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Preservice Teachers' Beliefs and Attitude About Teaching and Learning Mathematics Through Music: An Intervention Study

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This article presents exploratory research investigating the integration of music and a mathematics lesson as an intervention to promote preservice teachers' attitude and confidence and to extend their beliefs toward teaching mathematics integrated with music. Thirty students were randomly selected from 64 preservice teachers in a southern university. A 90-minute mathematics lesson integrated with a music composition activity was taught by the first author. Pre- and postquestionnaires were provided to evaluate the change in preservice teachers' attitude and beliefs toward mathematics. The results demonstrated that the mathematics lesson integrated with music had a positive effect on preservice teachers' attitude and beliefs toward mathematics teaching and learning.

Both the National Council of Teachers of Mathematics (NCTM, 2000) and the National Consortium of Arts Education Associations (1994) in their standards explicitly documented that all students from kindergarten to 12th grade should be able to recognize and apply knowledge to other content areas (e.g., making connections between mathematics and the arts). Research has consistently found benefits of teaching mathematics connected with science and language arts in recent years (i.e., Keen, 2003; Marrongelle, Black, & Meredith, 2003). These connections provided opportunities for students to make sense of mathematics and to apply mathematical knowledge in meaningful ways when connecting new knowledge to existing knowledge (Schoenfeld, 1988). One of the methods in teaching mathematics was to integrate arts as a catalyst for mathematics learning (Betts, 2005).

Expanding Preservice Teachers' Pedagogical Content Knowledge

According to previous studies, pedagogical content knowledge was a major component of teachers' knowledge (e.g., Fennema & Franke, 1992; Shulman, 1986). For preservice teachers, their pedagogical content knowledge, or knowledge of teaching and learning, influenced their future teaching behavior (Dooren, Verschaffel, & Onghena, 2002). However, a major challenge for teacher preparation programs was to prepare preservice teachers with pedagogical content knowledge (Niess, 2005). Lacking experiences in classroom teaching, preservice teachers need guidance with regard to how to learn and develop their pedagogical content knowledge, the central component of teachers' practical knowledge (Niess; Van Driel, Verloop, & De Vos, 1998).

In recent years, traditional teacher preparation programs have often been criticized for being excessively theoretical, having little connection with practice, offering fragmented courses, and lacking a clear conception of teaching (Darling-Hammond & Baratz-Snowden, 2007). The NCTM (2000) standards advocated an emphasis on teaching mathematics with understanding. Many preservice and in-service teachers, however, had difficulty adopting this focus in teaching practices despite their enthusiasm for reform (Hiebert & Stigler, 2000). The NCTM's Equity Principle requires teachers to develop effective methods for supporting the learning of mathematics for all students: Regardless of students' personal characteristics, backgrounds, or physical challenges, teachers should provide opportunities and support for all students in mathematics learning. The goal of success for all can be achieved by providing opportunities for students to experience the esthetics of arts in mathematics learning (Betts & McNaughton, 2003; Eisner, 2002).

Reducing Preservice Teachers' Mathematics Anxiety

Researchers have identified two components comprising mathematics anxiety (Morris, Davis, & Hutchings, 1981): (a) cognitive—including the worrisome thinking about personal performance, and (b) potential negative consequences and emotions—including nervousness, fear, and discomfort when involved in mathematical-related tasks (Vance & Watson, 1994). As a unique group of college students containing a high percentage of females, preservice teachers, compared with their peers from other majors, have poorer attitudes and higher anxiety toward mathematics (Bursal & Paznokas, 2006). Even worse is that preservice teachers may transmit this negative attitude toward mathematics to students in their future classrooms (Furner & Berman, 2005).

Traditional ways of teaching mathematics is considered one of the key factors that caused mathematics anxiety: Assigning the same problem to every student, teaching through lecturing by the textbook, insisting on the only one way to solve problem, neglecting conceptual understanding, and others were argued as the origins of mathematics anxiety (Furner & Berman, 2005). Teaching mathematics in nontraditional ways such as using problem-solving activities, simulations, discoveries, challenges, and games was proposed as effective methods in reducing students' mathematics anxiety (Tobias, 1998). Researchers suggested that in order to reduce preservice teachers' mathematics anxiety as well as to develop a positive attitude toward mathematics, teacher educators should demonstrate various mathematical strategies for preservice teachers with an emphasis on teaching through manipulatives and real-life activities that focus on conceptual understanding (Bursal & Paznokas, 2006; Gresham, 2007).

Teaching Mathematics Connected With Arts

The link between music and mathematics has deep historical roots. In the sixth century BC, the Greek philosopher Pythagoras found the ratio among music intervals. For example, the corresponding ratio between the intervals of an octave is 1:2, whereas that between the intervals of a fifth is 2:3 (Ferreira, 2002). However, as an essential part of arts, music, along with literature and visual arts, was rarely found integrated into mathematics lessons (Johnson & Edelson, 2003; Rothenberg, 1996). Also, even existing ways of teaching mathematics through music were usually only superficially focused on the relationship between mathematics and music, such as counting rhythms or learning the fractional nature of note values (Rogers, 2004).

Music is related internally and externally to mathematics from multiple perspectives. Mathematical knowledge existed from the kindergarten to the university levels and can be used from basic music elements to whole works (Fauvel, Flood, & Wilson, 2003; Harkleroad, 2006; Loy, 2006). For example, notes, intervals, scales, harmony, tuning, and temperaments are related with proportions and numerical relations, integers, logarithms and arithmetical operations, trigonometry, and geometry (Beer, 1998; Harkleroad). Melody and rhythm can be represented mathematically, and music forms can also be represented by mathematical patterns (Beer). The mathematical concepts of the *Fibonacci sequence* and the *Golden Section* theory were also used by some music composers (Garland & Kahn, 1995; May, 1996).

Fiske (1999) summarized and demonstrated that 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 adults' involvement; (e) offer new challenges for successful students; and (f) connect learning experiences from school to the world.

Recent research has reported beneficial results not only for students with special characteristics but also for all students learning mathematics and other subjects when integrating topics with arts: (a) significant enhancement in students' attitudes and beliefs toward learning mathematics (An, Kulm, & Ma, 2008); (b) effective motivation in students' engagement in mathematics (Shilling, 2002); (c) remarkable improvement in understanding mathematics (Autin, 2007; Peterson, 2005); (d) development in cognitive ability (Eisner, 1985; Peterson); (e) improvement in critical thinking and problem-solving skills (Wolf, 1999); (e) development of ability to work collaboratively in groups (MacDonald, 1992; Wolf); (f) enhancement in students' self-confidence (MacDonald); (g) improvement of empathy and tolerance in class (Hanna, 2000); (h) improvement in mathematics achievement (Harris, 2007); (i) development of the imagination (Greene, 2001); (j) improvement of motivation for learning (Csikszentmihalyi, 1996); and (k) increase in students' creativity and social skills and decrease in dropout rates (Catterall, 2005).

The current study was characterized by a sequence of classroom activities aimed at reinforcing preservice teachers' beliefs and pedagogical content knowledge specifically on teaching mathematics integrated with music. We demonstrated how a suitable musical composition activity incorporated with mathematics can play a fundamental role in bringing preservice teachers' mathematical reasoning experiences into play by creating a new tension between school mathematics and music. The overarching goal of the activity was to examine the relationship between music and school mathematics and the ways each can inform the other in the development of abstract mathematical knowledge. In this case, the focus was on understanding aspects of the multiplicative structure of problem solving. More specifically, the research questions were (a) What are the effects of mathematics–music connection activities on preservice teachers' engagement, confidence, attitude, and beliefs toward teaching and learning mathematics? and (b) How do preservice teachers' beliefs change as a result of experiencing teaching and learning mathematics integrated with music?

Theoretical Framework

With the adoption of the theoretical framework used in the previous study (An et al., 2008), the current study is grounded on theories and research that suggest (a) focusing on the individual abilities of students from multiple intelligences theory to enhance classroom learning (Gardner, 1993) and (b) implicating motivation theory by teaching mathematics associated with creative and active involvement of aesthetics to provide a rich and emotionally stimulating mathematical learning context, reducing students' mathematics anxiety and engaging students in mathematics learning (Eisner, 2002; Sylwester, 1995; Upitis & Smithrim, 2003; West, 2000; Witherell, 2000).

Implications of Multiple Intelligences

Gardner (1983) argued that there are multiple intelligences among different learners, including linguistic, musical, logical-mathematical, spatial, bodily kinesthetic, interpersonal, and intrapersonal intelligences. All intelligences can route individuals through development and communication. The differences in intelligences can serve both as the content of instruction and as the means for communicating the content. Based on multiple intelligences, if a student had difficulties in understanding principles of content in mathematics, the teacher should provide an alternative route to develop conceptual understanding (Kassell, 1998). Embedding music activities into mathematics can not only increase students' mathematical understanding but also provide them an enjoyable means for developing logical/mathematical intelligences along with their musical/rhythmic intelligences (Shilling, 2002).

Greene (2001) defined learning through aesthetics as an "initiation into new ways of seeing, hearing, feeling, moving, a reaching out for meanings, a learning to learn integral to the development of persons—to their cognitive, perceptual, emotional, and imaginative development" (p. 7). Learning through arts allowed students to view the world from different perspectives and to experience rewards from success in mathematics through the arts (Gamwell, 2005). Gardner found that using music to enhance children's enjoyment and understanding of mathematical concepts and skills could help students gain access to mathematics through new intelligences. The arts enabled students to use different learning styles and prior knowledge, pulling together diverse cognitive and affective experiences and organizing them to assist understanding (Selwyn, 1993). As an application of multiple intelligence theory, teaching mathematics integrated with music facilitates students whose strengths lie in areas other than the logical-mathematical intelligence to learn mathematics more easily (Johnson & Edelson, 2003).

Implication of Motivation Theory

Pavlov (1927/1960) introduced the concept of motivation as a new habit that occurs when two stimuli are provided simultaneously. Motivation theory can provide a framework to facilitate students' learning and to interpret how students' learning is associated with their emotions and attitudes (Ormrod, 2008). Ormrod also suggested a key implication of the motivation theory that states that students should study in a positive learning climate and associate learning with positive emotions. According to motivation theory, when students have formed a new stimulus–response connection, for example, learning mathematics joyfully associated with an enjoyable arts environment, they will maintain their positive attitude as a conditioned response to the mathematics lessons as conditioned stimulus in the future.

Emotion is essential in students' learning because it focuses attention on learning (Sylwester, 1995). Arts bonded with emotions enabled students to express themselves and to communicate ideas (Stevens, 2002). As an application of motivation theory to reduce mathematical anxiety as well as to increase motivation and engagement, Miller and Mitchell (1994) suggested that teachers should create a positive learning environment, free from tension and other possible causes of embarrassment or humiliation. Arts, with its aesthetical features, have the potential to provide students an enjoyable environment in which they can discover and think about mathematics concepts in various ways and can build fundamental understandings and appreciation for both mathematics and the arts (Lawrence & Yamagata, 2007). What is more, arts can provide students a learning environment with less prejudice and violence, helping them become better risk takers and communicators (Trusty & Oliva, 1994).

Methodology

Participants and Intervention Lesson

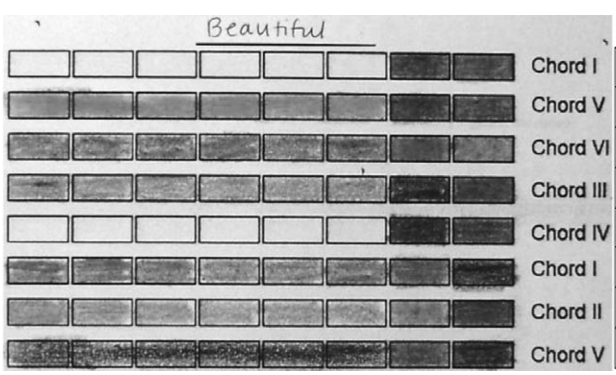
This study was guided by the first author's personal academic background of music and teaching experiences as a mathematics teacher and was carried out in a large, southern public university. Thirty (n = 30) middle school mathematics/science preservice teachers were randomly selected from N = 64 students who were enrolled in two sections of a required problem-solving course to participate in the present study. Students were mainly traditional and female matching the population of preservice teachers at the university. Random selection was accomplished by shuffling all the pre- and postquestionnaire sheets and by choosing 30 sheets from both the pre- and postquestionnaires.

All the preservice teachers (N = 64) participated in a 90-minute interactive intervention activity led by the first author between the pre- and postsurveys. Two worksheets were provided for preservice teachers to compose their own music and to answer mathematics problem-solving tasks. Crayons and a digital piano were prepared for the class. During the Microsoft PowerPoint-assisted lecture, fundamental music composition rules were presented on how to use graphic notation to compose music based on simple mathematical rules. Participants were then asked to use seven different color bars to represent music scales and the numbers of bars to represent the duration of notes. In this graphic notation system, red, white, yellow, blue, green, black, and purple were employed to represent C, D, E, F, G, A, and B in music. Chords (three or more different notes that sound simultaneously) were represented by different combinations of color. Based on a typical popular music chord sequence (sequenced as I, V, VI, III, IV, I, II, and V), preservice teachers learned to compose their own music by choosing colors from specific chords to fill in the first four blanks and choosing any color to fill in the following blanks in each music sentence (see Figure 1). After preservice teachers finished their music task, their compositions were played on the digital piano (see Figure 2)—the specific chord was played by the left hand and the preservice teachers' melody was played by the right hand. Preservice teachers enjoyed the performance by listening to and sharing their own musical creations with their classmates.

After listening to the preservice teachers' composition works, we assigned three problem-solving tasks for them to complete: (a) How many different combinations of songs will you have based on this composition rule? (b) If the song has 12 pieces, how many different structures may you have in your group? and (c) Alice composed three songs with time duration for each song of 7-piece composition (245 seconds), 11-piece composition (385 seconds), and 13-piece composition (455 seconds). Can she determine the time duration of a song with nine pieces?

Instruments and Data Collection

A week before the intervention lesson, all preservice teachers completed a survey measuring their



Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Purple	Blue
Red	Red	Red	Red	Red	Red	Purple	Green
Purple	Purple	Purple	Purple	Purple	Purple	Red	Yellow
Green	Green	Green	Green	Green	Green	Black	Green
White	White	White	White	White	White	Purple	Blue
Blue	Blue	Blue	Blue	Blue	Blue	Red	Black
Red	Red	Red	Red	Red	Red	Yellow	Blue
Black	Black	Black	Black	Black	Black	Green	Purple

Figure 1. A sample of students' composition work *Beautiful* presented by graphic notation.

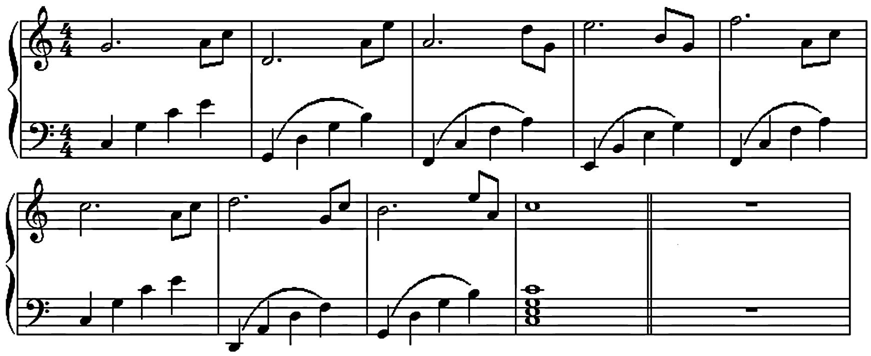


Figure 2. A sample of students' composition work *Beautiful* presented by grand staff.

beliefs about teaching and learning mathematics integrated with music. The same survey was collected as a posttest a week after the intervention lesson. The questionnaire (see Table 1) consisted of 20 closed-ended Likert items with five levels ranging from strongly disagree to strongly agree and two open-ended items. These items focused on four categories: items 1–4 were designed to assess preservice teachers' views about the engagement of mathematics; items 5–9 were designed to assess preservice teachers' beliefs toward mathematics as well as the relationship between music and mathematics; items 10–13 were designed to assess preservice teachers' attitude toward mathematics; and items 14–20 were designed to assess preservice teachers' confidence in mathematics learning. The two open-ended questions were designed to assess preservice teachers' beliefs toward teaching a mathematics lesson integrated with music.

Data Analysis

A paired-sample *t*-test was used to determine statistically significant differences in mean scores and standard deviations between pre- and posttests of the close-ended questionnaire, and a Bonferoni correction was employed because of using multiple univariate tests. The original alpha value was .05. After correcting for four paired *t*-tests, the new adjusted alpha for all tests was .025. Effect sizes were calculated for each category and expressed in Cohen's *ds* to determine whether those differences were important in educational terms (Capraro, 2004). For the open-ended questions, we coded, categorized, and compared students' responses (Lincoln & Guba, 1985) to analyze how preservice teachers' views on mathematics and the relationship between music and mathematics changed from pretest to posttest.

Results

The results of the paired-samples *t*-test displayed in Table 1 demonstrated that the means on all 20 items on the closed-ended questionnaire improved from the pretest to the posttest. The results showed that preservice teachers' engagement, beliefs, motivation, and confidence toward mathematics teaching and learning were statistically significantly improved from pretest to posttest. Additionally, the effect sizes for these four categories with significance were considered in the moderate to large range (67–.80), indicating that the intervention activity had a considerable educational impact on the preservice teachers. The reliability of the pretest calculated in coefficient alpha was .873 and .881 for the data in hand.

Statistically significant improvement was found for preservice teachers from pretest to posttest on the following factors: The *p* value for engagement in mathematics learning was .016 on items 1–4; the *p* value for beliefs toward mathematics teaching and learning was .003 on items 5–9; the *p* value for motivation in mathematics teaching and learning was .003 on items 10–13; and the *p* value for confidence in mathematics teaching and learning was .006 on items 14–20.

The results of the two open-ended questions demonstrated that the preservice teachers' beliefs toward teaching mathematics integrated with music and the relationship between mathematics and music experienced had considerable changes. In terms of open-ended question 1, "What is the relationship between music and mathematics?" (see Table 2), more responses were provided on the posttest than on the pretest. On the pretest, the total number of relationship themes mentioned by preservice teachers was eight,

Table 1
t-Test Results on Closed-Ended Questions of Preservice Teachers' Pretest and Posttest

—	Item	Pretest Mean ± *SD*	Posttest Mean ± *SD*	Cohen's *d*	*p* value	*t*
Engagement	1. Math class will be less boring if math can be integrated with music properly.	3.23 ± .97	3.93 ± .91	.67	.016	2.553
	2. Math class could be exciting and interesting if integrated with music.	3.60 ± 1.16	4.23 ± .94			
	3. Music can effectively motivate students to learn math.	3.80 ± 1.00	4.23 ± .86			
	4. Music is an effective method to engage students to learn math.	3.77 ± 1.10	4.33 ± .84			
Beliefs of math and music	5. Math should be taught connected with other math contents.	4.53 ± .73	4.57 ± .63	.80	.003	3.258
	6. Math should be taught integrated with other subjects.	4.53 ± .68	4.73 ± .52			
	7. Math and music have lots of relationships.	3.37 ± 1.16	4.43 ± .77			
	8. Music is an alternative way to help learners to understand math acoustically.	3.80 ± 1.03	4.13 ± 1.01			
	9. Math can be taught integrated with music.	3.73 ± 1.05	4.47 ± .78			
Attitude	10. I would feel happy if math class was integrated with music properly.	3.27 ± 1.08	4.00 ± 1.03	.78	.003	3.181
	11. Music can provide learners a joyful environment to learn math.	3.73 ± 1.11	4.47 ± .73			
	12. Math learners may feel less anxious if math is integrated with music.	3.33 ± 103	3.57 ± 1.04			
	13. Math is fun when integrated with music.	3.43 ± 1.07	4.26 ± .91			
Confidence	14. I think I can handle more difficult mathematics.	4.07 ± .87	4.17 ± .70	.68	.006	2.993
	15. I think I can handle more difficult mathematics if integrated with music.	3.13 ± .97	3.70 ± .95			
	16. I can teach mathematics better if I know how to integrate music into math.	3.17 ± 1.09	3.73 ± 1.23			
	17. It will be easy for a student to learn math if I teach math integrated with music.	3.06 ± 1.01	3.70 ± .99			
	18. I am confident in engaging my student to learn math by integrating it with music.	3.13 ± 1.07	3.50 ± .82			
	19. It would be great to receive more reward for my students when they achieving mathematics tasks.	4.13 ± .90	4.33 ± .66			
	20. I have confidence in teaching mathematics integrated with music.	2.83 ± 1.02	3.33 ± 1.06			

Note. $n = 30$.
SD = standard deviation.

Table 2
Preservice Teachers' Response on the Relationship Between Mathematics and Music

Category	Theme	Response Rate (n = 30) Pre (%)	Post (%)
Superficial relationship	Amount of measures	16.7	16.7
	Number of count beats (tempo or rhythm)	60	40
	Amount of notes	33.3	13.3
	Difference among pitch (addition in music scale)	10	23.3
	Fraction (ratio) among note values (time signature)	10	33.3
	Song words with math contents	6.7	3.3
Profound relationship	Patterns in music works	10	26.7
	Regulation in instrumentation	3.3	0
	Combination of notes in chords	0	30.3
	Formula in music composition	0	6.7
	Sequence in music arrangement	0	6.7
	Math problem designed based on music work	0	16.7
	Factor in music composition	0	3.3
	Statistics graph to analyze music work	0	6.7
	Multiplication, division, and power in composition	0	10
	Probability in composition	0	6.7
	Transposing among different keys	0	6.7
No idea	—	10	0

Note. n = 30.

and on the posttest, this number increased to 16; on the pretest, the total response rate of relationship themes mentioned by preservice teachers was 130%, and on the posttest, the response rate increased to 260.4%. Specifically, on the pretest, most answers that preservice teachers provided were categorized as superficial relationships based on their common sense and the obvious information from the music as well as the music sheets. Very few preservice teachers provided profound relationships based on advanced music knowledge integrated with complicated mathematics content. On the posttest, the amount of superficial relationships provided by the preservice teachers decreased; however, most preservice teachers provided some profound relationships demonstrating a deeper understanding of both mathematics and music.

In terms of open-ended question 2, "What is the mathematics content that can be taught by integrating music?" (see Table 3), more answers were given on the posttest than on the pretest. On the pretest, the total number of lesson themes mentioned by preservice teachers was eight, whereas on the posttest, this number increased to 17. On the pretest, the total response rate of relationship themes suggested by preservice teachers was 150%, while on the posttest, the response rate increased to 217%. Specifically, on the pretest, most lessons themes that preservice teachers described were based on basic musical knowledge integrated with simple mathematics content. Very few preservice teachers discussed lessons based on advanced musical knowledge integrated with complicated mathematics content. On the posttest, the

Table 3
Preservice Teachers' Response to Mathematics Content Taught by Integrating Music

Category	Theme	Response Rate (n = 30) Pre (%)	Post (%)
Basic music knowledge integrated with simple math content	Teach counting by count words in a song	6.7	0
	Teach counting by count notes (beats) in a music sheet	33.3	23.3
	Teach fraction with key signatures	3.3	3.3
	Teach ratio by compute beat per minute	16.7	6.7
	Teach fraction form note values and beat type	23.3	0
	Play music when students doing math works	3.3	3.3
	Put math contents into songs	30	3.3
	Teach time by playing songs	3.3	0
	Teach addition and subtraction from music composition	0	10
	Teach fraction from music composition	0	26.7
Advanced music knowledge integrated with complicated math content	Teach frequency from music composition	0	3.3
	Teach statistical chart from music composition	0	33.3
	Teach combination from music composition	0	33.3
	Teach pattern finding from music composition	0	40.0
	Teach sequences from music composition	0	3.3
	Teach problem solving from music composition	0	26.7
	Teach probability from music composition	0	30.0
No idea	—	0	6.7

Note. n = 30.

amount of some lesson themes based on basic music knowledge integrated with simple mathematics content decreased; however, most preservice teachers provided some lessons themes based on advanced musical knowledge integrated with complicated mathematical content.

Discussion

The present study seeks to investigate the effects of a mathematics–music-integrated intervention activity on preservice teachers' belief, confidence, motivation, and engagement toward teaching and learning mathematics. Consistent with previous research on the positive impact of a music-integrated mathematics intervention activity on elementary students' attitudes, confidence, and belief toward mathematics as well as learning mathematics (An et al., 2008), in the present study, preservice teachers' attitude, confidence, engagement, and beliefs toward learning and teaching mathematics also show significant positive shifts throughout the intervention.

Changes in Preservice Teachers' Mathematics Attitudes, Confidence, and Beliefs

In this study, we try to use aesthetics as a medium to present preservice teachers a music–mathematics-integrated activity in order to investigate the knowledge of teaching mathematics interestingly and meaningfully integrating with music. The improved scores for all items on the closed-ended questionnaire indicate that the mathematics activity integrating music not only improves preservice teachers' attitudes, engagement, and confidence but also changes

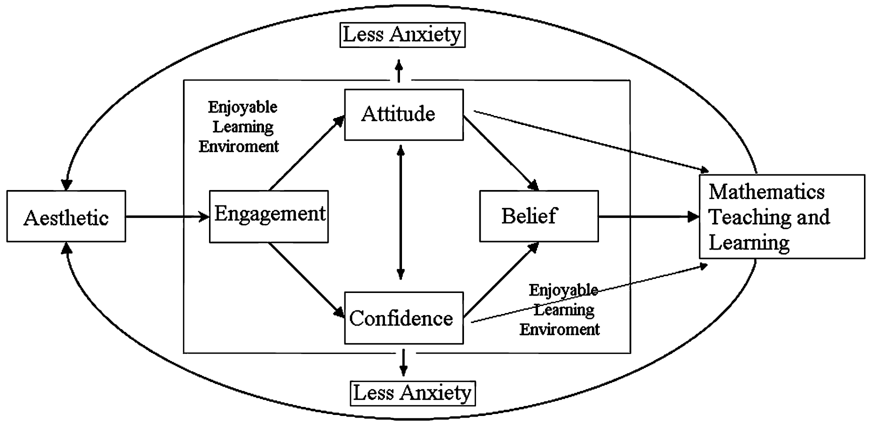


Figure 3. The process of improvement on preservice teachers' engagement, attitudes, confidence, and changes on beliefs toward mathematics teaching and learning.

their beliefs about teaching and learning mathematics. Figure 3 displays a model explaining why these changes occur among preservice teachers participating in this study.

In this carefully designed enjoyable learning environment, preservice teachers are aesthetically engaged. During this intervention activity, preservice teachers' improvement of engagement in mathematics demonstrates three distinct levels: (a) In the beginning, their original interests to and previous joyful experience from music as well as their curiosity toward the relationship between music and mathematics engage them to participate in this mathematics lesson; (b) The pleasant experiences of drawing colorful pictures using crayons as a method to create music and to play their own work immediately on a digital piano further enhance their engagement; and then (c) Through this engagement, they are enabled to solve closely related mathematical problem-solving tasks by analyzing their own musical pieces.

During the same period of time that preservice teachers enhance their engagement in mathematics, their attitude and confidence toward mathematics teaching and learning also improves. During the mathematics lesson, the preservice teachers experience the power of mathematics in an aesthetic creation as mathematical knowledge is used to organize and arrange musical elements such as pitches and rhythms. The harmonic and powerful sound effects appear through their perceived and excited feeling increasing their positive attitude. Furthermore, when completing the activities during the intervention activity, preservice teachers not only feel a cheerful sense of accomplishment when completing the mathematical tasks but also receive an extra reward by enjoying their own composition works accompanied by the digital piano. This experience might be one of the reasons that preservice teachers' positive attitudes increases. During the whole process of using mathematics to create music, playing music, and using mathematics' knowledge to engage in mathematical tasks constructed from music of their own, participants in this study have enough freedom to create music and solve contextually meaningful mathematical problems while their confidence improves. They experience learning and flexibly use mathematics in a joyful environment without painful experiences. They feel that it is fairly easy to teach mathematics by integrating music. Thus, their confidence is enhanced while their anxiety toward mathematics decreases. Moreover, during the sharing of musical works while discussing mathematical tasks, classmates reveal and recognize each other's potential abilities. A strong sense of participants' personal discovery journeys emerges as they construct and explore meanings through their own works; thus, their attitude and confidence are further enhanced.

The change in preservice teachers' beliefs is followed by their improvement of engagement, attitudes, and confidence toward mathematics teaching and learning. Their experiences during this intervention activity helps them understand that there are rich connections between mathematics and music, and that it is possible to create a joyful mathematics learning environment by integrating music into mathematics lessons. Moreover, this activity allows preservice teachers to become aware that the process of music creation does not only depend on intuition; mathematics also functions importantly in the composition process. Finally, from the class discussion about how to apply music into mathematics teaching, more methods and topics to teach mathematics content with music are revealed, and their beliefs are further changed; meanwhile, their confidence is further strengthened.

Understanding in Teaching Mathematics Connected With Music

The change in preservice teachers' answers on the two open-ended questions from pretest to posttest is also evidence to demonstrate how preservice teachers in this study change their belief and expand their knowledge toward mathematics teaching and learning. From the results, we find that not only the themes of relationship between music and mathematics as well as such integrated lesson topics but also the response rates are considerably increased. This demonstrates that preservice teachers not only identify and construct more connections between mathematics and music but also generate more lesson themes teaching mathematics integrated with music. This might be explained by the intervention activity that provided preservice teachers with successful and effective examples of mathematics–music-integration activities. To some extent, the intervention activity enlarges preservice teachers' visions of both pedagogical knowledge and pedagogical content knowledge about teaching mathematics integrated with music. This mathematics–music-integrated activity provides and inspires preservice teachers' ways of teaching and learning mathematics. In this activity, preservice teachers experience the whole process of music production from introducing theories and rules, to composing based on rules, to playing and communicating music works.

During this composition process, several links between mathematics and music focus on multiple mathematical content topics by (a) employing a mathematical formula to compose music; (b) exploring the combination of chords in music; (c) investigating the probability of different songs that can be composed based on this formula; (d) investigating the probability of different songs that can be composed by a combination of different music pieces; (f) trying to propose mathematics problem-solving questions based on this activity; and (g) discussing other relationships between music and mathematics. At the beginning, preservice teachers experience the feeling of being a learner in trying these mathematics–music-integrated activities and solving mathematics problems. They then need to transition to the role of a teacher in reflecting on these activities and problems. This might be one explanation for why the preservice teachers who participated in this study change perceptions and expand their knowledge toward the relationship between mathematics and music and the lesson themes that can be taught connected to music. Unlike those preservice teachers' previous perceptions that mathematics and music had few relationships or just superficial relationships, such as counting beats or rhythms or singing mathematics concepts (Rogers, 2004), after this activity's intervention as the results summarized in Tables 2 and 3 show, most preservice teachers' perceptions and knowledge toward music, as well as mathematics, increase to higher-order relationships that combine more complex mathematics with more insightful music knowledge. After the intervention, as the results show, preservice teachers could offer a variety of mathematics topics, which can be taught through similar music-related activities (e.g., statistical graphs, basic operations, fractions, ratio, percentage, and decimal numbers).

Conclusion and Educational Implication

In this study, we have presented the effects of a mathematics activity integrated with music composition. According to the results, this explorative study demonstrates that a mathematics lesson integrated with music has positive effects on preservice teachers' attitude, beliefs, engagement, and confidence toward mathematical learning and teaching.

Teaching mathematics integrated with other subjects can improve students' knowledge in both areas (NCTM, 2000): "Students . . . should have frequent experiences with problems that connect to real-world experiences, that interest, challenge, and engage them in thinking about important mathematics" (p. 182). Teachers should take advantage of the opportunities that music offers to help all students learn mathematics in challenging and enjoyable ways (Johnson & Edelson, 2003). We believe that by connecting arts or music into mathematics teaching and learning, preservice teachers may have more opportunities to change their beliefs about and attitudes toward mathematics. By designing appropriate music integrated into mathematics lessons, students can understand, analyze, and interpret mathematics through different routes. This strategy allows students to present and understand mathematics in alternative ways, especially for those who have a high level of musical-rhythmic intelligence. To achieve this goal, lessons or curriculum tailored to the needs of specific children may be designed and employed (Gardner, 1983). This exploration study, in turn, could serve to broaden and deepen educators' understanding of different ways students experience their learning and contribute to the creation of successful learning environments where more students can be engaged. The findings from this study invite further longitudinal research on other types of mathematics lessons using different links from music and mathematics and focusing on different mathematical content areas at various grade levels, concentrating not only on attitude and beliefs toward mathematics but also on mathematics achievement. Also, it is important to note the involvement of technology support necessary in this kind of integration so that every mathematics teacher can teach similar music–mathematics-integration lessons without intensive learning of music knowledge and skills.

Limitations were also noted in this study. First, the intervention period was short; thus, further changes in preservice teachers' attitude and belief in their later college years as well as in their future teaching is unknown. Second, the sample was fairly small, and the findings may not be generalized to other preservice teachers who study at other universities. However, even with all these limitations, this intervention study provided an opportunity to observe the connection between music and mathematics. 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. We argue that the development of mathematical understanding, beliefs, and attitudes should not emanate from a single curriculum but should permeate the curricula with content other than mathematics, such as music.

We are not suggesting that preservice teachers should study an inventory of teaching all mathematics content with connections, especially, with music. However, preservice teachers should understand that mathematics is connected with other subjects outside of mathematics and can be taught by integrating other content. Thus, teachers' pedagogical content knowledge of how to teach students mathematics with sense-making, especially linked with arts, might provide an alterative way to design and teach an effective lesson. We suggest that teacher education programs familiarize preservice teachers with various connections—the connection within and out of mathematics contents.

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