

Learning to Teach Music-themed Mathematics: An Examination of Preservice Teachers' Beliefs about Developing and Implementing Interdisciplinary Mathematics Pedagogy

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The study presented in this paper sought to offer a group of 21 preservice teachers with opportunities to learn about interdisciplinary mathematics pedagogy, plus the experience of implementing it with elementary students. It provided the participating preservice teachers' with an opportunity to reflect upon the potential advantages, as well as challenges, involved in developing music into an educational resource for teaching engaging elementary mathematics lessons. Analysis of the 391 pieces of qualitative reflections that were collected from the participating preservice teachers during focus group discussions, individual interviews, and self-reflection essays revealed the participants' general perceptions about the benefits and challenges of teaching mathematics through music activities.

Keywords • interdisciplinary curriculum • interdisciplinary mathematics instruction • preservice teachers' perceptions • pedagogical content knowledge

Review of Literature

Currently, much of the interdisciplinary research about combining music and mathematics education can be characterised as pertaining to one of following three dimensions: (1) mathematics as a tool during music creation; (2) music as a catalyst for mathematical cognition; and (3) music as a pedagogical approach to mathematics. Along the first dimension, mathematics and music complement each other as two subject areas—mathematics has been used as a tool by musicians toward the goal of refining music theories and improving instrument design and performance (e.g., Fauvel, Flood, & Wilson, 2006). Along the second dimension, researchers have investigated the impact of musical experiences on mathematical cognitive processes and capabilities (e.g., Rauscher, Shaw, & Ky, 1995). Contrasted with the first two dimensions, research about the third dimension—music as a context for classroom educational activities—has been comparatively limited, and more empirical evidence would be beneficial in providing both support and refutation of uncertain theoretical assumptions, as well as practical attempts at developing and implementing music-mathematics integrated

curriculum and instruction (e.g., Eisner, 2002; Fiske, 1999; Johnson, 2009; Johnson & Edelson, 2003).

Since the 2000s, curriculum developers and educational researchers have piloted and evaluated different ways of contextualising arts and popular culture components as mathematics teaching methods, including athletic sports (e.g., Gallian, 2010); extreme sports (e.g. Robertson, Meyer, & Wilkerson, 2012); graphical arts (e.g., Jarvis & Naested, 2012); choreographic arts (Rosenfeld, 2013); and theatre arts (e.g., Duatepe-Paksu, & Ubuz, 2009). Teaching mathematics through music-themed activities is one approach to helping preservice elementary teachers develop improved mathematics teaching self-efficacy (An, Ma, & Capraro, 2011; An, Tillman, & Paez, 2015) and to help elementary students better understand mathematics concepts and reduce mathematics anxiety (An, Capraro, & Tillman, 2013; An, Tillman, Boren, & Wang, 2014; An & Tillman, 2015; An et al., 2015). For preservice elementary teachers, music-themed activities can provide a bridge connecting mathematics pedagogy with a meaningful and accessible context capable of lessening anxiety toward both teaching and learning mathematics (Ernest, 1991; Gresham, 2008; Robertson & Lesser, 2013).

Mathematics as a Tool in Music Creation

The earliest documented investigation regarding the relationships between mathematics and music can be traced back to 500 BC, when the Greek mathematician Pythagoras recognised the ratios among pieces of percussion instruments; specifically, that the two pitches that have harmonic sound effects will have specific ratios in instrument sizes and weights. For example the corresponding ratio between an octave is 1:2, and between a fifth is 2:3 (Harkleroad, 2006). A variety of mathematical concepts such as arithmetic computations, geometrical transformations, and algebraic patterns, calculus, linear algebra, and analytical geometry have all been utilized in contemporary music composition and instrument design processes (Beer, 1998). With the help of mathematicians' contributions, musicians have improved the acoustical qualities of instruments, auditory measurement tools have been standardised, and complex musical instruments such as the electronic piano have been created (Fauvel, Flood, & Wilson, 2006).

Additionally, Fibonacci numbers, the golden section, transpositions, and inversions have been used to support musical composition methods among classical and popular music (Beer, 1998; Loy, 2006). Moreover, in one of the most revolutionary music movements during the eighteenth century, music-mathematicians created and applied equal temperament (i.e., an artificial music system in which all adjacent chromatic notes have an identical frequency ratio determined by logarithms and differential equations) on a piano, which enabled players to transpose keys without changing musical instruments (Cho, 2003).

Music as a Catalyst in Mathematical Cognition

The "Mozart effect" studies (Rauscher et al., 1993; Rauscher, Shaw, & Ky, 1995) have been one of the most influential series of research investigating measureable correlations between music-themed activities and proficiency at mathematical cognition. During these studies, Rauscher and his colleagues designed and conducted experimental research in lab settings, wherein participants were randomly assigned to one of three groups: (1) listening to Mozart's *Sonata for Two Pianos in D Major*; (2) listening to generic relaxing music; and (3) silence. Research findings demonstrated that participants who were assigned to listen to Mozart's music significantly outperformed their peers on spatial-reasoning assessments. A variety of studies conducted to replicate aspects of Rauscher's research, by changing music intervention methods and mathematics assessment tasks, found consistent evidence that music-related activities temporarily improved the participants' mathematical cognition capacities including mental visualisation of three-dimensional figures, mathematics problem solving skills, and memory abilities (Billhartz, Bruhn, & Olson, 1999; Hui, 2006; Ivanov & Geake, 2003; Nantanis & Schellenberg, 1999; Rauscher, Shaw, & Ky, 1995; Rauscher & Zupan, 2000; Rideout & Laubach, 1996).

More broadly, researchers have found reliable correlations between musical instrument playing and mathematics achievement. For example, researchers have compared students who participated in musical instrument lessons with peers who did not receive music lessons. Findings showed that the students with opportunities to learn and play a musical instrument or to practise vocal music demonstrated significantly higher mathematics achievement scores than their non-music peers (Costa-Giomi, 2004; Cox & Stephens, 2006; Haley, 2001; Kafer & Kennell, 1999; Rauscher & Zupan, 2000; Whitehead, 2001). Based on such findings, one of the proposed hypotheses is that musical experiences can stimulate areas of the brain responsible for mathematical reasoning. In keeping with this hypothesis, previous studies have demonstrated that the cognitive mechanisms relating the experiences of melody, harmony, and rhythm activate the same areas of the brain as do mathematical cognition abilities such as numerical calculation and estimation (Spelke, 2008).

Music as a Mathematics Pedagogical Approach

When students experience difficulty understanding mathematics concepts and lack any meaningful applications for mathematics in their life outside of school, their motivation for understanding mathematics is reduced, which in turn further impedes their development of mathematics knowledge (Gresham, 2008). One way to reduce both elementary students' and preservice elementary teachers' mathematics anxiety is to provide them with experiences with integrative teaching strategies that contextualise mathematics education into meaningful problem solving activities; often involving simulations, discoveries, challenges, and games (Gresham, 2007). Teaching mathematics through contextualisation within music-themed activities can be an effective approach to helping preservice elementary teachers understand mathematics concepts as well as develop mathematics teaching self-efficacy (An et al., 2011). Recent studies have demonstrated that pedagogy utilising music-themed mathematics lessons has helped students to better understand mathematics concepts and reduce mathematics anxiety (Eisner, 2002; Glastra, Hake, & Schedler, 2004; Robertson & Lesser, 2013). For preservice elementary teachers, music-themed mathematics activities can provide a bridge connecting mathematics pedagogy with a meaningful and accessible context, capable of lessening anxiety toward both teaching and learning mathematics (An, Tillman, Shaheen, & Boren, 2014; Vinson, 2001).

Music has been identified as a potent domain containing potentially rich educational resources for complementing mathematics pedagogy by offering a context for students to employ mathematical processes such as representations, connections, and communications (NCTM, 2000). Researchers have investigated the opportunities within music-integrated pedagogy, based upon meaningful inquiry activities, for students to apply and comprehend mathematics through alternative approaches (An et al., 2011; Cheek & Smith, 1999; Cornett, 2007; Robertson & Lesser, 2013). Using music-themed activities in mathematics classrooms not only facilitates students' understanding of mathematics concepts and dispositions toward mathematics (Eisner, 2002; Glastra, Hake, & Schedler, 2004; Robertson & Lesser, 2013), but also helps elementary teachers improve mathematics pedagogy and mathematics teaching self-efficacy (An et al., 2011, 2015). Specifically, positive findings have been reported across studies investigating the effects of music-mathematics integrated instruction, including: (a) motivating students to participate in more challenging mathematics tasks (Glastra, Hake, & Schedler, 2004); (b) engaging students in exploring relationships among mathematical concepts (Eisner, 2002); (c) creating a collaborative and enjoyable learning environment for students (Robertson & Lesser, 2013); and (d) providing a teaching strategy to minimise language barriers for English-language learners (ELL) and bilingual students (An et al., 2014).

Research Questions

Unlike many Asian countries where elementary teachers are prepared as specialists in individual school subjects, elementary teachers in the United States are generalists, responsible for teaching multiple school subjects, including language arts, mathematics, science, and social

studies (Cai, 2005; Midgley, Anderman, & Hicks, 1995). Thus, teacher education programs focus on preparing preservice elementary school teachers to instruct multiple school subjects, with an emphasis on generalisable pedagogy rather than advanced or domain-specific pedagogical content knowledge (Anderson & Clark, 2012). As a special type of elementary generalists, bilingual generalists are responsible for teaching all subjects in two languages (e.g., Spanish and English). Due to the higher level of preparation necessary for teaching in two languages with effective communication skills, many preservice bilingual generalists do not achieve high self-efficacy for teaching subject areas with complex symbols and abstract concepts, such as mathematics and science (Cowan & Albers, 2006).

While there has been empirical literature on the benefits to preservice elementary teachers in receiving professional development on utilising integrative mathematics pedagogy, most teacher education programs—due to various limitations such as curricular pacing and traditions emphasising monodisciplinary pedagogy—do not offer preservice teachers any opportunities to develop their knowledge for teaching interdisciplinary or contextualised mathematics before they perform actual student teaching (Araujo et al., 2013). Specifically, most preservice elementary teachers are not provided with professional development in the areas of: (1) strategies, resources, and supports for preparing interdisciplinary mathematics lessons; or (2) practice in teaching interdisciplinary mathematics lessons to elementary students (Sleeter, 2001; van Driel, Verloop, & de Vos, 1998). With the overriding goal of assessing preservice elementary teachers experiences of designing and implementing interdisciplinary mathematics lessons for elementary students, the current study aimed to collect and analyse data addressing the following research question: How did the participating preservice teachers examine the pedagogical effectiveness and challenges throughout their experiences of implementing music-mathematics interdisciplinary lessons?

Methods

Participants and Settings

The study took place at a medium-sized research university in a predominantly bilingual south-western metropolitan area in the United States, where over 75% of the undergraduate student body is Hispanic. The current study is a part of a larger funded research project involving 173 preservice elementary teachers from five sections of a senior level mathematics methods course (see Acknowledgment). The goal of the study is to improve preservice teachers' knowledge and self-efficacy for mathematics pedagogy (especially regarding interdisciplinary approaches). Participants in the current study were preservice teachers (n=21) from one section of an undergraduate elementary mathematics teaching methods course, during a summer semester. Preservice teacher participants were purposively selected because this session of students had a class schedule that overlapped with the summer camp. Except for one bilingual generalist who had high-school band experience, none of the preservice teachers had a musical background. Among the 21 participants, there were 19 female preservice teachers and 2 male preservice teachers; and there were 11 participants who were pursuing degrees as elementary generalists (preservice teachers preparing to teach in monolingual English classrooms), and 10 elementary bilingual generalists who were preparing to teach in both Spanish and English at dual-language elementary schools. Demographic data collected from the participants indicated 86% of participants self-reported as Hispanics.

The current study was designed and constructed for the purpose of analysing participants' reflections upon developing and implementing interdisciplinary pedagogy that emphasised music-mathematics integration. The research site was located in one of the educational research laboratories within the university's College of Education. A group of student-volunteers with parental permission and teacher-volunteers (n=5) were recruited from the local elementary schools via an online application system. Student-volunteers (n=21) were selected from applicants (n=34) based on upper elementary grade levels and a preference for creating a diverse demographic in specific areas, considerations of student-volunteers also including the balance of gender, ethnicity and family social economic statutes. So as to ensure a collaborative

multidisciplinary effort, the research team included professors from departments of teacher education, mathematical sciences, and music as well as doctoral students in the STEM education program, which worked together to maintain a respectful and secure learning environment for student-volunteers in the research lab where the data collection took place.

Data Collection

Data collection occurred during one summer semester over a period of four weeks (see table 1). There were 21 lesson plans along with 391 corresponding qualitative pieces collected from the participants; including online discussion entries with follow up comments, individual reflection essays, and interview transcripts. In Week 1 of the intervention, 21 preservice teachers were directed to develop a lesson plan for teaching a mathematics topic using music themed activities as the key instructional approach for a group of 5th-graders, and 21 lesson plans were collected. In Week 2, after the participating preservice teachers' original lesson plans were produced, each participant demonstrated his or her instructional design to their peers in a regular class meeting. After the lesson plans were demonstrated, the 21 preservice teachers participated in a series of four online interactive discussions by explaining their instructional design rationales and strategies, and offering feedback on their classmates' lesson plans. Such online discussion generated 84 major entries as well as 223 follow up comments, resulting in a total of 307 written pieces. In Week 3, each preservice teacher implemented a 40-minute lesson to a group of student-volunteers who were recruited for the study. After the lesson implementations, each participating preservice teacher was asked to write a comprehensive reflection essay to self-evaluate their lesson design and teaching experiences, and 21 comprehensive reflection essays were collected. In Week 4, each preservice teacher was interviewed to inquire about their perceptions of teaching and learning mathematics through music. Specifically, the interviews focused on three topics: (1) attitudes towards mathematics; (2) understanding of mathematics; and (3) mathematics teaching beliefs. A total of 63 pieces of responses were collected from the individual interviews.

Table 1
Tasks and Data Collection Timelines

	Stage 1	Stage 2	Stage 3	Stage 4
Instructional Tasks	Lesson plan development	Lesson demonstrations to peers	Lesson implementations to students	Post-teaching reflections
Data Collection Tasks	Lesson plans	Online group discussion	Personal reflection essays	Individual interviews

To facilitate qualitative analysis of the preservice teachers' perceptions of their interdisciplinary teaching experiences, data analysis employed a grounded theory approach involving "systematic, yet flexible guidelines for collecting and analysing qualitative data" with the goal of "construct[ing] theories grounded in the data themselves" (Charmaz, 2006, p. 2). The qualitative data was analysed iteratively by two researchers who coded data independently. With an inter-rater agreement rate of 92.2%, the inconsistencies of the coding results were resolved collectively through discussions between the two researchers and the third researcher.

Within the grounded theory approach, the specific data coding method utilised was the constant comparative method, where: (1) qualitative data was compared case by case while generating flexible categories and integrating additional cases into the categorisation scheme; (2) the qualitative data categorisation was then refined based on responses to check the orientation that each data piece indicated; and (3) once the main categories were determined and the subsets were saturated, the remaining qualitative data was coded using those categories previously developed by the research team (Glaser, 1978).

Results

The preliminary analysis of the lessons plans developed by the 21 participants showed that both generalists and bilingual generalists utilised a variety of strategies to create integrative music-mathematics pedagogy. Specifically, a classification of 12 different strategies was found across all lesson plans (see Table 2). Coding determined that there were four main types of music activities that were integrated within five general mathematics content areas. The majority of music activities were categorised as either: (1) music singing and listening activities; (2) music composing and performing activities; (3) musical notation learning activities; or (4) musical instrument designing and making activities.

All mathematics lesson topics identified in the lesson plans were categorised into one of five content areas (following NCTM, 2000): (1) numbers and operations; (2) geometry; (3) algebra; (4) data analysis and probability; and (5) measurement. A variety of strategies for linking mathematics with music were found throughout the lesson plans but certain mathematics content areas were noticeably more adaptable to integration with music activities via multiple strategies, whereas other mathematics content areas had fewer routes for integration with music.

Table 2
Mathematics Content Foci and Music Strategies in Lesson Plans Created by Preservice Teachers

Content Foci	Music Listening & Singing	Music Composing & Performing	Music Notating	Musical Instrument Designing
Number & Operation	G6 B3 B4 B9	G1 B5	G7 B6	G10 --
Geometry	-- B1 B8	G4 G5 --	-- --	G9 B2
Algebra	-- --	G2 G11 --	-- --	-- --
Data Analysis & Probability	G3 --	-- B10	-- --	-- --
Measurement	-- B7	-- --	-- --	G8 --

Note: G indicates elementary preservice generalist and B indicates elementary preservice bilingual generalist, and the number after the letter indicates the specified teacher.

Analysis of the 391 pieces of qualitative reflections that were collected from the participating preservice teachers during focus group discussions, individual interviews, and self-reflection essays revealed the participants' general perceptions about the benefits and challenges of teaching mathematics through music activities. In total, four main themes and 20 specified subthemes were identified for the benefits; and three main themes and 12 specified subthemes were identified for the challenges. Additionally, both similarities and differences were found between preservice generalists and bilingual generalists in perceptions of the benefits and challenges of teaching mathematics through music activities.

Benefits of Teaching Mathematics through Music Activities

As stated earlier, there were four main themes containing 20 specified subthemes identified within the qualitative data collected (see Table 3). Most participants indicated that teaching mathematics through music benefited both their own teaching processes and students' learning processes. *Students' Motivation* (e.g. facilitate students' engagement) was the most prevalent theme that we identified across all 21 participants, with a total response count of 26 times. The

two next most common themes were *Lesson Preparation & Delivery* (e.g. allow multiple and novel ways of teaching) and *Students' Learning & Applying Math* (e.g. facilitate conceptual understanding) with total response count of 18 and 19 respectively. The theme that had the lowest response count was *Differentiated Instruction & Personalisation* (e.g. alternative way for assessment) with 16 response counts.

Table 3
Preservice Teachers' Perceptions of Benefits of Designing and Implementing Music-Mathematics Integrated Lessons

Main Themes	Subthemes	Preservice teachers	
Lesson Preparation & Delivery	Allow multiple and novel ways of teaching	G2, G4, G5	B1, B7
	Contextualise math into engaging scenarios	G5, G11	B4, B6
	Present flexible and meaningful strategies	G1, G7, G10	B2
	Provide various non-drill activities	G8, G9	--
	Link concepts with activities	G2, G3	B10
Students' Learning & Applying Math	Assist memorisation of facts	--	B3, B5, B10
	Help students internalise knowledge	G2	B7
	Facilitate conceptual understanding	G4, G5, G6, G11	B2, B9
	Apply math in real life scenarios	G3, G10	B1
	Identify connections within and out of math	G6, G8	B2, B6, B8
Students' Motivation	Facilitate students' engagement	G1, G2, G4, G8	B1, B3, B7
	Inspire students' curiosity and imagination	G3, G4	--
	Offer enjoyable learning environment	G6, G7, G11	B4, B5, B6, B9
	Reduce math anxiety and stress levels	G2, G3, G9, G10	B2, B10
	Improve students' confidence	G5, G6, G9	B2, B8
Differentiated Instruction & Personalisation	Fit students with different learning styles	G2, G7	B3, B4, B8
	Challenge for high achievers	--	B1, B9
	Flexible for changing difficulty / grade levels	G5	B2, B10
	Alternative representation / expression	G8, G11	B5
	Alternative way for assessment	G6	B4, B10

Note: G indicates elementary preservice generalist and B indicates elementary preservice bilingual generalist, and the number after the letter indicates the specified teacher.

Lesson preparation and delivery. Most preservice teachers indicated that using music activities as educational resources for teaching mathematics facilitated their lesson preparation and delivery processes. Specifically, participating preservice teachers reported that teaching mathematics through music offered them more choices to presenting mathematical concepts, as well as alternative ways for contextualising mathematics topics into sense-making scenarios. In addition, music activities provided students opportunities to explore mathematics through non-drill approaches including musical notating, singing, playing, composing, and instrument designing. For illustration, one of the participating preservice teachers (G4) articulated that mathematics-music integrated teaching strategies offered her more ways to contextualise mathematics concepts, as well as design class activities with a variety of options that can meet different students' needs and interests. As she described in her own words:

I believe by using music [activities] as mathematics manipulatives such as colour-coded hand bells, I would have more choices when selecting their strategy and can show different teaching styles to students. More than simple things like teaching number and geometry, algebra even calculus can be incorporated with music. When I have difficulty to find a way to contextualise some math concepts by using classroom activities, I can always consider music. With music there

is so many ways to complement math: half notes, full notes, sizes of instruments. You can use the hand bells and actually take the students mind into math, or you can simply let students sing for a song with any math topics and math songs are available in a variety of music genres for students of all backgrounds. Students nowadays are drawn to music, [music] is part of their lives and interests, [and to use music] is a key point teachers need to consider when teaching their students. This particular experience really inspired me things that I would have never thought about. I know it is going to make me a better teacher and I know my students will enjoy math as much as I do.

Students learning and applying math. Preservice teachers also acknowledged that teaching mathematics through music not only helps students internalise knowledge, memorise, and retrieve facts, but also facilitates students' comprehension of mathematics concepts through real life applications and interdisciplinary connections. As a preservice teacher (D) noted, without understanding of meaningful connections between mathematics and real-life contexts, students may feel frustrated during mathematics learning processes. This participant also stated that the music-math integrated lessons offered students' opportunities to explore mathematics beyond merely getting the right answer, and he also explained that this interdisciplinary approach helped students connect and apply mathematics in meaningful contexts. In the participant's own words:

Math is an important subject for students of all ages to learn, but may be overwhelming for some students. Students who have difficulty understanding math may become bored during class. By having music activities that contain creative experiences, my students will be able to test and try their new knowledge and see how it can be applied to real-life experiences and with time it will make sense to learn mathematics at school. I think the fact that learning mathematics through the use of music is fantastic because it makes it more memorable and engaging to both teacher and students. Everything around us is mathematically and musically connected, although it is up to teachers to make those connections with the students. This type of integration helps make learning more meaningful versus just getting the right answer to the problem, which is important. It is important to know the structure of mathematical concepts, but what's more important is how that transcends to a real-world situation.

Students' motivation. The participating preservice teachers shared a variety of reasons explaining their beliefs about how music can be used as the substance for creating a highly motivating environment for students to learn mathematics with better attitudes and less anxiety toward mathematics. Specifically, preservice teachers noted that music can be used as an educational resource to engage students in mathematical instruction, and such creation-oriented activities may inspire students' curiosity and imagination for receiving more challenging mathematics tasks with more confidence.

Preservice teacher (G6) further reflected that using music in mathematics lessons can help students feel relaxed, and the music-themed activities can be used as the hook for developing engaging mathematics lessons that keep students' attention and interests. As she described:

I had always thought that teaching and learning mathematics was a hard and somewhat boring task, and since my personal experiences in learning mathematics weren't great, I didn't have a positive approach to the matter. But after actually having experienced teaching mathematics through music, I learned that students are more interested in learning math than I assumed. I have now a different perspective: I believe that music is a great way to teach not only math, but an array of other subjects. I believe that music is a great way to help my students feel relaxed and motivated to learn math or any subject. Because most people relate music to enjoyment and when you enjoy something you relax. So helping students relax and find something joyful through music is a great experience for students and a change to the traditional ways of learning. I also have learned that the effectiveness of a lesson depends on the engagement of the students, and I think music automatically draws kids' attention and interest. Such activities can get them hooked on what we are teaching them.

Differentiated instruction and personalisation. Many preservice teachers reported that teaching mathematics through music provided them opportunities to design their mathematics lessons to meet their students' personal needs, as well as to implement culturally relevant instruction. In particular, the participating preservice teachers mentioned that mathematics topics that were integrated with music activities could be developed into learning tasks for students across a

variety of grade levels. As instructional approaches, students could solve mathematics problems that were based on their own musical compositions, and apply mathematical concepts to create their own original musical arrangements. It was noted that, as a pedagogical context, music can be used as both (1) components to create an entertaining learning environment, and (2) resources to explore mathematical patterns, conduct numerical experiments, and analyse data through inquiry-based learning. One of the participating preservice teachers (B2), who had received K–12 education as an ELL student, discussed how music-integrated mathematics teaching may help students learn via alternative approaches.

Further, a preservice teacher (B2) stated:

I think using music-mathematics teaching strategies is a very complete approach to teach students, because it taps on the different learning styles, giving all the students a fair chance to learn. Every student learns in different ways. Some are visual learners; others auditory learners and kinaesthetic (sic) learners. Some students might need to hear the music to make sense of a math pattern, besides using visualisation. In my class, I had ESL children and some really bright students that would qualify as gifted and talented so I had to keep a balance in my classroom. To my surprise by using the piano I was able to involve an ESL student that did not understand well the lesson in the beginning. I could see how easy it became for her to understand the concept when I let her play the piano and do their own song. By incorporating music into the lesson, I strongly believe that all the different styles of learning will be addressed at the same time. Math is a subject which is often discriminated because of the teaching methods used for the students, but now thanks to music, math can be viewed very differently. Being an ELL student myself as well as a future teacher, I strongly believe that by teaching math with music, ELL students are able to better understand what is being taught.

Challenges of Teaching Mathematics through Music Activities

For the perceptions of challenges during music-math integrated lessons that the preservice teachers reported, three main general themes with 12 more specific subthemes were identified from the qualitative data (see Table 4). In general, participants revealed some key problems, difficulties, and weaknesses throughout their teaching experiences. The results indicated that *Classroom Management & Control* (e.g. students not following instructions) was the most prevalent challenge with a total response count of 16 times. The other challenges *Diversity of Students* (e.g. different grade levels or math abilities), and *Instructional Processes* (e.g. lack of time during activities/assessment) had a response count of 14 and 13 times, respectively. Although both groups of preservice teachers described challenges in all three major themes, differences were found in some subthemes between regular generalists and bilingual generalists.

Table 4
Preservice Teachers' Perceptions of Challenges during Music-Math Lessons

Main Themes	Subthemes	Preservice teachers	
Classroom management and control	Too fast during instruction	G2, G5, G6	--
	Too slow during instruction	--	B2, B7
	Students talking out of turn	G4, G5	B3, B9
	Students not following instructions	G5, G10, G8, G9	B6, B5, B9
Diversity of students	Lack of challenge for gifted students	G4, G7	B1
	Language barrier for ELLs	G2, G5, G11	--
	Cultural backgrounds	G10	B4
Instructional processes	Different grade levels or math abilities	G7, G8, G9	B3, B10
	Lack of explanations of math concepts	G1, G4,	B1, B3, B7
	Lack of explanations of activity rules	G7, G5, G11	B2
	Lack of modelling and examples	G3	B8, B9
	Lack of time during activities/assessment	G8, G9	B2, B5, B4, B10

Note: G indicates elementary preservice generalist and B indicates elementary preservice bilingual generalist, and the number after the letter indicates the specified teacher.

Classroom management and control. Some preservice teachers expressed their challenges during their music-mathematics integrated lesson implementation processes. Generally, the disordered instructional pace and uncontrolled students' behaviours in classrooms are key challenges for preservice teachers.

In particular, regular generalists stated more challenges pertaining to going too fast during instruction, whereas bilingual generalists reported more challenges pertaining to going too slow during instruction; with a related effect that bilingual generalists also reported more challenges from a lack of time during student activities. As one of the regular generalists (G5) said:

I was planning to take longer but I went fast because I was nervous and started talking fast. Something that I would do differently the next time I teach a lesson is take time to talk slower in order for the students to understand much better and make sure I do not rush. Another thing that I noticed was that some students needed more time for the assignment because they work at a slower pace. The slower students were feeling pressured by their peers and that did not allow them to do the assignment correctly. Something that I would do differently on my next lesson is make sure that the slower students get more time to finish their assignment and let them know that it is ok if they do not finish at the same time as the rest of their peers. The last thing that I would do differently on my next lesson is make sure to be well prepared in case something goes wrong or unexpected in my lesson.

Diversity of students. Preservice teachers identified a number of challenges pertaining to diversity of students during their mathematics teaching process. This included recognition that they had challenges because it was difficult to: (1) modify learning tasks for gifted students to meet their needs; (2) communicate with English language learners because of language barriers; (3) provide culturally relevant teaching materials to fit students with a variety of cultural backgrounds; and (4) differentiate instruction for students with different levels of math abilities. For example, in her reflection of teaching experiences, a preservice teacher (G7) noted that different students had varying paces during their learning, and she shared how recognising this challenge would help her improve her weaknesses in lesson design, thereby making her a better teacher in the near future. In her own words, she stated:

I now know that some students are more advanced than others. For example, during my teaching lesson, some students were working on problem number four, while other students were barely finishing problem number one. When I saw that two students were still working on the problems, I and my group gave them a bit more time. We didn't make it obvious that they were slower than others. One more thing that I learned from the teaching is that I really need to make sure I have

materials for students who are GT, so that I can challenge their thinking more, those kids amazed me in how smart they are. I was glad that I had this experience because as a future educator, I need to make sure that I don't have my fast learners and gifted students waiting for the other students who are slower or have a learning disability. As a future educator, I will make sure that every student finishes their work without feeling rushed or forced to. In addition, I will make sure that when I start doing my lesson plans, I take into consideration the different students that I have. I will make many accommodations, even if it takes time, but I want for every student of mine to learn and enjoy coming to school every day.

Instructional processes. A variety of issues were described by the preservice teachers when they were implementing the music-mathematics integrated lessons that they had individually designed. Although preservice teachers acknowledged many benefits of using the music-themed activities as one of the instructional methods during the teaching process, some difficulties were also revealed.

Difficulties included the disordered instructional sequences, missed instructional segments, and insufficient time during one or more instructional segments. One of the preservice teachers (B10) commented about her teaching experiences as follows:

It was overwhelming at first and even when I prepared [the lesson] to death and I spent a lot of time planning the lesson plan activities, there were so many things that I missed when delivering the lesson plan. I would like my students to work in cooperative learning environments in which they interchange knowledge and ideas and therefore have a better understanding of what they are learning. I also want my students to be able to reflect on their learning and think of the world that they live in. However, there are so numerous things that I had to do while delivering the lesson plan: I had to keep students attention, explain in detail, walk through the classroom to check for understanding and that sounds hard but even when I did that we missed a lot of things. For example, I missed to check for understanding for students whose first language wasn't English, and also many students were not at the level of other students and I missed that too. There were many things that had to be changed throughout the lesson plan, and I had to have a lot of improvising. I think this [teaching experience] was really helpful because now I will be more careful with my future students.

Discussion

The study presented in this paper sought to offer a group of preservice teachers with opportunities to learn about interdisciplinary mathematics pedagogy, plus the experience of implementing interdisciplinary mathematics pedagogy with elementary students. Rather than treating music-themed activities as merely a sensory stimulation or as a separate learning process to mathematics education (e.g., Costa-Giomi, 2004; Rauscher et al., 1995), the current study situated music within a series of mathematics lessons that incorporated the musical elements as a central, rather than superficial, component of the mathematics pedagogy. Consequently, the study provided the participating preservice teachers' with an opportunity to reflect upon the potential advantages, as well as challenges, involved in developing music into an educational resource for teaching engaging elementary mathematics lessons. Additionally, the results from this study revealed some empirical differences between generalists' and bilingual generalists' strategies and perceptions pertaining to the designing and implementing of music-mathematics integrated teaching methods and materials.

Overall, the findings indicated that the participating preservice teachers' perceptions about effectiveness of teaching mathematics through music were consistent with previous research on arts-based interdisciplinary instruction within K-12 settings and teacher education programs, which determined the importance of high-quality elements within four chief categories, including: (1) *Lesson preparation and delivery* (An & Tillman, 2014; Glastra, Hake, & Schedler, 2004); (2) *Students' learning and applying math* (An & Tillman, 2015; Eisner, 2002); (3) *Students' attitude and motivation* (An et al., 2014; Robertson & Lesser, 2013), and (4) *Differentiated instruction and personalisation* (Brown, 2013; Colwell, 2008).

The preservice teachers also pointed out a number of challenges that they experienced during their lesson preparation and teaching process, and these challenges were consistent with previous studies' findings, which discussed the need for addressing: (a) the problem of time

management during instruction; (b) difficulty meeting different students' needs; (c) a disorganised instructional process and the resulting classroom management issues; and (d) gaps in pedagogical and content knowledge (Darling-Hammond & Baratz-Snowden, 2007).

The findings from this study imply that the participating preservice teachers recognised that integrating mathematics with an engaging real-life context such as music could potentially address some of the common mathematics education problems, including a lack of engagement and the presence of mathematics anxiety (An et al., 2014; An et al., 2015). Most of the participating preservice teachers indicated that music as a pedagogical strategy allowed them to go beyond traditional mathematics instruction, and stated that they believed such contextualised activities allowed students to understand mathematics concepts in meaningful ways. Moreover, both groups of preservice teachers believed that these innovative mathematics strategies that they were applying during their lessons offered multiple non-rote forms for contextualising activities so as to help students view mathematics from diverse perspectives. Likewise, many of the participating preservice teachers stated that their students demonstrated more ideas and approaches when solving mathematics problems within contextualised activities, such as the ones employed using music as the theme. Findings from the study also indicated that both generalists and bilingual generalists were convinced that the interdisciplinary activities could be used as to help in creating an engaging learning environment for elementary students to participate in mathematics tasks and be involved with more challenging mathematics.

Although the preservice teachers in this study created several ways to integrate music within mathematics lessons, it is noteworthy that some differences between regular generalists and bilingual generalists were found. For example, the elementary preservice generalists proposed more lessons based on music composition and playing, whereas the bilingual generalists proposed more lessons involving musical singing and listening. Based upon the data analysis performed, this difference can be interpreted as indicating that the regular generalists' lesson plans were constructed with a consideration of locating the music activity in the middle of the lesson for providing students with opportunities to explore mathematics, conduct experiments, and analyse data through inquiry-based learning. Conversely, the bilingual generalists' primary consideration when providing music activities was to include that at the beginning of the class, as a means to create an entertaining and language-rich learning environment for ELL students, and then again at the end of the lesson to summarise key mathematical concepts, vocabulary, and formulas, in a manner memorable for the students struggling with spoken language issues.

Moreover, the regular generalists and the bilingual generalists described how they had experienced different challenges when they implemented their lesson to actual students. Specifically, under the theme of *Classroom management and control*, the regular generalists stated more challenges pertaining to going too fast during instruction, while the bilingual generalists reported more challenges pertaining to going too slow during instruction. A related effect was that the bilingual generalists also reported more challenges pertaining to a lack of time during student activities. Under the theme of *Diversity of students*, the regular generalists stated more challenges from language barrier for ELLs, while none of the bilingual generalists mentioned this challenge. The differences that were noted in this study between regular generalists and bilingual generalists are indicators that there are subtle but important, dissimilarities between the two groups of preservice teachers, primarily in regards to how they go about both applying educational resources and coping with teaching challenges.

The differences between bilingual generalists and regular generalists when it comes to designing and implementing mathematics lessons has been documented empirically in previous studies (e.g., Cooper & Schleser, 2006; Saalbach, Eckstein, Andri, Hobi, & Grabner, 2013) that collectively have illustrated the need for providing differentiated teacher preparation activities based on the distinctive pedagogical, cognitive, and linguistic requirements required for becoming effective high-quality bilingual teachers. With differentiated pedagogical methods for developing, implementing, and evaluating mathematics teaching strategies that include engaging students in preservice teachers' own real-life interests can be used as a means for nurturing interest and success in mathematics (Gresham, 2007; Knoblauch & Hoy, 2008).

Within the context of the discussion described, the current study aimed to provide teacher educators and teacher education researchers with a richer understanding of the participating preservice teachers' perceptions of the pedagogical effectiveness, and challenges of implementing an interdisciplinary teaching strategy, to generate engaging mathematics pedagogy. Moreover, the current study provided insights of differences between preservice monolingual generalists and bilingual generalists in developing and implementing mathematics lessons to elementary students. The identified differences of challenges during mathematics instruction such as *Diversity of students* and *instructional processes* may help researchers in future studies to identify and design differentiated teacher education programs between monolingual generalists and bilingual generalists, especially in mathematics teaching methods courses that focused on interdisciplinary-themed and culture-relevant pedagogy.

Conclusion

The primary goal of this study was to determine the participating preservice teachers beliefs pertaining to the craft of designing and implementing music-themed mathematics lessons, thereby furthering the examination of alternative approaches to improving the preparation of preservice teachers' in their development of mathematics pedagogy. This study identified several potential opportunities for facilitating preservice teachers' understanding of interdisciplinary mathematics pedagogy. The findings from this study invite further longitudinal research on the impacts from classroom implementations of music-mathematics integrated lessons, as well as other interdisciplinary approaches to mathematics pedagogy. This particular study focused on determining the impacts from this type of curriculum. The findings invite further research into the advantages and challenges pertaining to interdisciplinary mathematics curriculum development, particularly with regards to efforts to expand beyond music-mathematics towards a broader curriculum span across STEM and the arts. Such an all-encompassing STEM and Arts driven curricula can expand to include using other artistic formats such as the visual arts, theatre arts, and choreographic arts, as creative pedagogical elements to facilitate STEM education.

Previous empirical research has found that many teacher education programs have failed to develop preservice teachers' positive perceptions toward mathematics education, often because of a lack of opportunities to develop engaging mathematics teaching methods during their preservice preparation (Darling-Hammond & Baratz-Snowden, 2007). To address this issue, mathematics teacher educators and curriculum developers should support development and research regarding generating innovative teaching strategies that can more effectively engage students in learning mathematics via such pedagogical strategies as problem-solving, simulations, discovery, contextualised challenges, and interdisciplinary projects (Gresham, 2007; Knoblauch & Hoy, 2008). Preservice teacher educators should be given the opportunity to learn pedagogical practice in mathematics methods courses such as the Finland teacher education program did (Malinen & Savolainen, 2012) to emphasise nurturing connections between mathematics, arts, and authentic student interests, as the scaffold for teachers' own development and for the implementation of mathematics lessons, which will engage their future students (Gresham, 2007; Knoblauch & Hoy, 2008).

Additionally, many of the existing teacher education resources that claim to provide entertainment-contextualised mathematics pedagogy are in actuality primarily entertainment-oriented (e.g., Moomaw, 2011, 2013). As an illustration, the referenced instructional materials offer only shallow connections between the mathematics instruction and the contextualisation of the mathematics within games, and thereby misguidedly de-emphasise the importance of authentic contextualisation, which have repeatedly been demonstrated as neither helpful nor relevant to the mathematics pedagogy process. Instead, preservice teachers need to participate, implement and evaluate high-quality contextualised mathematics activities that may facilitate students' conceptual understanding. Many national teacher organisations unambiguously acknowledge in their curriculum standards that educators should strive to provide students with opportunities to identify and apply knowledge across school subjects in a manner that is relevant to the students' real-life experiences—including those standards developed by the

National Art Education Association (NAEA, 1994), the National Science Teachers' Association (NSTA, 2003), the Association for the Advancement of Science (AAAS, 1998), the National Research Council (NRC, 2004), and the National Council of Teachers of Mathematics (NCTM, 2000). This study has provided empirical findings pertaining to the connections between music and mathematics to illustrate the concept of the entertainment-education learning strategy (Robertson & Lesser, 2013). Through this strategy, preservice teachers can develop more opportunities for their students to explain, represent, and really apply mathematics during interdisciplinary pedagogy. To support the aim of improving preservice teachers' knowledge for how to effectively implement mathematics teaching strategies with their future elementary students, teacher educators should strive to improve preservice teachers' awareness of, and capacity for, making mathematics education more engaging for students (Robertson & Lesser, 2013). Further research continuing this line of inquiry should aim to both broaden and deepen the teacher education research community's collective theoretical understanding of how to optimise preservice teachers' capacity for high-quality contextualised mathematics pedagogy, through professional development that cultivates interdisciplinary teaching and learning experiences.

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