe I can do well on a math test.					
5. I worry that I will not be able to use math when I get a job one day.					
6. I worry that I will not be able to get a good grade in my math class.					
7. I believe I can complete all of the assignments in a math class.					
8. I worry that I will not be able to do well on a math test.					
9. I believe I am the kind of person who is good at math.					
10. I believe I will be able to use math in my future career when needed.					
11. I feel stressed when listening to math instructors in class.					
12. I believe I can understand the content in a math course.					
13. I believe I can get an "A" when I am in a math course.					
14. I get nervous when asking questions in class.					
15. Working on math homework is stressful for me.					
16. I believe I can learn well in a math course.					
17. I worry that I do not know enough math to do well in future math classes.					
18. I worry that I will not be able to complete every assignment in a math class.					
19. I feel confident when taking a math test.					
20. I believe I am the type of person who can do math.					
21. I feel that I will be able to do well in future math classes.					
22. I worry I will not be able to understand the math.					
23. I believe I can do the mathematics in a math class.					
24. I worry that I will not be able to get an "A" in my math class.					

25. I worry that I will not be able to learn well in my math class.					
26. I get nervous when taking a math test.					
27. I am afraid to give an incorrect answer during my math class.					
28. I believe I can think like a mathematician					
29. I feel confident when using math outside of school.					

APPENDIX G: BEAMMS

Beliefs, Engagement, and Attitude Math Motivation Scale (BEAMMS) Items

1. _I like doing math.
   _I do not like doing math.
2. _Doing math makes me sad.
   _Doing math makes me happy
3. _I feel good when I do my math work.
   _I feel bad when I do my math work.
4. _I like spending my energy doing math.
   _I do not like spending my energy doing math.
5. _When I do math I would rather be doing other things.
   _Math is the only thing I want to do.
6. _Math is easy for me.
   _Math is hard for me.
7. _Math goes by pretty fast.
   _Math takes too long to do.
8. _I get bored when I do math.
   _I get excited when I do math.
9. _I do not care how well I do in math. Math is not important.
   _I really want to do well in math. Math is important.
10. _I choose to do math because I like it.
    _If I had a choice I would not do math.

APPENDIX H: MATH ASSESSMENT 1

Name____________________ School Name_________________

Answer the following Questions. Please do this on your own. **It is important that you do not receive any help while completing this assignment.**

1. $\frac{1}{2} + \frac{1}{2} =$

Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

2. $\frac{1}{4} + \frac{1}{4} + \frac{1}{2} =$

Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

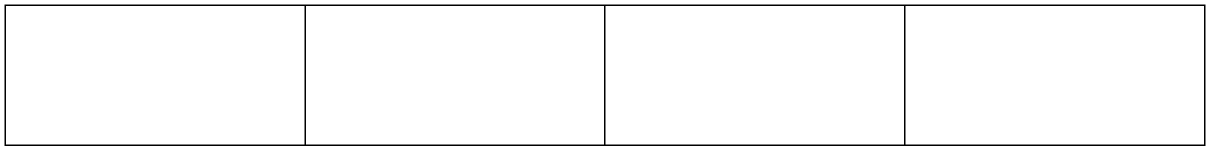
3. $\frac{1}{2} + 1/8 + x = 1$

What is x? In other words, what number is missing so that the answer is 1?

Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

4. Shade ¾ of the boxes.

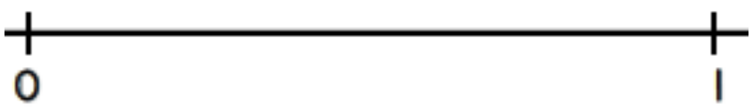


Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

5. Draw a dot at the point ¼ in this line segment.



Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

6. Tracy said, “I can multiply 6 by another number and get an answer that is between 2 and 4.”

   Pat said, “No you can’t. Multiplying 6 by another number always makes the answer 6 or larger.”

   Who is correct?

Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

7. Brandon said, “I can multiply 3/4 by another number and get an answer that is between 11 and 13 .”

   Is he correct?

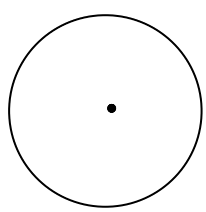
Explain <u>why</u> you think your answer is correct

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

8.

Using the circle below, shade in approximately the same fraction that is shaded in the rectangle above.

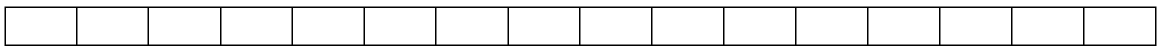


Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

9. Each segment is 1/4th. Shade in the box that represents 3 ¾ .



Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

10. To mix a certain color of paint, Alana combines 5 gallons of red paint, 2 gallons of blue paint, and 2 gallons of yellow paint.

    What is the ratio of red paint to the total amount of paint?

    A. 5/2

    B. 9/4

    C. 5/4

    D. 5/9

Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

11. Circle the answer that is correct.

X= 4

A. (55/49)X > (44/37)X
B. (55/49)X < (44/37)X
C. (55/49)X = (44/37)X

Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

APPENDIX I: MATH ASSESSMENT 2

Name____________________ School Name_________________

Answer the following Questions. Please do this on your own. **It is important that you do not receive any help while completing this assignment.**

1. 2/4 + 2/4 =

Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

2. ¼ + ¼ + ½ =

Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

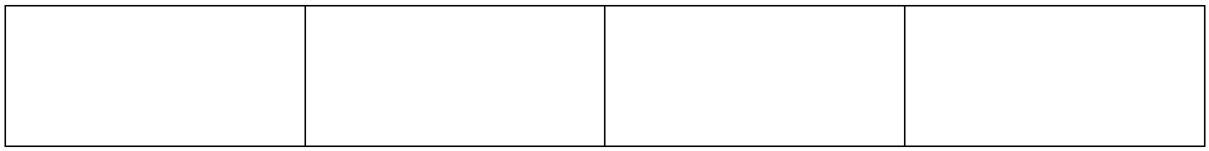
3. $\frac{1}{4} + \frac{1}{8} + x = 1$

What is x? In other words, what number is missing so that the answer is 1?

Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

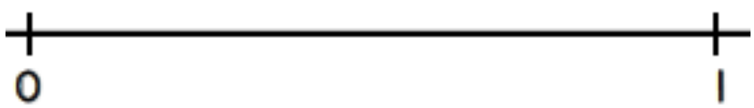
4. Shade $\frac{2}{4}$ of the boxes.



Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

5. Draw a dot at the point ¾ in this line segment.



Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

6. Tracy said, “I can multiply 5 by another number and get an answer that is between 1 and 3.”

   Pat said, “No you can’t. Multiplying 5 by another number always makes the answer 5 or larger.”

   Who is correct?

Explain <u>why</u> you think your answer is correct.

How confident are you that your explanation is correct? [circle one]

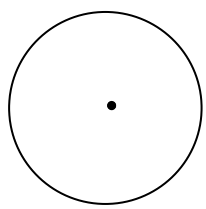
Not at All Sure					Very Sure
1	2	3	4	5	6

7. Brandon said, “I can multiply ¼ by another number and get an answer that is between 12 and 14 .”Is he correct?

Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

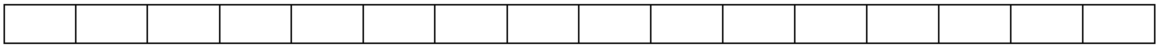
8. Using the circle below, shade in approximately the same fraction that is shaded in the rectangle above.



Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

9. Each segment is 1/4th. Shade in the box that represents 2 ¼ .



Explain <u>why</u> you think your answer is correct
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

10. To mix a certain color of paint, Alana combines 7 gallons of red paint, 4 gallons of blue paint, and 4 gallons of yellow paint.
    What is the ratio of red paint to the total amount of paint?

    A. 7/15

    B. 7/2

    C. 7/4

    D. 5/15

    Explain <u>why</u> you think your answer is correct

How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

11. Circle the answer that is correct.
X= 5

D. (63/50)X > (99/70)X
E. (63/50)X < (99/70)X
F. (63/50)X = (99/70)X

Explain <u>why</u> you think your answer is correct.
How confident are you that your explanation is correct? [circle one]

Not at All Sure					Very Sure
1	2	3	4	5	6

APPENDIX J: TECHNOLOGY ACCEPTANCE MODEL

Usefulness Items

Using MuSciQ in school would help me accomplish tasks more quickly.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

Using MuSciQ would improve my school performance.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

Using MuSciQ at school would increase my productivity.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

Using MuSciQ at school would increase my effectiveness during school.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

Using MuSciQ at school would make it easier to do my schoolwork.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

I would find MuSciQ useful at school.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

Ease of Use Items

Learning to operate MuSciQ would be easy for me.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

I would find it easy to get MuSciQ to do what I want it to do.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

My interaction with MuSciQ would be clear and understandable.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

I would find MuSciQ to be flexible to interact with.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

It would be easy for me to become skillful at using MuSciQ.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

I would find MuSciQ easy to use.

Extremely Agree	Agree	Slightly Agree	Neither	Slightly Disagree	Disagree	Extremely Disagree

APPENDIX K: MUSCIQ WORKBOOK

MuSciQ

WORKBOOK

MATH EDITION

WHAT IS MUSCIQ?

MuSciQ is a four to eight-week curriculum that highlights mathematical concepts rendered in a musical fashion. It strategically covers concepts such as fractions, arithmetic, intervals, and algebraic thinking. It is broken into two primary musical components—rhythm and melody. Students will spend time gaining a foundational understanding of music theory. The theory is coupled with popular loops and phrases that serve as a static tempo for practice. Over the remaining weeks, students are given multiple in-class projects. The end goal of each project is to use math to determine the melody line that is being played. First, students are given a rhythmic phrase that they must write out entirely. After the rhythm is analyzed, as a group, the rhythm is clapped or performed with a rhythmic device. Next, students are given notes to derive using frequency ratios. Using algebraic thinking, students will identify the new frequency. The last part of the project is melodic and rhythmic synthesis. The rhythms and melody are played simultaneously, and the "hook" is revealed. Although some students do not prefer math, MuSciQ encompasses a different motivational factor that encourages students to persevere long enough to play a popular song. The goal is to reduce math anxiety by introducing mathematical foundations of music while teaching students to engage those concepts in a musical fashion. Additionally, the classroom application will aid in the teaching of math and will inevitably result in a better understanding of principles related to both math and music.

RHYTHM

WHAT IS RHYTHM?

- A strong, regular, repeated pattern of movement or sound.
- A particular type of pattern formed by rhythm.

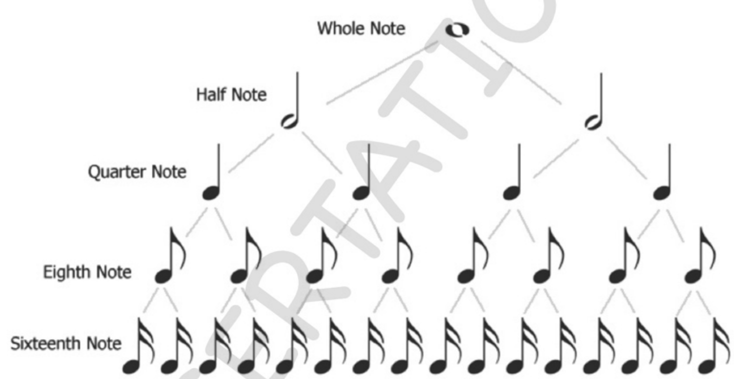
What are some examples of rhythm? List as many as you can....ready...GO!!!!

NOTES AND RESTS

Name	Note	Rest	Beats	How many can fit in one Measure/Bar?	One Measure Picture	How many can fit in 1 beat (quarter note)?	Reduced Value
Whole	𝅝	𝄻	4	1	𝅝	1/4	1
Half	𝅗𝅥	𝄼	2	2	𝅗𝅥 𝅗𝅥	1/2	1/2
Quarter	♩	𝄽	1	4	♩ ♩ ♩ ♩	1	1/4
Eighth	♪	𝄾	1/2	8	♫ ♫ ♫ ♫	2	1/8
Sixteenth	𝅘𝅥𝅯	𝄿	1/4	16	♬♬ ♬♬ ♬♬ ♬♬	4	1/16

Grab one of your MuSciQ practice sheets and let's take some time and practice drawing some of the notes and rests.

RHYTHMIC HIERARCHY



The rhythmic hierarchy explains the relationship between notes that have different rhythmic values. Here are the rules for how each type of rhythmic value is counted:

- **Whole notes** are played for four beats each. "**1** 2 3 4 **1** 2 3 4 **1** 2 3 4 **1** 2 3 4"

- **Half notes** are played for 2 beats each. There are twice as fast as whole notes.

"**1** 2 **3** 4 **1** 2 **3** 4 **1** 2 **3** 4 **1** 2 **3** 4"

- **Quarter notes** are played for 1 beat each. They are twice as fast as half notes.

“1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4”

- **Eighth notes** are played for 1/2 of 1 beat each. They are twice as fast as quarter notes. Here we go! “1 and 2 and 3 and 4 and 1 and 2 and 3 and 4 and 1 and 2 and 3 and 4 and 1 and 2 and 3 and 4”

- **Sixteenth notes** are played for 1/4 of 1 beat each. There are twice as fast as with notes. “1 e and a 2 e and a 3 e and a 4 e and a 1 e and a 2 e and a 3 e and a 4 e and a 1 e and a 2 e and a 3 e and a 4 e and a 1 e and a 2 e and a 3 e and a 4”

In-Class Exercise 1

1.How many half notes can fit into a whole note?

2.How many with notes can quarter note?

3.How man eighth notes can fit into a quarter note?

4.How many sixteenth notes does it take to equal a whole note?

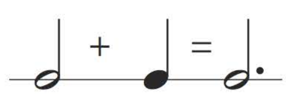
5.Which type of note/rest gets 1/2 a beat?

6.Which note/rest gets 1/4 a beat?

DOTTED NOTES

We've talked about five different types of rhythmic values, but what about dotted notes? Here are some examples of dotted notes:

When dots are placed to the right of the note, it adds half of the original value of the note. For example, a dotted half note now gets 3 beats instead of 2.



DURATION AND MILLISECONDS

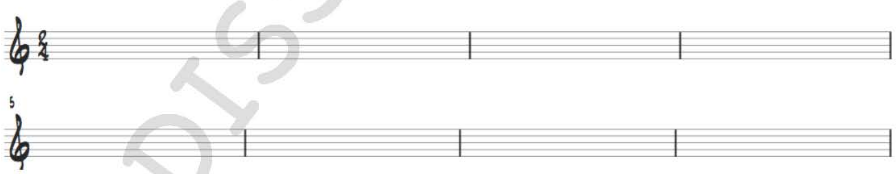
Next we will discuss the length of a note, also called the **duration** of a note. When we talk about duration, we will discuss it in two ways. First is the duration of a note in musical language. For example, in 4/4 time signature we say:

- A whole note gets 4 beats
- A half note gets 2 beats
- A quarter note gets 1 beat
- An eight note gets one half of a full beat
- A sixteenth note gets one quarter of a full beat

The previous examples show how we talk about duration in musical terms, but is there another way we can talk about it? How about seconds or milliseconds? For example, if a quarter note is 1 second long, how many seconds is 1 full measure. In order to do this we would need to know that 4 quarter notes fit in one measure. So, 1 second x 4= 4 seconds.

MEASURES

Measures separate groups of rhythms into equal rhythmic values. Measures are also called bars.



In Class Exercise 2. How many measures are in the example above? Label them all (Measure number 5 is given).

TEMPO

What is your favorite song? Is it fast or slow? How do you know? **Tempo** determines how fast or slow a rhythm, melody, or song is. **Tempo** is the rate or speed of the music in real time. At the top of the sheet music, you may see something that looks like this:

♩ = 90

This shows the tempo of the song. In this case, the song is 90bpm (90 beats per minute)

PARSING RHYTHMS

"Parse" means "to analyze into smaller segments". In music, there are musical sentences called "phrases". Each phrase contains notes. Each note has a rhythm that can be performed or written out(parsed). Lets look at an example.

Each note in this phrase gets a certain number of beats (as mentioned above). Once the rhythm is parsed, this is what it looks like:

Notice that each note and rest are accounted for. From here on out, you will be asked to parse out each rhythm.

When parsing rhythms, these are the steps you should follow.

1. Determine the time signature. This will help you identify how many beats are in the measure and which type of note gets the beat.
2. Identify and separate each bar into the number of segments as the number of beats in the time signature. If the time signature is 4/4, then identify beats 1, 2, 3, and 4. If the time signature is 3/4, identify beats 1,2, and 3.
3. Parse any other rhythms that have not been identified.

Let's practice the rules by doing an exercise!

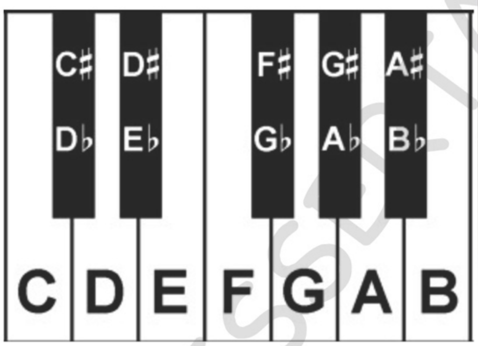
In Class Exercise 4. Parse the following rhythms. Account for each note or rhythm.

PITCH

WHAT IS PITCH?

- The degree of highness or lowness of a tone
- The quality of a sound determined by the rate of vibrations producing it
- What are some examples of pitch? List as many as you can....ready...GO!!!!

Today, we have a standard way of identifying musical pitches. We call these single notes of definite pitch **notes**. In western style music there are 12 different notes. Here are the 12 different notes as seen visually on a piano.



In music when you see # you say "sharp" and when you see b you say "flat". When a note is sharp, that means it is **raised by one half step**. When a note is flat, that means it is **lowered by one half step**.

PITCH AND FREQUENCY

We just talked about the relationship between pitch and each pitch can be associated with a note. In the world of STEM (Science, technology, engineering, and mathematics), there is another way of describing pitches. They are called fundamental **frequencies**. Frequencies are also measured in Hertz (Hz). For example, if you see 440 Hz, we would say "the frequency is four hundred forty H**ertz**". 440 Hz happens to be the note "A natural".

As the frequency increases so will the pitch, and therefore the note. For example, if 440 Hz increases to 523 Hz, the note will change from A to C.

Remember, there are notes that are associated with frequencies. Download the Note to Frequency Identifier and let's practice!

In Class Exercise 5. Determine the frequency of these notes using the Note to Frequency Identifier

1. C5
2. D#6
3. G2
4. A7
5. Bb6
6. F#3
7. B0
8. A0
9. Eb5
10. G#3

USING FREQUENCIES AND FRACTIONS TO UNDERSTAND PARTS OF A MELODY

Notes can be ordered in a stepwise fashion to created **scales**. For example the C major scale is C D E F G A B C. Notes within a scale can be analyzed according to the distance they are from another note. The term used to determine the distance from one note to the other is interval. I will play some examples of scales and intervals. Combinations of notes can be used to create memorable lines to songs called **melodies**. Melodies can be derived in many ways. In this class we will use our knowledge of frequencies and fractions to determine melodies of songs.

In order to talk about intervals, let's look at this ratio chart. Here are the list of intervals in the C major scale using C as a reference point.

Interval	Number of Half Steps	Ratio	Decimal
Unison	0	1/1	1
Minor 2nd	1	196/185	1.059463
Major 2nd	2	55/49	1.122462
Minor 3rd	3	44/37	1.189207
Major 3rd	4	63/50	1.259921
Perfect 4th	5	578/433	1.334840
Tritone	6	99/70	1.414214
Perfect 5th	7	433/289	1.498307
Minor 6th	8	100/63	1.587401
Major 6th	9	37/22	1.681793
Minor 7th	10	98/55	1.781797
Major 7th	11	185/98	1.887749
Octave	12	2/1	2

So what does all this mean? What is the importance of ratios and intervals? We will use this information to determine notes. Let's check out some examples!

C= 261 Hz. What is a major 6th above C. In order to determine this interval we will need to multiply 261 Hz by 5/3 and the answer is 435 Hz. The note is A.

In Class Exercise 6. Given the information, answer each question.

1. A = 440 Hz. What note is a major third above A? What is the frequency of the note?

2. G = 195 **Hz**. What note is a major 7th above G? What is the frequency of the note

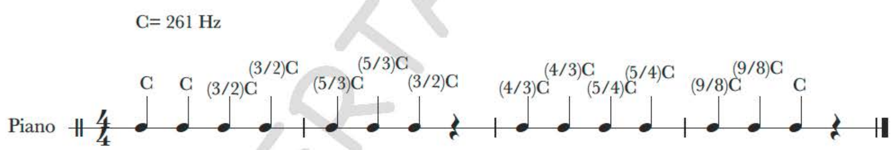
3. C#= **554 Hz**. What note is a perfect 4th above C#? What is the frequency of the note?

4. F= ? **Hz**. C is a Perfect 5th above F. C=261 **Hz**.

PUTTING IT ALL TOGETHER

Now that we've learned about rhythm and pitch, we are ready to start making some music! From here one out you will be taking the concepts you've learned and applying them to the MuSciQ modules. Let's do a practice module.

In Class Exercise 7. Follow the instructions and see if you can figure out what song it is!



Let's figure it out!

1. Write out the rhythm. Practice clapping the rhythm.

2. Determine the frequencies by multiplying C by the ratio given.

3. Determine the note for each fraction using the ratio chart and a piano sheet.

4. Let's put it all together. Let's see if we can figure out each rhythm and note at the same time.

What song is it?

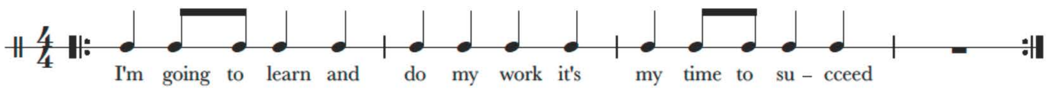
LET'S GET STARTED!

From this point forward, you will be putting together all the knowledge you've gained in order to learn some new songs and grooves. Remember, it is important to get the answers correct to ensure the song is played/learned correctly.

Each activity may be slightly different, but it is all based on foundational knowledge you've learned. Make sure you follow directions and most importantly HAVE FUN!

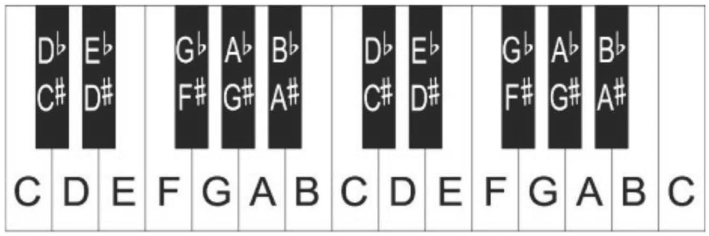
SONG #1 RHYTHM SHEET

1 Measure= 2500 ms ♩ = 96 BPM



Word	Type of note	What beat is the note played?	Duration (Beats)	Duration (Milliseconds)	Identify the beat in this picture
I'm					
going					
to					
learn					
and					
do					
my					
work					
I'ts					
My					
Time					
To					
Su-					
cceed					

SONG #1 MELODY SHEET



G=391.99 HZ

Word	Interval from G	Number of half Steps from G	Note	Ratio	Frequency	>, <, or = G
I'm	Major 3rd	4		(63/50)G		
going	Major 2nd	2		(55/49)G		
to	Perfect 1st	0		G		
learn	Major 2nd	2		(55/49)G		
and	Perfect 4th (Down)	5 Down		(433/578)G		
do	Minor 3rd (Down)	3 Down		(37/44)G		
my	Major 2nd	2		(55/49)G		
work	Perfect 1st	0		G		
I'ts	Perfect 4th	5		(578/433)G		
My	Major 3rd	4		(63/50)G		
Time	Perfect 5th	7		(433/289)G		
To	Major 6th	9		(37/22)G		
Su-	Major 2nd	2		(55/49)G		

cceed	Perfect 1st	0		G		

EXERCISE

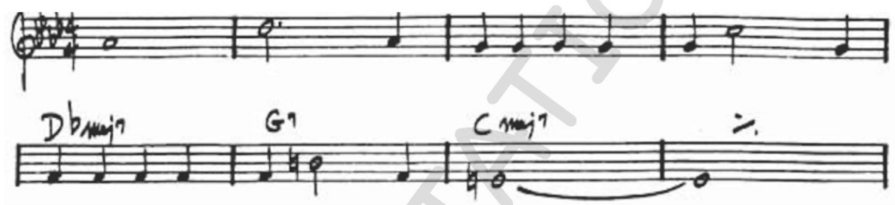
Add the following rhythms given ♩ = 1/4

♩ + ♩ =

𝅗𝅥 + 𝅗𝅥 =

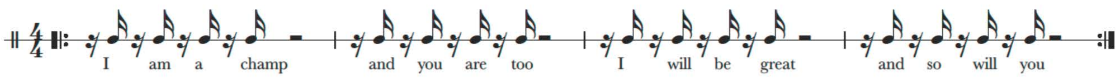
♩ + 𝅗𝅥 =

Show that the notes in each meter add up to 1 bar of 4/4



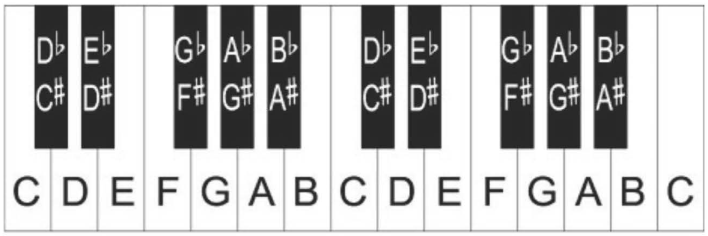
SONG #2 RHYTHM SHEET

1 Measure = 2892ms



Word	Type of note	What beat is the note played?	Note Duration	Duration (Seconds)	Identify the beat in this picture
I					
am					
a					
champ					
and					
you					
are					
too					
I					
will					
be					
great					
and					
so					
will					
you					

SONG #2 MELODY SHEET



C#=554 HZ

Word	Interval	Number of Steps from C#	Note	Ratio	Frequency	>, <, or =
I	Major 6th	9				554 Hz
am	Perfect 5th	7				523 Hz
a	Major 3rd	4				369 Hz
champ	Perfect Unison	0				554 Hz
and	Major 3rd	4				698 Hz
you	Perfect Unison	0				415 Hz
are	Major 2nd	2				311 Hz
too	Minor 3rd (Down)	3				92 Hz
I	Perfect Unison	0				277 Hz
will	Perfect 4th	5				739 Hz
be	Major 6th	9				659 Hz
great	Perfect 5th	7				879 Hz
and	Perfect 4th (Down)	5				783 Hz
so	Perfect Unison	0				523 Hz

will	Perfect 4th	5				739 Hz
you	Major 3rd	4				932 Hz

EXERCISE

Determine the frequency and note by completing the ratio math	>, <, or =	Determine the frequency and note by completing the ratio math
(44/37)F2		(578/433)Eb2
(37/22)G6		(185/98)E5
(100/63)A4		(196/185)B3
(99/70)B4		(578/433)A4
(63/50)G2		(99/70)A2
(578/433)D5		(98/55)C5
(2/1)A4		(44/37)F#4
(196/185)C3		(185/98)D2

RHYTHM PRACTICE

Write the following rhythms:

Measure 1: eighth rest, sixteenth rest, sixteenth note, 2 sixteenth rests, eighth note, dotted eighth rest, sixteenth note, eight rest, eighth note

Measure 2: Dotted eighth rest, sixteenth note, two sixteenth rests, eighth note, dotted eighth rest, two sixteenth notes, sixteenth rest, two sixteenth notes

Measure 3: eighth rest, sixteenth rest, sixteenth note, 2 sixteenth rests, eighth note, dotted eighth rest, sixteenth note, eight rest, eighth note

Measure 4: Dotted eighth rest, sixteenth note, two sixteenth rests, eighth note, dotted eighth rest, two sixteenth notes, sixteenth rest, two sixteenth notes

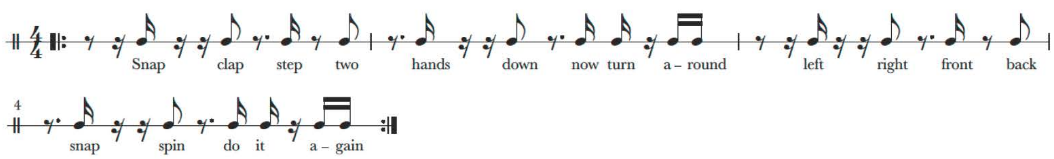
Now, double the value of each note and each rest. For example, an eighth rest will become a quarter rest.

1. **How do the number of measures in the first exercise compare to the number of measures in the second exercise?**

2. **How does the tempo of the first exercise compare to the tempo of the second exercise?**

SONG #3 RHYTHM SHEET

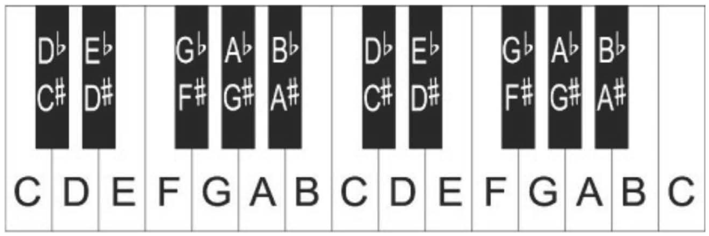
1 Measure = 93 bpm (2.581 Sec)



Word	Type of note	On which beat is the note played?	Note Duration	Milliseconds	Identify the beat in this picture
Snap	16th	"a" of 1	1/4 of a beat 1/16th of a measure	1/16 * 2.581sec 0.161 s	
Clap	8th	and of 2		0.323 s	
Step	16th	a of 3			
Two	8th	and of 4			
Hands	16th	a o 1			
Down	8th	and of 2			
Now	16th	a of 3			
Turn	16th	4			
Around	16th	and of 4			
Left	16th	a of 1			
Right	8th	and of 2			
Front	16th	a of 3			
Back	8th				
Snap	16th				
Spin	8th				
Do	16th				

It	16th				
A-	16th				
gain	16th				

SONG #3 MELODY SHEET



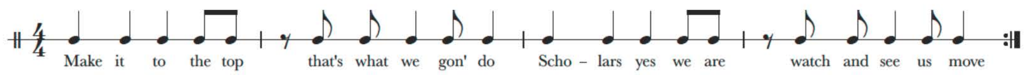
E=329.63 HZ

Word	Interval	Number of Steps from E	Note	Ratio	Frequency	>, <, or =
Snap	Unison	E				329.63 Hz
Clap	Major 2nd	F#				391.99 Hz
Step	Major 3rd	G#				493.88 Hz
Two	Minor 3rd (Down)	C#				246.94 Hz
Hands	Unison	E				440 Hz
Down	Perfect 4th (Down)	B				220 Hz
Now	Major 3rd	G#				415.30 Hz
Turn	Unison	E				349.22 Hz
A-	Perfect 4th (Down)	B				261.63 Hz
round	Minor 3rd (Down)	C#				277.18 Hz
Left	Unison	E				261.63 Hz
Right	Major 2nd	F#				440 Hz
Front	Perfect 5th	B				493.88 Hz

Back	Minor 3rd (Down)	C#				261.63 Hz
Snap	Unison	E				329.63 Hz
Spin	Major 2nd	F#				261.63 Hz
Do	Perfect 5th	B				261.63 Hz
It	Major 2nd	F#				329.63 Hz
A-	Major 3rd	G#				415.30 Hz
gain	Minor 3rd (Down)	C#				261.63 Hz

SONG #4 RHYTHM SHEET

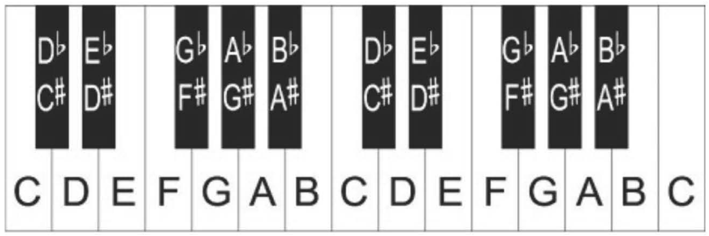
1 Measure = 2.286 s



Word	Type of note	What beat is the note played?	Note Duration	Seconds	Identify the beat in this picture
Make					
it					
to					
the					
top					
that's					
what					
we					
gon					
do					
Scho					
lars					
yes					
we					
are					
Watch					

and					
see					
us					
move					

SONG #4 MELODY SHEET



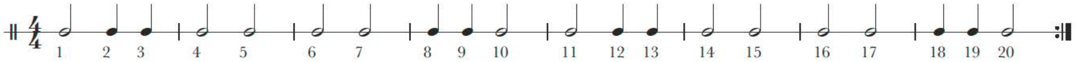
F#=369.994 HZ

Word	Interval	Number of Steps from F#	Note	Ratio	Frequency	>, <, or =
Make		4				F#4
it	Major 2nd					G#4
to			F#			C#4
the		2				A4
top	Minor 3rd (Down)					B4
that's	Major 3rd					Bb4
what		3 (Down)				Eb4
we				(1/1) F#		Gb4
gon'			G#			Ab4
do				(63/50)F#		A4
Scho					554.365 Hz	G4
lars		7				Db5
yes					415.305 Hz	C4

we					466.164 Hz	Gb4
are	Unison					Gb4
Watch	Major 3rd					A3
and		0				B4
see				(55/49)F#		F4
us					311.127 Hz	G#4
move						369.99 Hz =

we					466.164 Hz	Gb4
are	Unison					Gb4
Watch	Major 3rd					A3
and		0				B4
see				(55/49)F#		F4
us					311.127 Hz	G#4
move						369.99 Hz =

SONG # 5



Determine the note name given the clues. Write the note name above the note.

1. I am a perfect fifth above C#4. What note am I?
2. I am around 429 Hz + 37 Hz. What note am I?
3. I am a perfect fourth below E5. What note am I?
4. I am 311 Hz multiplied by 2. What note am I?
5. I am 1108 divided by 2. What note am I?
6. I am another name for Bb4. What note am I?
7. I am a major third above G4. What note am I?
8. I am the key of MuSciQ song #1. What note am I?
9. 558 Hz-92 Hz. What note am I?
10. I am 622 Hz divided by 2. What note am I?
11. I am a major second above F#4. What note am I?
12. I am 116.5 Hz multiplied by 4. What note am I?
13. I am a major seventh below A#5. What note am I?
14. I am a major seventh above G4. What note am I?
15. 357 Hz + 302 Hz. What note am I?
16. 2489 Hz divided by 4. What note am I?
17. 2 x 277 Hz. What note am I?
18. I am a minor sixth below D4. What note am I?
19. 103.83Hz x 4. What note am I?
20. I am a major third below B4. What note am I

MuSciQ Practice Sheet

APPENDIX L: SCORING RUBRIC FOR MATH ASSESMENT ITEM 6

Level	Identifiers	Examples of student responses
0	No work or states they do not understand with no answer given.	"I don't understand."
1	No evidence of understanding effect of multiplying 6 by a value less than 1.	"Pat is right." "Multiplication always makes things bigger."
2	Evidence of understanding that multiplying by zero will produce a product less than 6.	"You can get a number x6, but it's not between 2 and 4. It's 0. 0x6=0." "The lowest number you can multiply by is 1 and 0. If you multiply by 0 you get zero, but if you multiply by 1 you get 6.
3	An example of a solution is given, but the explanation does not state that any value less than 1 will have a product less than 6.	"6 x ½ = 3, so Tracy is correct."
4	Evidence of full understanding that multiplication of 6 by a value less than one will produce a product less than 6. [Note: At this grade, arithmetic with negative numbers has not been introduced, so "less than 1" can be taken to mean non-negative values.	"Tracy is right because you can multiply 6 by a fraction less than 1 and get less than 6. For example, 6 x ½ = 3."

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CURRICULUM VITAE

Alan B. Tyson II

Education

- Doctor of Philosophy in Music Technology—Indiana University (IUPUI), December 2022
  - Minor in Organizational Leadership
- Master of Science in Music Technology—Indiana University (IUPUI), May 2016
- Bachelor of Science in Music Technology—Indiana University (IUPUI), May 2013
- Bachelor of Science in General Science—Morehouse College, May 2013

Awards and Fellowships

- President's Graduate Diversity Fellowship, 2016-2021
- Indiana University-Purdue University Post-Baccalaureate Research Program Fellowship (IPREP)
  - Funded by the National Institutes of Health, 2014-2015
- Indianapolis Jazz Foundation Scholarship Recipient, 2011
- AUC Dual Degree Engineering Scholarship, 2011-2013
- Golden Key Member, 2011-Present
- Ronald E. McNair Scholar, 2011-2013
- Norman Brown Diversity & Leadership Scholar and Scholarship Recipient, 2011-2013
- Dr. John H. Hopps, Jr. Research Scholar and Scholarship Recipient, 2007-2011
- Alpha Lambda Delta Honor Society, 2007-Present

Academic Appointments

- Graduate Teacher Assistant—IUPUI, 2017-2020

K-12 Teaching Experiences

- Music Teacher, Nesbit Elementary School, Gwinnett County Public Schools, Tucker, GA, 2021-Present.

Presentations

Tyson, Alan B. (2020, October). *MuSciQ: A Musical Intervention for Math Anxiety*. Presentation at the 2020 ATMI/CMS National Convention, Online.

Tyson, Alan B. (2019, August). *MuSciQ: A Math-Based Music Curriculum*. Presentation at the Black Faculty and Staff Council Meeting, Indianapolis, Indiana.

Alan B. Tyson II, Scott Deal, and Kenneth Fields. 2016, April 8. *Artsmesh- An Incremental Development in Telematic Art*. Poster session presented at IUPUI Research Day 2016, Indianapolis, Indiana

Alan B. Tyson II and Scott Deal. 2015 April 17. *Using MaxMSP to Integrate Learning of Physics and Music.* Poster session presented at IUPUI Research Day 2015, Indianapolis, Indiana.

Courses Taught

- MUS-A130: Music Theory and History, IUPUI
- MUS-A131: Aural Skills, IUPUI

Professional Experience

- Girls STEM Institute- IUPUI, 2019- 2021
- Upward Bound Trio Program-IUPUI, 2019- 2021
- Graduate Emissary-IUPUI, 2016-2021

Professional Organizations

- National Council of Teachers of Mathematics (2019-Present)
- National Society of Black Engineers (NSBE), 2007-2013

Activities/Community Engagement

- MuSciQ Technology Club, Nesbit Elementary, 2022-Present
- Southeast Community Resource District Council, 2016-2020
- Keyboardist
    - The Father's House, Indianapolis, IN, 2012-August 2021
    - Greater Works Church, Indianapolis IN, 2012-2015
    - Sister's Chapel Sunday Worship Service (Spelman College), 2008-2011
- Saxophonist
    - All Nations Worship Assembly Atlanta, 2021-Present