Elementary Teachers Integrate Music Activities into Regular Mathematics Lessons: Effects on Students' Mathematical Abilities

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Abstract: *This article presents exploratory research investigating the way teachers integrate music into their regular mathematics lessons as well as the effects of music-mathematics interdisciplinary lessons on elementary school students' mathematical abilities of modeling, strategy and application. Two teachers and two classes of first grade and third grade students (n=46) participated in the present study. The two teachers designed and implemented music activities as an integrated part of their regular mathematics lessons across five weeks. Results demonstrated that both teachers integrated a variety of music activities with different mathematical content. The music-math interdisciplinary lessons had positive effects on multiple mathematical ability areas.*

Introduction

Evidence clearly indicates that the traditional mathematics curriculum and instructional methods are not serving students well (Hiebert, 1999). Traditional mathematics instruction that consists of assigning the same problem to every student, lecturing from the textbook, insisting on one way to solve problems, and neglecting conceptual understanding has not only been accused of being the cause for low mathematics achievement, but also as the origin of mathematics anxiety (Furner & Berman, 2005; TIMSS, 2003). The traditional method of instruction may be ineffective, because it is unable to reach all students and meet their needs. Thus, traditional instruction has prevented some students from making the most of their skills and abilities (Scott, 2005). In contrast, teaching mathematics using effective didactic strategies (Vinner, 1997), with the goal of developing students' conceptual understanding through the use of problem-solving activities, models, simulations, discoveries, challenges, and games, has the potential to close the achievement gap and reduce mathematical anxiety (Tobias, 1998; NCTM, 2006).

In response to findings from cognitive science, which show that learning is a situated, socially-constructed, and culturally intervening procedure, educational researchers have proposed several integrated curriculum and instructional models to provide students with learning experiences that can motivate intellectual and emotional understanding (Chrysostomou, 2004; Deasey, 2002; Mansilla, 2005). Because integration of subject areas has been shown to have powerful effects on learning, arts-integrated curricula can provide students with a socially-relevant democratic education that transcends disciplinary boundaries and engages learners through self-reflection and active inquiry (Parsons, 2004). According to Fiske (1999) and Erickson (2001), teaching through the arts can: (a) transform learning environments; (b) reach students who may not be easily reached; (c) promote communication among students; (d) provide opportunities for adult involvement; (e) offer new challenges to successful students; (f) address important problems, issues, and concepts; (g) decrease curricular fragmentation; (h) allow teachers and students to explore knowledge more deeply; (i) challenge higher-levels of thinking by helping students connect knowledge; and (j) connect in-school learning to the real-world.

Ellis and Fouts (2001) posited that interdisciplinary education can not only improve students' higher-order thinking skills and motivation for learning, but also provide opportunities to understand knowledge from multiple perspectives and assist in the transfer of learning (Erickson, 1998). In recent years, researchers have consistently found benefits for teaching mathematics integrated with science and language arts (Keen, 2003; Marrongelle, Black, & Meredith, 2003). These interdisciplinary connections provide students with an opportunity to make sense of mathematics and apply their mathematical knowledge in meaningful ways by connecting new knowledge to existing knowledge (Schoenfeld, 1988).

One method for teaching mathematics is to integrate arts into instruction (Betts, 2005). Music is an ideal form of art to be integrated in mathematics instruction. The links between music and mathematics are very rich and include melody, rhythm, intervals, scales, harmony, tuning, and temperaments. These musical concepts are related to the mathematical concepts of proportions and numerical relations, integers, logarithms and arithmetical operations and the content areas of algebra, probability, trigonometry, and geometry (Beer, 1998; Harkleroad, 2006). In the past decade, educators have implemented several different instructional strategies to provide a music-mathematics integrated curriculum, although the levels of integration have varied (An, Ma, & Capraro, 2011).

Mathematics-music integrated instruction has the potential of improving students' attitudes toward learning mathematics and of increasing students' mathematics achievement (An, Kulm, & Ma, 2008; An, Ma, & Capraro, 2011; Benes-Laffety, 1995; Omniewski, 1999). In regard to the first point, music can be used to engage students in learning mathematics in an enjoyable but also relevant way. Secondly, music can be used as a resource by teachers to present and design mathematical problems in non-routine ways. This provides students with the opportunity to apply their mathematical knowledge in meaningful ways and connect new mathematical knowledge to existing knowledge. The overarching goal of the current study was to examine the effects of a music-mathematics integrated intervention on elementary students' mathematical abilities.

Theoretical Framework

The current study was based on a theoretical framework that includes Gardner's (1993) multiple intelligence theory to enhance classroom instruction and the use of aesthetics as a way to provide a rich and emotionally stimulating mathematical learning context (Eisner, 2002; Sylwester, 1995; Witherell, 2000). From the perspective of the theory of multiple intelligence, if students have difficulties making sense of the principles of mathematical content, one should consider using alternative routes to present ideas that may facilitate students' conceptual understanding (Kassell, 1998). Embedding musical activities into mathematics instruction can help develop students' mathematical understanding and also provide students with an enjoyable experience for developing logical /mathematical intelligences associated with musical/rhythmic intelligences (Shilling, 2002). Moreover, as an application of multiple intelligence theory, teaching mathematics based on musical activities facilitates students' ability to complete the process of knowledge transfer. As a result, students whose strengths lie in areas other than the logical-mathematical intelligence learn mathematics more easily (Johnson & Edelson, 2003).

Motivational theorists have identified two forms of motivation: extrinsic and intrinsic. Extrinsic motivation refers to motivation that lies outside of the individual and the task being performed. Conversely, intrinsic motivation refers to motivation within the individual and the task that the individual is involved in (Csikszentmihalyi, 1996). According to motivational

theory, students who are intrinsically motivated are more likely to exhibit initiative, independence, sense making and enjoyment in learning mathematics (Csikszentmihalyi, 1996). Mathematics instruction integrated with music can effectively increase students' intrinsic motivation, because it fosters an enjoyable learning experience in which students may be more aesthetically engaged. When students possess intrinsic motivation, they tend to pursue more advanced mathematical knowledge based on their own initiative and accept more challenging tasks during learning (Glastra, Hake, & Schedler, 2004). Students with mild disabilities including, for example, speech/language impairment or autism, have been shown to benefit from mathematics learning activities that provide an engaging and authentic context for learning (Van De Walle, et al., 2007).

Although extrinsic motivation is not as effective in facilitating mathematics learning, educators can still take advantage of extrinsic motivation (Bronson, 2000). By teaching mathematics integrated with music, students can feel the power of mathematics in the process of making music. As a result of this music-mathematics instructional model, students may not only experience a sense of accomplishment when completing mathematical tasks, but also enjoy and share their own music works (An et al., 2008). In addition, by using music to motivate students extrinsically, students may have better concentration and become more cognitively engaged in mathematics learning (An et al., 2011).

Mathematics-Music Interdisciplinary Curriculum and Instruction Model

An and his colleagues developed a music-mathematics interdisciplinary curriculum (An & Capraro, 2011) and an alternative model of mathematics instruction by integrating music into mathematics lessons (An, 2012). Multiple intelligence theories and motivation theories contributed to the theoretical framework to determine the effectiveness of mathematics-music interdisciplinary curriculum and the instructional model.

In their curriculum, An and Capraro (2011) provide a series of music-mathematics integrated activities. In the music-mathematics interdisciplinary curriculum, there are two types of music-mathematics integrated frameworks for teachers to design and teach their own lesson based on specific mathematical content: (a) the framework of musical instrument designing activities, and (b) the framework of music composition activities. Specifically, in the framework of the musical instrument designing activities section, teachers are provided with historical and cultural information about the origin, development and the characteristics for each of the target musical instruments. The curriculum also contains two great masters' musical pieces and one contemporary musician as a reference for teachers to share with students. The recommended music pieces are uploaded on a video-sharing website for students to listen to and view. After students understand what the target instrument looks like and how it sounds, they are assigned to a musical instrument designing activity project and one or two discussion questions. Students will learn and practice various mathematics concepts and skills in each activity and have opportunities to share their ideas with classmates during each activity. In the framework of the music composition designing activities, teachers are provided with an introduction to one music composition theory to share with students at the beginning of each activity. After students have a basic understanding of the target composition method, they are assigned music composition activity projects and one or two discussion questions. Students will compose, play and share their

own music works and then be assigned several mathematics problems based on their own music works.

An (2012) proposed an instructional model for music-mathematics integrated lessons. The model has five phases, with each phase containing varying levels of focus on music and mathematics. In phase one, teachers introduce music knowledge using musical composition theories or musical instrument background. Music will be the sole focus of instruction in phase one. In phase two, teachers introduce the connection between the target music activity and the related mathematical objectives. Both music and mathematics will be the focus in phase two, but music will still retain more of a focus than mathematics. In phase three, teachers facilitate student engagement in the music activities by: 1) directing students to participate in the activity through a correct process; 2) encouraging students to think and ask questions to help them identify the key mathematical ideas from the music experience. Music and mathematics will have an equivalent focus in phase three. In phase four, teachers will use students' music activity products as a resource to: 1) design mathematical concepts or process examples; and 2) assign mathematics tasks based on students' own music activity outcomes. Both music and mathematics will be focused on in phase four, but a greater emphasis will be placed on mathematics. In phase five, teachers will focus on pure mathematics topics and help students improve their understanding of mathematical content from unsophisticated to rigorous levels. Music will not be included in phase five.

In An and his colleagues' curriculum and instructional model hypothesis, interactive music activities are used as a resource to create a highly motivational environment in which students are engaged in aesthetics through active participation. The key features of this model are that it allows students to make sense of mathematical concepts and processes through multiple pathways and to apply mathematics within real-world contexts (An, 2011).

Based on the music-mathematics interdisciplinary curriculum and instructional model to design and implement mathematics lessons, the present study was characterized by a sequence of classroom music activities aimed at providing teachers with a method of teaching mathematics integrated with music. The overarching goal of this study was to develop a music-mathematics interdisciplinary curriculum and then to examine how teachers adapted, designed, and taught such lessons. Additionally, the researchers desired to examine the effects of this curriculum and instruction model on elementary students' mathematics ability levels. Two specific research questions guided this study: 1) How and to what extent did two teachers from different grade levels integrate music into their regular mathematics lessons; and 2) Will the intervention of music-math integrated lessons significantly improve students' mathematics ability levels as measured by the MSA assessments?

Method

Participants

Two female elementary school teachers participated in the present study. Both teachers, identified as Asian American, had multiple years of teaching experience. Additionally, at the time of the study inception, both teachers were graduate students in mathematics education. Before the study, both had attended a series of professional development (PD) seminars (total of 10 hours) on mathematics/music integrated instruction. The PD was led by doctoral students and college professors. Additionally, both teachers had multiple interactions with the PD facilitators.

In this regard, the teachers had regular meetings with PD facilitators where they discussed lesson plan development. Prior to the study, the teacher participants had also prepared two pilot lessons teaching mathematics integrated with music and received feedback on these lessons from PD facilitators. Both teachers were also exposed to the pedagogical skills needed to teach mathematics lessons with music. Both were selected because of their prior involvement in a workshop, led by the first author, during a national teacher conference. Each of the teacher participants demonstrated the qualities and personality that the research team felt was appropriate for the current study.

A total of 46 students from two different classes taught by the participant teachers participated in the study. The classes were based at two separate schools in Southern California. Specifically, there were 25 students from the third grade class (n=11_{boys} and n=14_{girls}) ranging in age from 7 to 8 with 19 Asian, 1 African American, 1 Caucasian, and 4 Hispanic students. Among the 25 participants, 13 were English language learners at the intermediate, early advanced or advanced language levels. One participant who was at level 3 (Intermediate) had difficulty understanding the math problem solving questions. Additionally, there were 21 students in the first grade class ranging in age from five to six, and consisting of 5 Asians, 4 African Americans, 2 Caucasians, 5 Filipinos, and 5 Hispanics. Among the 21 participants, 6 were English language learners at the intermediate, early advanced or advanced language levels. In addition, 1 student was speech/language impaired and 1 student was autistic.

Intervention Procedures

The two participant teachers attempted to design and implement music activities as an integrated part of their regular mathematics lessons over a five-week period. During the intervention period, one 45-minute music-integrated mathematics lesson was introduced to the third grade student participants each week for five weeks. Each music-mathematics integrated activity was focused on one or more major mathematics content areas.

Music composition and playing activities were the two primary music activities that the teacher participants incorporated into their mathematics lessons. In the music-mathematics integrated lessons, students had opportunities to use graphical notation (e.g., music color cards) and a variety of musical instruments, such as handbells, drums, music sticks, and keyboards as manipulatives to learn mathematics. Some of the music-based mathematics manipulatives (such as digital piano) were made available to the participants by their schools that already owned this equipment, and some additional manipulatives (such as handbells) were provided by the researchers. Actual musical pieces in the form of graphical notation were also provided to the students to apply basic music theories to mathematics learning. Students had opportunities to experiment, practice, and apply various mathematics concepts and skills through a series of music-mathematics integrated lessons. Additionally, students had multiple opportunities to share their knowledge of basic concepts in mathematics with their classmates during each music integrated math lessons. For example, during the mathematics lesson, which incorporated a music composition activity, music composition color cards were provided to the students as their creative music composition tools. Students were taught to use color patterns, number patterns, and letter patterns written on the color cards to compose their own music. Students instinctively created music using patterns and played it using handbells, thereby sharing their musical works with the class. In addition, mathematics concepts were introduced and several mathematics word problems were provided based on the students' own musical works.

Research Design and Instrument

A quasi-experiment design with multiple pretest and posttest (Shadish, Cook, & Campbell, 2002) based on one treatment group with 10 observations before and after the treatment was utilized in the current study for investigating the effects of music-mathematics interdisciplinary lessons on students' mathematical abilities. The research design in the current study was diagrammed as:

Pretests					Posttests									
O_1	O_2	O_3	O_4	O_5	X	O_6	X	O_7	X	O_8	X	O_9	X	O_{10}

Before the intervention began, a series of five Model–Strategy-Application (MSA) assessments (O_1–$O_{5)}$ were administered to the participants. When the intervention began, another series of five MSA assessments (O_6–O_{10}) were administered to the participants after each music-mathematics interdisciplinary lessons.

Wu and An (2006 & 2007) developed the *model–strategy-application* (MSA) assessment as a method of determining students' mathematics ability in three areas. MSA was derived from the core strands of proficiency from NRC (2001) and RAND (2003), as well as the guiding principles of the *California Mathematics Framework* (2006). The MSA assessment includes three components: model, strategy, and application. Specifically, in the Model (M)column, students are asked to demonstrate their visual approach to solving a problem; in the Strategy (S) column, students use the mathematical terms and symbols to show the mathematical process to solve the problem; and in the Application (A) column ,students create their own word problems connecting and applying their learned knowledge to the real world. The MSA assessment (See Appendix 1) was administered to students after the music-mathematics integrated lessons each week, and all the MSA items directly assessed the content that was taught in the lessons based on the music-mathematics activity lessons. The overall reliability of the MSA assessment tests used in the present study is 0.904 for the first grade class and 0.893 for the third grade class.

Data Collection & Analysis

For the qualitative analysis, teachers' lesson plans and videos of all 10 music-mathematics lessons were collected and analyzed (five from the first grade teacher and five from the third grade teacher). Content analysis was used to analyze lesson plans and classroom implementations of lessons. The data were coded and categorized by careful viewing of lesson plans and video lessons. Each lesson's mathematics content focI,music integrated types, instructional materials and instructional process were generated from the coded categories and subcategories with the goal of determining how teachers integrated music activities into regular mathematics lessons.

For the quantitative analysis, the students' 10 MSA assessments pre and post intervention were collected to analyze change in mathematical abilities. The rubrics for the MSA were developed by professors and classroom teachers to establish content validity. Students' MSA work was assessed using the four-point rubric (Table 1). A series of paired-sample *t*-tests were used to determine statistically-significant differences in mean scores and standard deviations

between the pre assessments and post assessments throughout the intervention period that focused on students' learning in concepts, procedures, and problem solving through real world applications. The original alpha value was .05; after correcting for 15 paired *t*-tests, the new adjusted alpha for all tests was .003. Effect size estimates were calculated for each test expressed in Cohen's *ds* to determine whether those differences were important in educational terms (Capraro, 2004).

Table 1
MSA Assessment Rubrics for Students' Ability Level in Each Area

Level	Modeling	Strategies	Application
Level 1	Either no model or model completely inappropriate	Either missing computation or many computational errors	Problem either missing or impossible to follow
Level 2	Appropriate model used, but either not fully demonstrated, or possibly based on operation only, and did not show the process of conceptual developing	Only few computational errors, but followed rules and formulas on computations (routine way), or only by trial and error	Problem attempted, but difficult to understand
Level 3	Appropriate model used, and the process of modeling demonstrated	No computational errors, but solved problem by routine way or only by trial and error	Problem fairly clear, but not appropriate or connected to real life application
Level 4	Model used highly efficient and meaningful, revealing comprehensive understanding	No computational errors and used a flexible or creative strategy in computation, revealing complete understanding of solving	Problem very clear, appropriate, and connected to real life application

Results

How Teacher Participants Integrated Music into Mathematics Lessons

Based on the two participant teachers' lesson plans and lesson videos, it was determined that both teachers used a variety of music-related activities in teaching mathematics lessons with activities including singing, composition, playing handbells, the keyboard and percussion instruments, and music values. The 10 lessons taught by both teachers included all of five mathematics content areas listed in the *Mathematics Content Standards for California Public Schools* [MCSCPS] (2009), including: number sense (NS), algebra and functions (AF), measurement and geometry (MG), statistics, data analysis, and probability (SDAP), and mathematical reasoning (MR) (see Tables 2 & 3).

Table 2

First Grade Teacher's Weekly Intervention Lessons' Mathematics Standard Focus, Music Integrated Strategy, Instructional Materials and Instructional Processes

Week			Instructional Processes
1	Focus	NS 2.1 & MR 1.2	(1) Introduce the chant by discussing the lyric on visual poster; (2) Teach the chant: Rhythm in music; (3) Repeat the chant with whole class as they clap their hands on the steady beat; (4) Use function chart to organize the sum of beats in each line.
	Strategy	Using clap and chant to teach addition	
	Materials	Lesson slides; Apple, Apple – math chant on the poster; Math Music CD	
2	Focus	NS 2.1, 2.2 & AF1.1	(1) Start the lesson by singing *Five Little Speckled Frogs*; (2) challenge students to response as we sing the song with different numbers; (3) students respond to the subtraction song; (4) reflect on the song and start writing subtraction number sentence corresponding to the problems stated in the song; (5) teach academic vocabulary related to addition facts.
	Strategy	Using song: *Five Little Speckled Frogs* to teach subtraction	
	Materials	Five Little Speckled Frog slide; small white board; dry markers; flash card	
3	Focus	NS 4.0, 4.1, 4.2, 4.3	(1) Start the lesson by singing *Twinkle, Twinkle Little Star*; (2) use the pocket chart to organize unit fraction and the music notation values; (3) redirect students' attention to the music notation of *Twinkle, Twinkle, Little Star*; (4) show different notes and have students place each note next to the picture, fraction and the note – students match the name of each note.
	Strategy	Using note value to teach function	
	Materials	Pocket Chart: Circle shape divided into equal parts (e.g.1/2, 1/8); Unit fractions (e.g. 1,1/2); Music notations – corresponding note name cards; Music sheet – *Twinkle, Twinkle, Little Star*	
4	Focus	SDAP 1.0, 1.2; MR 2.2	(1) Show colored cards arranged in pocket chart for various songs; (2) Students count the number of notes in each line of *Twinkle, Twinkle, Little Star*; (3) help students create a function chart; (4) take the colored cards and stack in a pocket chart to create a bar graph for each color or note.
	Strategy	Handbells based instruction: exploring simple music composition using color patterns	
	Materials	Pocket chart – use different colors to represent music melody; Graphic notation cards (e.g. red cards represent the note of Do/C)	
5	Focus	MG 2.3, 2.4; SDAP 2.1	(1) Teach the song *Do Re Mi* from *Sound of Music*; (2) display *Twinkle, Twinkle, Little Star* color chart and ask students to identify any patterns; (3) examine patterns in the song, *Mary Had a Little Lamb*; (4) Student create and play their own music by following the instructions on the Music Composition Work Sheet.
	Strategy	Handbells and keyboard based instruction: learning data analysis based on students' own music work Probability	
	Materials	Music sheet to find patterns; Music CD – *Do Re Mi*; Music Composition Worksheet; Color cards to represent notes; Scale C through high C also color coordinated	

Note: The Mathematics Standard Focuses are based on the Mathematics Content Standards for California Public Schools.

Table 3

Third Grade Teacher's Weekly Intervention Lessons' Mathematics Standard Focus, Music Integrated Strategy, Instructional Materials and Instructional Processes

Week			Instructional Processes
1	Focus	NS 2.0	(1) Review and preview the lesson vocabulary and introduce the lesson materials and activity; (2) demonstrate how to connect the concept of fraction and music and explain the types of notes and their counting values using music charts; (3) use tambourine to demonstrate how many counts are in each music note; (4) have students come up to the class and play the music notes counting their counting values.
	Strategy	Counting music notes using percussion instruments	
	Materials	Music note chart with counting values: whole note, half note, quarter note, dotted half note, dotted quarter note; A variety of percussion instruments: (e.g. maraca, wooden cymbals); Handbells, mini-white boards	
2	Focus	SDAP 1.0, 1.1	(1) Explain to the students that they are now going to conduct a music color card drawing experiment and record the data on the index card; (2) teacher models the process of the experiment; (3) choose one table and perform the experiment together as a guided practice; (4) all groups perform their experiments independently.
	Strategy	Handbells and other percussion instruments based instruction	
	Materials	6 sets of music color cards in zip bags for 6 tables; Handbells: 1 red, 2 blue, 4 yellow; 1 big pouch and 6 big paper bags, 6 record sheets	
3	Focus	NS 2.0 & MG 1.0	(1) Explain to the students that they are now going to solve addition and subtraction word problems using the keyboard number line; (2) provide students with the sample word problems and solve them using keyboard number line together; (3) repeat forward and backward counting activities while solving related word problems; (4) students measure the length and the width of the paper keyboard number lines with their partners; (5) students show their answers of their measurement on their mini-white boards and teacher provides students feedback.
	Strategy	Keyboard Number Line Activity and Measurement Activity using percussion instruments	
	Materials	Keyboard written musical names, letters, and numbers; A variety of percussion instruments (e.g. maraca, banana shaker, wooden cymbals); Handbells, mini-white boards, a classroom set of paper keyboard number lines	
4	Focus	AF 2.2	(1) Pass out a set of color composition papers to each table and students create the color patterns in small groups; (2) choose one table's pattern and performs the color patterns musically using keyboard; (3) students play their own music/math patterns using hand bells to the class; (4) provide students feedback on the pattern creation they did and the outcome of their work as music.
	Strategy	Handbells based instruction: exploring simple music composition using color patterns	
	Materials	Basic 8 music note color papers written musical names, letters, and numbers; 6 sets of music composition color pattern packets; Hand bells	
5	Focus	NS 3.0	(1) Demonstrate how to connect the concept of fractions and music; (2) display the actual sheet music of *London Bridge*; (3) have students play the song using hand bells and teacher model how to relate the measures of the song and the concept of fractions; (4) use another song *Row, Row, Row Your Boat*, and repeat the same to reinforce student learning of the concept of fractions and one whole relationship.
	Strategy	Handbells and music sheet instruction: teaching fractions using measures of music	
	Materials	Basic 8 music note color papers written musical names, letters, and numbers; *London Bridge*, *Row, Row, Row Your Boat*, & *Twinkle, Twinkle, Little Star* color cards in a pocket chart; Handbells, mini-white boards	

Note: The Mathematics Standard Focuses are based on the Mathematics Content Standards for California Public Schools.

Specifically, on the mathematics content area, we located 6 lessons (3 - first grade and 3 - third grade) focusing on number sense, two lessons (1 -first grade and 1 - third grade) focusing on the algebra and functions, 2 lessons (2 - first grade and 1 - third grade) focusing on statistics, data analysis, and probability; 1 lesson (first grade) focused on measurement and geometry, and 3 lessons (2 - first grade and 1 - third grade) focused on mathematical reasoning. On the music-mathematics integrated strategies, we located two lessons that utilized singing activities (both in first grade), one lesson included a music-value activity (first grade), 4 lessons adopted handbell playing activities (1 - first grade and 1 - third grade), 3 lessons adopted composition activities (2 - first grade and 1 - third grade), 2 lessons adopted keyboard playing activities (1 - first grade and 1 - third grade) and 3 lessons adopted percussion instrument playing activities (all 3 in third grade).

Based on the analysis of the teachers' lesson plans as well as videos of the instructional process, we found that both teachers' lessons included music-math integrated activities and performances. Many similarities were found across the lessons designed by both teachers, including (a) guiding students to play various instruments while solving math-word problems and exploring the five major mathematics content standards; (b) helping students apply their newly acquired music knowledge to the understanding of math concepts and improving their mathematical reasoning skills; and (c) encouraging students to create their own word problems and apply the math concepts learned through music-math activities to their everyday lives.

The Improvement of MSA Ability Levels throughout the Music Intervention

In general, the ability levels of the first and third grade students in all three mathematical areas as assessed by MSA showed statistically-significant improvements after the intervention (see Table 4 & 5) with p values on all three MSA areas less than 0.001. Large effect sizes were found in both first grade and third grade students before and after three MSA areas with Cohen's $d > 1.66$.

Table 4

Results of Paired t-test on First Grade Students' Ability Levels for Each Pre and Post MSA Assessments

MSA Focus N=21		Mean	*SD*	*t* value	*p* value	Cohen's d
Post&Pre Model	Pre 1	2.62	1.02	-7.589	<0.0001	1.66
	Post 1	3.00	.93			
	Pre 2	2.19	.81			
	Post 2	3.24	.86			
	Pre 3	2.38	1.07			
	Post 3	3.43	.51			
	Pre 4	2.57	.75			
	Post 4	3.67	1.04			
	Pre 5	2.09	.83			
	Post 5	3.81	1.20			
Post&Pre Strategy	Pre 1	2.29	.90	-8.939	<0.0001	1.75
	Post 1	2.90	1.0			
	Pre 2	2.24	1.11			
	Post 2	3.14	1.15			
	Pre 3	2.14	.91			
	Post 3	3.29	1.18			
	Pre 4	1.95	1.16			
	Post 4	3.38	.91			
	Pre 5	2.19	1.03			
	Post 5	3.71	.78			
Post&Pre Application	Pre 1	1.90	.77	-8.221	<0.0001	1.70
	Post 1	2.33	1.08			
	Pre 2	1.62	.92			
	Post 2	2.67	1.24			
	Pre 3	2.00	.55			
	Post 3	2.81	.87			
	Pre 4	1.38	.74			
	Post 4	3.00	1.16			
	Pre 5	1.67	.97			
	Post 5	3.38	.79			

Table 5

Results of Paired t-test on Third Grade Students' Ability Levels for Each Pre and Post MSA Assessments

MSA Focus N=25		Mean	*SD*	*t* value	*p* value	Cohen's d
Post&Pre Model	Pre 1	2.28	.46	-11.71	<0.0001	3.40
	Post 1	2.80	.95			
	Pre 2	2.12	.60			
	Post 2	3.16	.62			
	Pre 3	2.28	.46			
	Post 3	3.36	.58			
	Pre 4	2.12	.60			
	Post 4	3.68	.48			
	Pre 5	1.96	.54			
	Post 5	3.96	.20			
Post&Pre Strategy	Pre 1	2.04	.68	-11.93	<0.0001	3.44
	Post 1	3.00	.76			
	Pre 2	1.68	.56			
	Post 2	3.20	.71			
	Pre 3	1.92	.64			
	Post 3	3.40	.87			
	Pre 4	1.68	.56			
	Post 4	3.68	.56			
	Pre 5	1.88	.53			
	Post 5	3.68	.69			
Post&Pre Application	Pre 1	2.28	.46	-12.59	<0.0001	3.00
	Post 1	2.88	.82			
	Pre 2	2.24	.44			
	Post 2	3.48	.40			
	Pre 3	2.28	.46			
	Post 3	3.60	.67			
	Pre 4	2.24	.44			
	Post 4	3.84	.87			
	Pre 5	2.12	.33			
	Post 5	3.92	.47			

Specifically, in the mathematical ability area of (M), the first grade students improved from 2.50±0.59 on the five pretests to 3.41 ±0.51 on the five posttests with an effect size of 1.66, while the third grade students' average level improved from 2.15±0.46 on the five pretests to 3.39 ±0.27 on the five posttests with an effect size of 3.40. In the mathematical ability area of (S), the first grade students' average level improved from 1.94±0.61 on the five pretests to 3.06

±0.67 on the five posttests with an effect size of 1.75, while the third grade students improved from 1.84±0.52 on the five pretests to 3.39 ±0.38 on the five posttests with an effect size of 3.44. In the mathematical ability area of (A), the first grade students' average level improved from 1.98±0.82 on the five pretests to 3.07 ±0.46 on the five posttests with an effect size of 1.70,while the third grade students improved from 2.23±0.37 on the five pretests to 3.54 ±0.40 on the five posttests with an effect size of 3.00.

Combining the results of first grade and third grade together, among the 15 sub-tests on the pretest of the three mathematical ability areas that we assessed, all the sub-tests showed that students had an average ability level lower than 2.5 including 7 sub-tests which had levels lower than 2.0. On the posttest, among all the 15 sub-tests on the pretest of the three mathematical ability areas assessed, all the subtests scores showed improvement in ability levels. All the sub-tests showed that students had an average ability levels lower than 2.5 including 11 sub-tests with an average ability level higher than 3.0 (Figures 1).

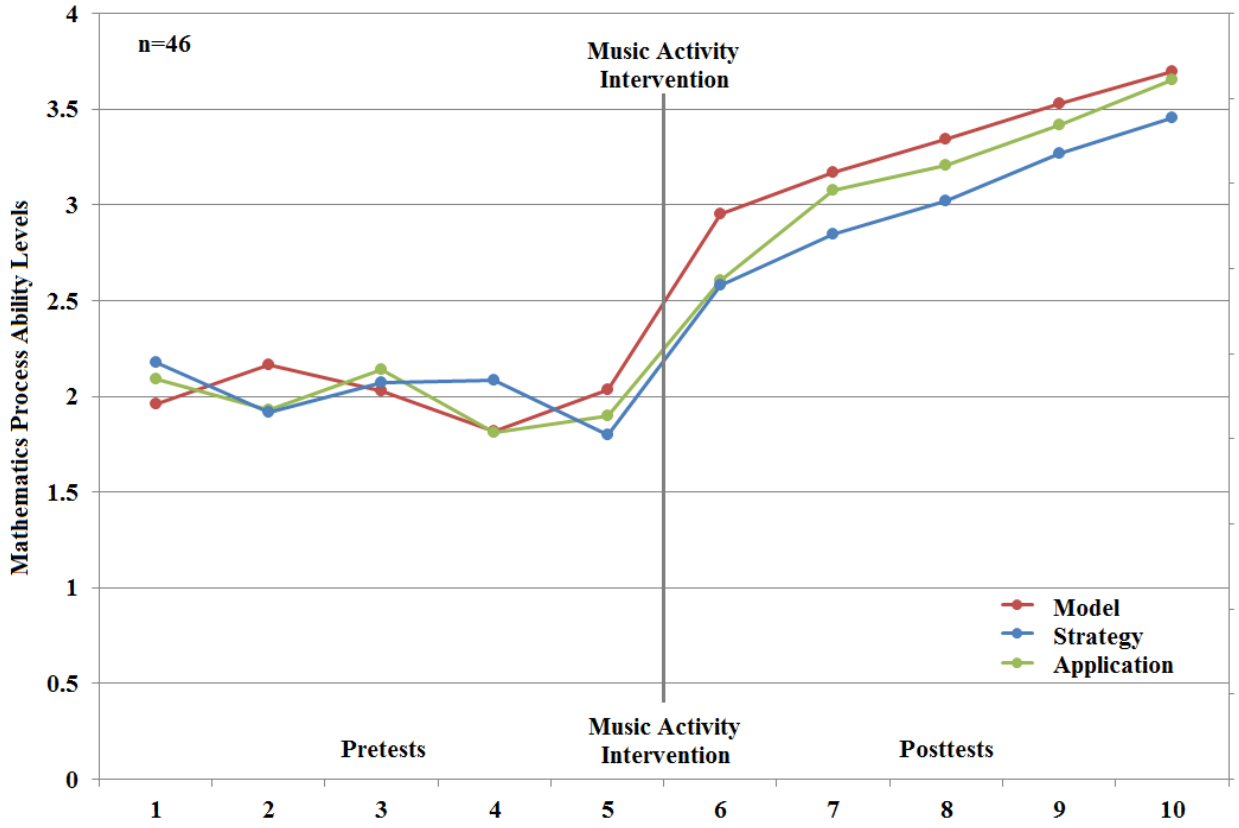

Figure 1. *Average ability level for each mathematics process pretests to posttests for first and third grade students.*

Discussion

The present study sought to investigate how two elementary school teachers designed music-mathematics interdisciplinary lessons by integrating a series of music activities into their

regular mathematics lessons, and also how these interdisciplinary lessons affected elementary students' MSA mathematics ability levels. The study began by identifying critical mathematics-music interdisciplinary lesson design elements in regular mathematics instruction for purposes of developing an intervention. The effects of the interdisciplinary lessons on students' mathematics abilities were measured by the MSA assessments. In the current study, music activities were used as curriculum resources to design and implement mathematics lessons. Teachers designed their own mathematics lessons using different music activities associated with different mathematics content areas. Consistent with previous research on the impact of music-integrated activities on students' mathematics ability levels (Benes-Laffety, 1995; Omniewski, 1999; Omniewski & Habursky, 1998), the present study's findings demonstrated that music-math integrated lessons have positive effects on multiple mathematical ability levels.

One of the goals of the present study was to examine how teachers integrated music into their regular mathematics lessons. The results showed that both teachers used various music composition activities and musical instrument playing across their series of music-mathematics integrated lessons covering all five major content areas listed in the [MCSCPS] (2009). This finding suggests that there are multiple ways to integrate mathematics instruction with music. Many current educators approach the integration of music into mathematics instruction on a limited and superficial level,i.e. focusing on low-level mathematics content such as counting beats and singing formulas (An et al. 2011; An & Capraro, 2011). This study provided an example of how to design and teach mathematics lessons in alternative ways and incorporate higher-order mathematics content.

This study showed that music can be used to make connections to all kinds of different mathematics content areas. For example, in the content area of NS, the first grade students utilized the song, "Five Little Speckled Frogs," to practice addition/subtraction fluency using singing activities; the third grade students learned how to add and multiply by counting music notes and solving related word problems from music composition activities. In the content area of FA, the first grade students could recognize and describe extended patterns as well as use position words to describe melody from musical composition activities. The third grade students could extend and recognize a linear pattern by its rules from music composition activities. In the content area of SDAP, the first grade students could collect, sort and display data using tally marks as well as a tally chart to make a bar graph and compare information. The third grade students conducted simple probability experiments by determining the number of possible outcomes and made simple predictions from instrument activities. In the content area of GM, the third grade students measured geometric figures using appropriate measurement tools from keyboard playing activities.

After the five-week intervention, the students demonstrated statistically-significant improvements in almost all post-test assessments of mathematical ability. This result indicates that the music-integrated mathematics lessons positively influenced students' mathematics ability levels in the areas of (M), (S), and (A). Specifically, the significant improvement in students' (M) levels indicates that their ability to draw pictures, tables, or charts to effectively solve mathematical word problems improved throughout the intervention. Moreover, as demonstrated by the significant enhancement of students' (S) levels, students' mathematical skills in using mathematical symbols, equations, and inequality to effectively show mathematical steps to solving mathematics word problems improved throughout the music implemented math instruction. Finally, the significant development of students' (A) levels showed improvement in

students' ability to create their own word problems by applying mathematical reasoning to the real world.

With the publication of *Principle and Standards* (NCTM, 2000), mathematics educators have paid greater attention to the mathematics processes of connection and representation, along with communication, reasoning and proof and problem solving proposed by NCTM. Mathematics learners can discover and understand mathematical ideas by experiencing different kinds of activities with connections made within and outside of mathematics. Music, with its unique features, can be used as a resource for students to make these connections and also as a way for students to represent mathematics in alternative ways.

The MSA assessment was used to examine students' mathematical abilities related to mathematical processes and content. The overall growth in mathematics ability from the pre to post assessment demonstrates that through music-mathematics interdisciplinary experiences students had multiple opportunities to improve abilities about mathematics process. Students can communicate mathematics ideas with their peers, represent mathematics concepts with multiple forms, connect mathematics content with different real life situations, think mathematics meanings from reasonable and logical perspectives and solve mathematics problems by using various problem solving strategies. During the intervention period, the students were offered different mathematics content related to a variety of mathematical-musical concepts. Throughout these non-traditional learning experiences, students were able to connect their mathematical intelligences with other intelligences such as bodily-kinesthetic, interpersonal, and spatial intelligences (Gardner, 1993).

The factors of increased engagement and motivation in learning mathematics could account for the improvement of students' mathematics ability levels as shown from the MSA assessments. In the present study, based on the carefully designed instructional pedagogy of teaching mathematical content and processes integrated with music, an enjoyable learning environment was created using a series of music-mathematics interdisciplinary lessons. As An et al. (2011) posited, the music-mathematics interdisciplinary instructional model may engage and motivate students to learn mathematics at several distinct levels: (a) in the beginning, students' original interests in, and the joyful experiences from, music appreciation of master pieces, engaged them in mathematics lessons; (b) the pleasant experiences of music composition and music playing further enhanced their engagement; and then (c) through this engagement, students were able to explore, apply and understand mathematics by designing their own musical instruments and composing their own musical works. The intervention lessons facilitated student engagement and motivation and thus assisted students in achieving the instructional goals in each lesson effectively.

Limitations and Educational Implications

It is important to note the limitations of this research. First, as the intervention period was only five weeks long, and a novel teaching strategy was used by teachers, the Hawthorne effect may have impacted the study results. Second, because the cluster sampling method was used to purposefully select one class of students in both first and third grade in an elementary school, the findings may not generalize to other elementary school students from different backgrounds.

The students who learned through the various music-integrated instructional settings demonstrated increased mathematics ability levels over the intervention period in the present study. Other factors may have accounted for this improvement, due to the emphasis on mathematics processes in each music-mathematics interdisciplinary lesson. By integrating music connections and representations in mathematics, teachers may have produced effective instruction for students to better understand mathematics from multiple approaches (Fiske, 1999; Gardner, 1993). Providing students with opportunities to create and explore mathematics problems by themselves can improve their ability to learn essential mathematical processes involving representing mathematical concepts in different ways, as well as making connections among mathematical content (Clayden, Desforges, Mills, & Rawson, 1994). Music composition and instruments playing activities in mathematics instruction enables students to enjoy mathematics and make sense of important mathematical concepts.

An important aspect of this study is the multidimensional nature in which we observed the ways that teachers integrate music into their mathematics lessons and the effect of using connections between music and mathematics to improve students' mathematics learning. Rather than using a single activity to intervene with a single group of people taught by researchers (An et al, 2008; 2011), two teachers from different schools and grade levels were invited to participate in active classroom research. The results demonstrated a similar pattern of improvement in mathematics abilities for students in both classes at different grade levels.

In conclusion, we do not suggest that the intervention activities that integrated music into mathematics described in this study are a prototype for all classroom activities related to mathematics. Instead, we argue that the development of a higher-level mathematical ability, such as the abilities we investigated in the current study (M, S, and A) should not emanate from a single curriculum or instrumental model, but rather should be developed by using multiple instructional strategies connected to content other than mathematics, such as music. We also believe that teachers should understand that in effective mathematics instruction subjects are interconnected. These interdisciplinary connections can be used to design and teach effective lessons.

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Appendix

Sample MSA question for first grade students:

14 little speckled frogs, sitting on the speckled log, eating most delicious bugs, yum, yum.
7 jumped in the pool, where it was nice and cool, now there are how many speckled frogs?

Sample MSA question for third grade students:

Mary's mother made two cakes with the same size, and she cut each cake into 6 pieces. Mary ate 1/4 of the two cakes. How many pieces of cake did Mary eat in total?