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Music Activities as an Impetus for Hispanic Elementary Students' Mathematical Disposition

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A group of upper elementary grade students (n=71) from an elementary school located in a southern bilingual metropolitan in the United States participated in this research study. The current study emphasized exploring the effects of implementing music themed mathematics lessons on upper elementary students' mathematics dispositions. A pretest-posttest design was utilized to examine changes of students' mathematical dispositions before and after the intervention. The results of the paired-sample t-test demonstrated statistically significant differences from pretest to posttest in all five disposition themes including (1) value of math, (2) self-confidence, (3) enjoyment of math, (4) motivation, (5) attitude. The encouraging findings in the current study invite further larger scale investigations involving more student participants with broader ranges of grade levels based on more types of music activities.

Key words: music-math integrated curriculum, mathematics disposition, innovative mathematics instruction, and interdisciplinary education.

A recent national census indicated that Hispanics are the fastest growing ethnic minority population in the United States. However, the achievement gap between Hispanic students and students from other ethnicities is still evident (Singham, 2003; Augustine, Zhang & Panzica, 2010). Since researchers have identified the phenomenon of vanishing Hispanic populations in higher education (Saenz & Ponjuan, 2009), more research needs to be done to investigate effective strategies for retaining Hispanic students in higher education in general and in Science, Technology, Engineering, and Mathematics (STEM) education in particular. With the nation's continuing shortage of scientists and engineers (Augustine, Zhang & Panzica, 2010), there is an urgent need for diverse students, especially Hispanic students, to enter and complete STEM education at all levels. Statistics are indicative of the fact that many Hispanic students have not received the mathematical background necessary to succeed economically in a technologically advanced society which is largely reliant on math performance (Stevens, Olivarez, Lan, & Tallent-Runnels, 2004). The current study attempted to engage economically disadvantaged Hispanic students in mathematics activities in classroom settings and entertaining learning environments that could increase their disposition toward mathematics.

In the past decade, educators proposed and assessed a variety of ways of integrating arts, entertainment and popular culture components into mathematics lessons as approaches to improving students' mathematics learning including athletics (e.g., Gallian, 2010), skateboarding (e.g. Robertson, Meyer, & Wilkerson, 2012), visual arts (e.g., Jarvis & Naested, 2012), dance (Rosenfeld, 2013), and drama (e.g., Duatepe-Paksu, & Ubuz, 2009). However, these proposed contextualized teaching strategies were very limited in their empirical assessment on their effects on students' learning of mathematics. Instead, a music-mathematics integrated teaching strategy was identified as an effective approach and empirical evidence with consistent findings was accumulated and showed the improvement of students' mathematics achievement and disposition, as found throughout a line of inquiries (e.g. An, Kulm, & Ma, 2008; An, Ma, & Capraro, 2011; Benes-Laffety, 1995; Bilhartz, Bruhn, & Olson, 2000; Costa-Giomi, 2005; Omniewski & Habursky, 1998). One of the key rationales for music and mathematics integration is due to the similarities between the two subjects and the professionals from the two disciplines. Even though musicians emphasize expression of emotion and mathematicians seek for abstraction and logic, both groups of professionals analyze and synthesize patterns to create elegant products with complex structures.

Conceptual Framework

Engagement and Disengagement in Mathematics

Researchers in the past decade identified that disengagement is one of the critical problems that restraint students' development of mathematical capacity. The negative consequences of students' disengagement in learning mathematics were noticed on declines in students' achievement in mathematics and students' motivation in taking mathematics or mathematics related courses in high school and college (Forgasz, 2006; Sullivan, Mousley, & Zevenbergen, 2006). In a recent study of students that had dropped out of high school, nearly half (47 percent) cited a major reason for dropping out was boredom and finding classes to be disengaging (Bridgeland, DiIulio, & Morison, 2006). Students' emotional condition is one of the key factors in the process of learning mathematics because there are significant correlations between mathematics learners' cognitive learning process and affective learning process (Sylwester, 1995). However, in reality only a limited number of mathematics teachers focus on developing students' mathematics dispositions during the mathematics teaching process parallel with developing students' procedural fluency and strategic competence (Kilpatrick, Swafford, & Findell, 2001). Riconscente (2014) stated that in order to better understand the high incidence of dropout rates among minority students, it is vital to identify factors that foster students' individual interests in mathematics as a subject area.

Kilpatrick and colleagues (2001) proposed that a well-developed mathematics learner with satisfactory proficiency in mathematics is required to be competent in five strands coherently including conceptual understanding, procedural fluency, strategic competency, adaptive reasoning, and productive disposition. Productive disposition deals with students' beliefs toward the value and usefulness of mathematics as well as confidence, attitude, self-efficacy and self-identity toward learning mathematics. As a unique strand, the development of productive disposition is closely interrelated with the development of the other four strands. Particularly, students with negative mathematics dispositions may reduce their motivation to participate in mathematics-related tasks such as seeking for multiple solutions to challenging mathematics problems or making connections across mathematical concepts amongst different content areas (Ashcraft, 2002; Tobias, 1998). Instead, students who positively developed their disposition may put more effort on mathematics by demonstrating conceptual understanding, procedural fluency, strategic competency, adaptive reasoning throughout the learning process. Students may also recognize themselves as good problem solvers with confidence, which in turn may influence students' college courses and profession choices that are related to mathematics (Kilpatrick et al., 2001). Confidence in their abilities helps students determine how they will apply the knowledge and skills they possess, the amount of effort they are willing to expend in working the problems, the persistence they utilize when facing difficulties, and the thought patterns and emotional reactions they experience (Pajares & Kranzler, 1995).

Researchers have shown that negative dispositions toward mathematics were extensively identified among K-12 mathematics learners (Rameau & Louime, 2007; Ashcraft, 2002; Tobias, 1998). However, the origins of the cause of such phenomenon are multifaceted and more sophisticated methods are needed to be implemented for unraveling the mystery entirely. Among all recognized reasons, teaching mathematics through teacher-centered passive approach based on the model of "textbook content lecturing—drill problem assigning—single correct answer grading—standardized multiple-choice testing" was considered one of the major causes of students' negative dispositions (Furner & Berman, 2005). The development and maintenance of students' productive disposition requires teachers to integrate multiple teaching methods highlighting contextualization and real-life application with orientation of conceptual understanding and strategic competency (Bursal & Paznokas, 2006; Geist, 2010). Effective teaching approaches that may develop students' productive disposition include using problem solving activities based on learning opportunities via simulations with multiple ways of representation, self-inquiries with group collaboration and interdisciplinary connections with meaningful themes (An & Tillman, 2015; Geist, 2010; Gresham, 2007). It is important that a leaner-centered method requiring active student participation in a dynamic learning environment is a constant presence in the classroom.

Develop Disposition through Music Themed Mathematics Pedagogy

There are numerous links between music and mathematics. Mathematical concepts in all content areas (number operation, algebra, measurement, geometry, and data analysis and probability) are related with musical elements within music composition, instrument development, music playing and singing process (Beer, 1998; Harkleroad, 2006). Although most existing literature investigating the relationship between music and mathematics was performed (1) at the subject level by musicians focusing on mathematics application for developing music and designing instruments and (2) at the cognitive level by psychologists focusing on the impacts of musical experiences upon cognition in mathematics, some educational researchers explored the music-mathematics integration at the pedagogical level (An et al., 2008; 2011a; 2011b; 2013; 2014a; 2014b; 2014c; 2015a; 2015b).

In particular, An and Capraro (2011) developed some of the preliminary music-mathematics interdisciplinary activities in their book *Music-Math Integrated Activities for Elementary and Middle School Students*. In this book more than 50 activities were generally categorized into music composition and musical instrument designing. In addition, An and Tillman (2014a) analyzed 78 lesson plans of music themed mathematics pedagogy developed by preservice teachers and inservice teachers and found that there are 15 specific ways of associating music contents with mathematics contents (see figure 1). Moreover, An and Tillman identified that music-mathematics integrated teaching approach may provide additional emphasis on mathematics processes including (1) solving mathematics problems based on students' original musical works; (2) creating their music works based on mathematical patterns; (3) communicating among peers through music playing and sharing; (4) connecting concepts within mathematics concepts and between mathematics and music; and (5) representing mathematics through alternative ways such as music notating, singing, playing, composing, and instrument designing.

Learning mathematics in a music-based interdisciplinary curriculum has provided students with opportunities to comprehend the world from a different perspective, leading to success in mathematics (Gamwell, 2005). Music themes for mathematics lessons can help students in developing conceptual understanding through reassuring diverse cognitive and affective experiences (Selwyn, 1993). Researchers have found that such type of curriculum can offer students an emotionally motivating mathematical learning environment with less anxiety about mathematics (Eisner, 2002; Sylwester, 1995; Upitis & Smithrim, 2005). An integrated music-mathematics teaching approach can enable students to support knowledge transfer from the arts to non-arts content, as they build the connections between empirical music experiences and abstract mathematical concepts (Fiske, 1999). By contextualizing mathematics education within music composition and instrument design, the natural overlap between these two disciplines offers students additional opportunities to explore, understand, analyze, and interpret mathematics (An et al. 2011; 2013).

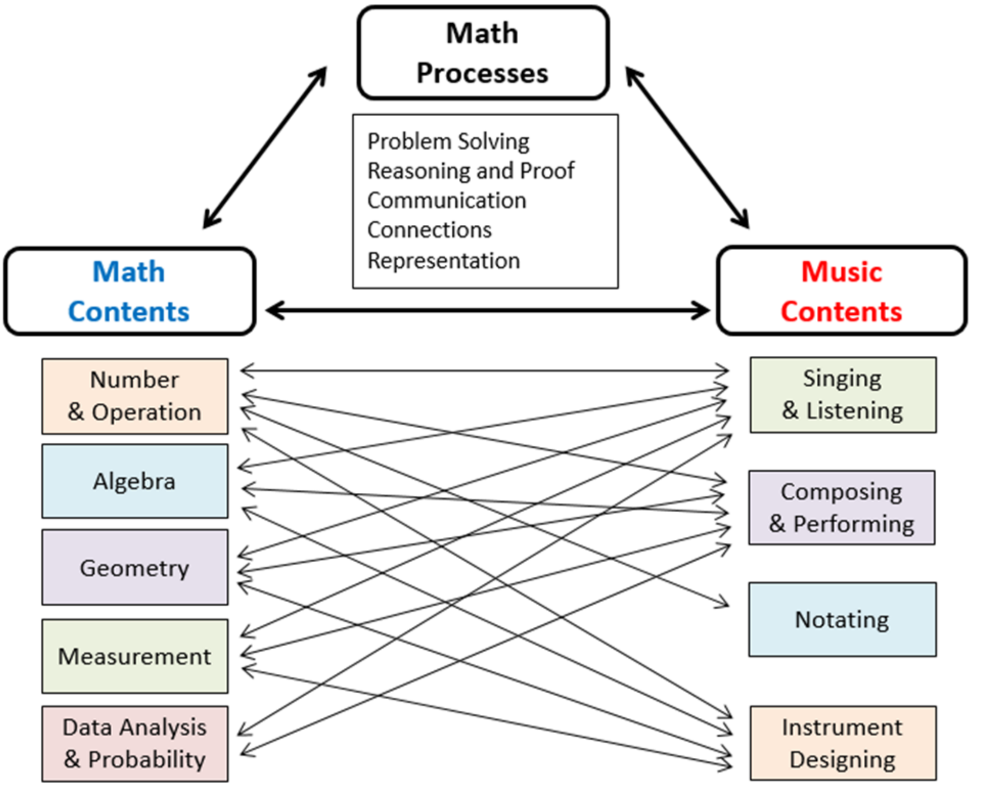

Figure 1. *Identified ways of integrating mathematics and music contents through mathematics processes.*

Specifically, in one of our earlier exploratory studies (An et al., 2011) we proposed a theoretical framework for illustrating the logical model of the effects of music on mathematics learners' dispositions (see figure 2). Aesthetics can be developed as a valuable educational resource to offer students inventive opportunities to see, hear, feel, make, and create meaningful contexts, through which students may construct their knowledge cognitively, perceptually and emotionally (Greene, 2001). Music related activities as an atheistic resource can set up a high motivational environment, within which students can participate in enjoyable and sense making mathematical activities. In this high motivational learning environment, students may aesthetically be engaged by (1) their original interests in and previous musical experiences along with their curiosity toward the relationship between music and mathematics, and (2) the pleasant musical creation experiences.

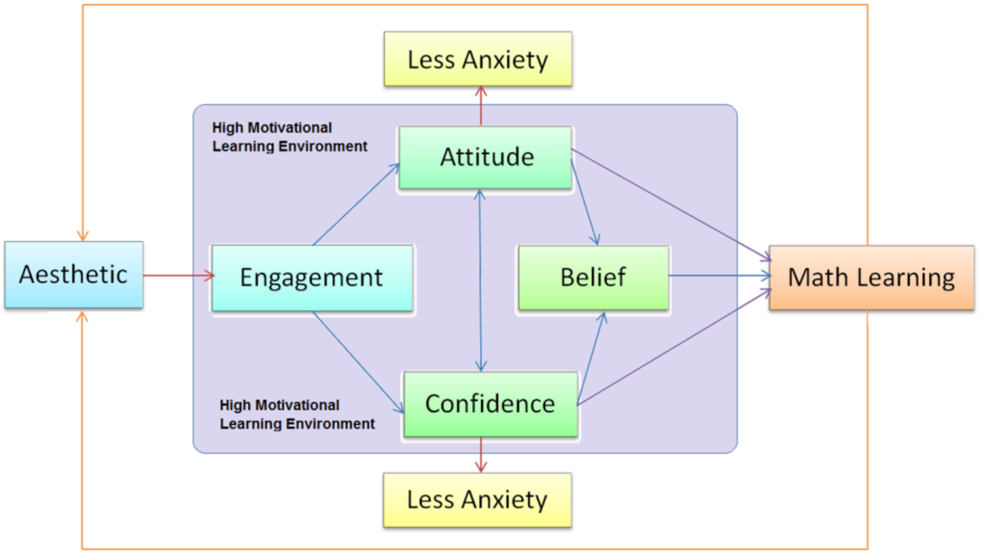

Figure 2. *Conceptual framework of the effects of music on students' learning of mathematics.*

By learning mathematics through music students may understand the critical role of mathematics in creating aesthetic works. The beauty appreciation process within both music and mathematics through playing music, especially the self-composed music based on self-designed musical instruments may externally and internally motivate students' mathematical learning behaviors. As the pleasant feeling emerges in the high-motivational learning environments filled with aesthetic elements, students' anxiety of mathematics may be relieved as the results of exploring and investigating mathematical concepts associated with enjoyable musical related practices. Such music-mathematics integrated product-oriented learning experiences may not only provide students a cheerful sense of achievement when finishing mathematical tasks contextualized in music themes but will also offer them an additional reinforcement by playing and sharing music works that they created by themselves. The positive reinforcement, in turn, may further improve students' engagement in learning other new mathematical knowledge and facilitate the effort needed to do more challenging problems in mathematics.

As part of a larger federally funded project dedicated to improving K-8 students' STEM achievement and dispositions through contextualized mathematics and science education, the current study emphasized exploring the effects of implementing music themed mathematics lessons on upper elementary students' mathematics dispositions. The specific research question for the current study is, "What are the effects of music themed mathematics pedagogy on developing upper elementary Hispanic students' mathematics dispositions?"

Method

Setting and Participants

The study took place at an urban charter school in an English-Spanish bilingual metropolitan area located in the southwest region of the United States. At the time of the study, the preparatory school served approximately 260 students from Pre-K through 7th grade, with around 87% of the student body having Hispanic ethnicity. Six classes of students in grades four, five and six (n=71) and six teachers, participated in the current study. More detailed information is presented in table 1.

Table 1

Teacher and Student Information by Grades and Classes

Grade Levels	4th Grade		5th Grade		6th Grade	
Class/Teacher	A	B	C	D	E	F
No. of Students	11	12	12	12	13	11

The study was conducted during the target school's annual complimentary three-week summer camp. The school was running based on a regular academic semester schedule for the summer camp from 8:00 am to 2:30 pm—breakfast and lunch were offered from 8:00 to 8:30 and 11:30 to 12:30 respectively. During the regular instructional time, 90-120 minutes were offered daily to students for receiving the target intervention activities. To facilitate researchers' observations and teachers' sharing of musical instruments, manipulatives and instructional materials, teachers from different grade levels offered sessions at different times with minimum overlaps of instructional time.

Intervention Procedure

The music-themed mathematics lessons that were implemented in the study were developed by a group of college professors collectively with common research interests; however, with diverse academic specializations on mathematics education, music education, mathematical science, and educational technology. The meta-curriculum was developed first with more than 70 available lesson plans (see An & Tillman, 2014), and the six participating teachers working in groups selected 10 lessons to be implemented with their students in the summer camp. Prior to beginning the intervention, all participating teachers completed a series of workshops (total of 12 hours) led by the curriculum development team members four weeks before the intervention. Each of these individual music-mathematics integrated lessons was focused on at least one major mathematics content area. Within the 10 lessons, music activity themes were categorized into three major themes: (1)

music appreciation and orchestration, (2) *music composition and playing*, (3) *musical instrument investigation and development*.

In the theme of *music appreciation and orchestration*, students observed videos of professional musicians' music production processes and performances based on a variety of instruments and music from different cultures (e.g. Hispanic, Middle Eastern, Chinese). Using a musical instrument classification system, students were faciliated to identifying and understanding the mathematics relationships behind the sound production of idiophones, membranophones, chordophones, aerophones and electrophones. Such mathematical relationships included the structures of complex music forms, waveform shapes, frequency components, timbre, wave modulation (strike/attack, sustain, tremolo, fade), rhythm and dynamic patterns. For example, students explored arithmetic sequences in terms of overtone series and explored geometric sequences in terms of chromatic scale and guitar fret/flute figuring locations.

In the theme of *music composition and playing*, students investigated how scientists and artists alike use an iterative creative process to arrange and combine pieces to satisfy human needs and desires. To facilitate students in composing and playing their own music, graphical notation (An et al, 2011, 2013) was used as the main approach to represent music by using colors, shapes, numbers and letters to represent the music notes. Based on this graphical notation system, students composed music by placing a group of color cards on their desk and playing color coded instruments such as handbells and boomwhackers. Specifically, students (1) explored and analyzed algebraic patterns and proportional relationships, (2) made geometrical transformations, (3) conducted measurement and designed measurement instruments, and (4) designed and conducted experiments to explore probabilities (e.g. exploring permutation and combination in chords and melody development processes) in self-composed or professional music works.

In the theme of *musical instrument investigation and development*, students discovered the principles of scientific inquiry and formulated a hypothesis about how changing the properties of an instrument would affect its sound and tested the hypothesis. Students explored one, two, and three dimensional geometric concepts and relationships in different types of musical instruments (idiophones, membranophones, chordophones, and aerophones) and explored acoustical physics to understand how the patterns of shapes, dimensions and materials affected instrument sound and tones. Specifically, students (1) used geometry and measurement concepts to design and construct different types of instruments, (2) used knowledge of sound production for basic acoustic instrument types to experiment with combinations of vibrating strings, pipes, bells, membranes and reeds and manipulate variables (e.g., length, size, volume, shape, material, and tension); (3) determined the impact of such manipulation on the sound properties of pitch, tone quality or timbre, loudness, resonance time, and so forth.

Data Collection and Data Analysis

The mathematics disposition survey themes along with individual items adopted in the current study were adapted from the *Attitudes towards Science Inventory* (Gogolin & Swartz, 1992) and *Attitudes towards Mathematics Inventory* (Tapia & Marsh, 2000) by choosing appropriate items, and then revising them to be more specifically orientated towards assessing mathematics dispositions. The instrument was developed by all team members (four professors, an external evaluator, and three graduate students) with several iterations of changes, the final survey instrument consisted of 22 items. The instrument had five levels of responses based on a Likert scale ranging from "strongly disagree" to "strongly agree". The instrument items focused on five major themes: (a) four items were on the value of mathematics, (b) four items were on self-confidence in mathematics, (c) five items were on enjoyment of mathematics, (d) four items were on motivation of learning mathematics, and (e) four items on attitude towards mathematics.

The collection of pretest and posttest data was conducted in the first day and the last of the study. With the purpose of ensuring that the students can comprehend the meaning of each individual survey item with minimum miscommunication, in both pre-and-posttest each classroom teacher followed the same three-step procedure for the assessment administration. First, the teacher displayed each individual survey by using a projector, and simultaneously read the item with interpretations and provided certain Spanish translations for specific terms. Second, student participants then quietly re-read the survey item to themselves, and individually responded on the survey item by marking the target level of the scale. Finally, the teacher walked around the classroom offering assistance to individual students and once all students reported the completion of an item the teacher would then switch to the next item and replicate the same process listed in steps one and two. Based on the data collected from the pre-and-posttest, a paired-sample t-test was implemented to compare the differences and identify statistically significant differences in mean scores and standard deviations. Specifically, descriptive statistics including means and standard deviations were computed and matched, and significant tests were examined to determine the statistical differences between the results of two surveys that the student participants reported before and after the interventions.

Results and Discussion

The results of the paired-sample t-test (see table 2) demonstrated statistically significant differences from pretest to posttest in all five disposition themes including (1) *value of math*, (2) *self-confidence*, (3) *enjoyment of math*, (4) *motivation*, and (5) *attitude.* Specifically, in the theme of *value of math*, student participants' mean scores improved 0.35 points based on a five-point Likert scale with a p value smaller than 0.001 and a medium-large effect size;

in the theme of *self-confidence*, student participants' mean scores improved 0.55 points based on a five-point Likert scale with a p value smaller than 0.001 and a large effect size; in the theme of *enjoyment of math*, student participants' mean scores improved 0.51 points based on a five-point Likert scale with a p value smaller than 0.001 and a medium-large effect size; in the theme of *motivation*, student participants' mean scores improved 0.80 points based on a five-point Likert scale with a p value smaller than 0.001 and a large effect size; in the theme of *attitude*, student participants' mean scores improved 0.42 points based on a five-point Likert scale with a p value smaller than 0.001 and a medium effect size.

As the findings indicate, the students who participated in music-math interventions showed an increase in positive dispositions towards mathematics (see Table 2). This can be contributed to a variety of reasons such as the level of anxiety and engagement exhibited by these students (An, Tillman, Boren, 2014). These students were actively engaged in their learning experience, which increased their enjoyment of math. According to Sousa (1995), in order for the brain to learn and retain new information, the information must make sense and have meaning to the learner. Incorporating music into mathematics instruction not only enhances the learning experience for students, but also creates a meaningful learning experience that increases students' dispositions towards mathematics. As students experience these different forms of mathematics instruction, they begin to realize and understand the value of math in real-life situations (An, Tillman, Boren, 2014).

Integrating music as a different approach to teaching mathematics also enables students to better understand mathematics. (An, Capraro, Tillman, 2013). As students are able to better understand mathematics, their motivation to participate in mathematics lessons generally increases. This is because their attitudes adjust from being anxious to being engaged learners, actively participating in these lessons. It should be noted that although former research does indicate an improved disposition towards mathematics after music-related instruction, students can become engaged at any grade-level and music activities can be used in a variety of mathematical content areas to increase student involvement and dispositions.

The positive attitudes that students exhibited can also be due to the enjoyment students reveal during these types of activities. Their attitudes adjust as they become more confident in mathematics, thus allowing diverse cognitive and affective experiences. It is through this enjoyment of mathematics that students can be open to creative expression that facilitates the learning process. This is because creating music and being involved with music improves spatial-temporal reasoning (Sousa, 1995). Such improvement can also contribute to the positive shift towards mathematics instruction as it allows for students to visualize spatial patterns.

Further studies have shown that playing music at a certain tempo can change the heart rate (Bernaldi, 2007). The playing of slower tempo music causes the heart rate to decrease, thus affecting the disposition of the students in the classroom, allowing for a calmer approach towards mathematics. Similarly, when focusing on graphical notation, it is pleasing to find patterns and reasons why music is written the way it is. As students begin to understand the patterns and proportions found in music, they are able to apply that knowledge in a mathematical context. As the brain makes connections to prior knowledge associated with the pleasing aspects of the arrangement of music, a correlation can be made with a resolution of mathematical components. This is significant because it allows for positive dispositions towards mathematics to be made.

Table 2

Results of the Paired-Sample t-test for Each of the Disposition Themes

Disposition Themes	(n=71)	Pretest	Posttest	Sample Items (# of Items)
Value of math	Mean ± SD	3.73 ±0.68	4.18±0.46	Math is important in everyday life. (4 items)
	p & *t* values	<0.001 (4.348)		
	Cohen's *d*	0.76		
Self-confidence	Mean ± SD	3.17±0.51	3.72±0.60	I believe I am good at solving math problems. (4 items)
	p & *t* values	<0.001 (6.106)		
	Cohen's *d*	0.99		
Enjoyment of math	Mean ± SD	3.46±0.60	3.97±0.62	Math is a very interesting subject. (5 items)
	p & *t* values	<0.01 (4.606)		
	Cohen's *d*	0.84		
Motivation	Mean ± SD	3.39±0.81	4.19±0.46	I plan to take as much math as I can in school. (5 items)
	p & *t* values	<0.001 (6.666)		
	Cohen's *d*	1.21		
Attitude	Mean ± SD	3.53±0.62	3.95±0.83	I have a good feeling toward math. (4 items)
	p & t value	<0.001 (3.349)		
	Cohen's *d*	0.57		

Different from the curriculum that claimed to be entertainment-contextualized mathematics but in actuality primarily entertainment oriented with a limited level of offering sense making hands on activities for students to discover mathematics (e.g. Moomaw, 2011, 2013). During the intervention described in the current study, the student participants experienced mathematics learning through an interdisciplinary approach based on engaging age-appropriate inquiry activities. Our intervention of implementing music-mathematics integrated curriculum exposed the possibility of developing higher levels of mathematics lessons with meaningful contextualized themes—using music as mathematics manipulatives for students to conceptualize mathematical relationships and patterns. The overall findings according to the comparison between pretest and posttest indicated that the student participants' mathematics dispositions were improved as a result of the intervention. In this current study, the natural connections between mathematics and music were developed into educational materials, and a highly engaging learning environment was created based upon these lessons. When students are learning mathematics in a high motivational learning environment with musical elements that can be analyzed, synthesized and created, they deliberately assimilate the delighted mood with the mathematics learning process.

Although the findings in the current study consisted with existing literature on music themed pedagogy for teaching mathematics as well as the impacts of music related practices on learning mathematics, our current exploration offered new insights about the implementation of music-mathematics integrated lessons in formal classroom settings. In our previous research attempts based on small scale implementation of music-mathematics integrated curriculum for certain grade levels (An et al., 2014a; An & Tillman, 2015a) and short intervention of music-mathematics integrated pedagogy (An et al., 2011; An et al, 2015b), we accumulated empirical evidence of the benefits of music themed mathematics pedagogy on students and preservice teachers' dispositions and performances in mathematics. The current study made it clear that a music-mathematics integrated teaching approach can be widely implemented across different grade levels.

Limitations should be noted in this study. First, the sample size of student participants was fairly small and their grade levels were limited to upper elementary grades. Moreover, the study included only certain type of music themed mathematics teaching strategies. Many other types of music-mathematics integrated approaches for teaching mathematics were not included. For example, Robertson and Lesser (2013) and Lesser (2014) discussed a variety of methods of using mathematical lyrics and harmonic notes to engage and to motivate students to learn middle school and college level mathematics. The encouraging findings in the current study invite further large-scale investigations involving more student participants with broader ranges of grade levels based on more types of music activities. The second limitation in our study is that the intervention duration only lasted three weeks and the retention of the positive shifting of students' mathematics disposition is unknown. A logical next step would be to conduct longitudinal studies with multiple years to assess and track students' future mathematics dispositions, achievements, and career choices.

While the current education system is marginalizing arts in K-12 school curriculum, the current study demonstrated the value of arts as well as how arts elements can be used as an educational resource for teaching mathematics. The results contribute to an exemplary model for elementary teachers to improve their students' productive disposition toward mathematics: aesthetics can be explored as a methodology to create an emotionally stimulating learning environment for designing and teaching mathematics lessons, where students can be cognitively and affectively engaged with less anxiety when participating in inquiry tasks in mathematics (e.g. Eisner, 2002; Sylwester, 1995; An et al., 2015a). Along with this identified benefit of music themed activities on students' mathematics dispositions, it is important to recognize how students comprehend mathematics in a setting that facilitates mathematical processes, especially focusing on connections and representations.

This study is part of a line of research investigation that appears to be gaining cumulative empirical evidence (e.g., Tillman, An, Cohen, Kjellstrom, & Boren, 2014; Tillman, An, Boren, & Slykhuis, 2014; Tillman, An, & Boren, 2015) that mathematics educators should adopt and develop a curriculum with contextualized themes as well as interdisciplinary tasks. We do not claim that music should be the solitary theme for developing mathematics pedagogy. Instead, we believe that the development of students' mathematics dispositions should transcend single subject curriculum boundaries and link school subjects with students' personal interests.

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