

A Quasi-Experimental Study of Using Music-Related Concepts to Teach High School Geometry

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The purpose of this research was to test the use of music-related concepts to teach mathematics. A quasi-experimental study of two high school remedial geometry sections was conducted during a review lesson of ratios and proportions. Group A received normal textbook instruction while Group B received the treatment, Get the Math in Music – an online activity involving proportional reasoning in a music-related context. Then Group A received the treatment and took a second posttest. All participants took a survey asking if their appreciation of mathematics grew after receiving the treatment. Interviews were conducted to provide better understanding of the results. Interviews revealed that many students were apathetic to geometry, if not to mathematics in general. A conclusive, generalizable recommendation for or against using music-related concepts to teach mathematics was not found.

Key words: quasi-experimental study, high school math, music activities, geometry.

As an educator, one way to make mathematics more interesting for students is to use real world examples (Ben-Chaim, Keret, & Ilany, 2007). Also, using real world examples that specifically connect to students' interests has been shown to be effective (Vasquez, Sneider, & Comer, 2013). Providing these examples motivates students. Consequently, such examples may give students more perseverance to understand difficult mathematical ideas.

What real world examples will motivate the greatest majority of an adolescent class? Evidence shows that most teenagers love music (North & Hargreaves, 1999). For teens, choosing music is part of forming their identity. Music is a badge which reflects adolescents' personalities and influences who they want to associate with. Considering the connection between adolescents and music, using music-related real world examples may be an ideal choice for mathematics educators. Other subjects besides music may be of more interest for some individuals. But if a high school teacher wants to spark an interest in mathematics for the *most* students, then using music-related examples makes sense.

What mathematics concepts do many adolescents struggle with that have examples in some context related to music? Ratios and proportions are challenging concepts introduced in pre-Algebra – when students are

adolescents – that have applications in music. Would using music-related real world examples be a good method to teach ratios and proportions to teens? The purpose of this research was to test such a strategy.

I implemented a music-related online activity called “Get the Math in Music” in a high school remedial geometry class. I chose this activity because I helped to build it and as such, I am very familiar with it (I wrote the code for it). This activity served as the treatment in my study which was based on a quasi-experimental design (Trochim, 2006). Get the Math in Music is an activity in which students use the concepts of ratios and proportions in a real world scenario involving music production.

The research questions of this study were: to what extent does doing Get the Math in Music improve students’ academic performance in a remedial geometry review of ratios and proportions, and to what extent does participation in the Get the Math in Music activity improve students’ attitudes towards mathematics? The treatment Get the Math in Music was the independent variable. Two dependent variables were measured. One was the level of improvement in solving problems involving ratios and proportions. Another dependent variable was the attitude of the students towards mathematics.

Literature Review

Music and Mathematics Integration Theory

Articles discussing the theory of integrating mathematics and music often trace its historical path. Cohen (1961) shows that the concept of mathematics and music as complementary disciplines is not new. The Pythagorean school of Greek antiquity founded a fourfold path to knowledge called the Quadrivium. It consisted of arithmetic, geometry, music, and astrology. Mathematics and music remained grouped in Western education until the Renaissance. Cohen points out three aspects in which mathematics and music are related. First, they are similar because they are both systems of symbols that do not necessarily point to anything – only to themselves, their antecedents, and their successors. In other words, mathematics and music are self-referential. Second, the creative process of doing mathematics and of doing music involves selecting from a multitude of possibilities. This choice is driven by aesthetics and a desire for elegance in both disciplines. For example, a concise, well-proportioned proof can be compared to a musical masterpiece. Lastly, both music and mathematics are created by building from a set of predetermined presumptions, or axioms. In this endeavor order is important. Each new statement is connected to the preceding with a system of logic. The arrangement of the statements in time is important. In conclusion, the enjoyment of doing mathematics is related to the same kind of satisfaction one may have when composing or performing music.

Music integration is useful in mathematics-related disciplines like engineering. Music exemplifies both structure and aesthetics important to

engineers. According to Baggi (2007) the disciplines of music and musicology produce skills which positively impact creative engineering because they pose similar problems. The study of music involves the search and identification of structures, as well as developing a sense of intuition and aesthetics. Such skills are important to engineers. The author presents a hierarchy of engineering solutions in a chain of command structure ascending as follows: mechanical, electrical, software, artificial intelligence, and art/music. Each piece builds upon the previous. The art/music layer is the aesthetic and intuitive component of engineering design. Another reason why the study of music is beneficial for engineers is because the practice of music illustrates how working on one problem may help find the solution for another. For example, studying a Joplin rag may improve a pianist's ability to play a piece by Chopin. The view of a given problem – how to play the piano – using different representations gives a better understanding of its real nature. The author also points out that the strong dichotomy between art and science is relatively new. He lists musical skills which involve computational thinking such as the realization of unfigured bass, the improvised substitution of chords, and the construction of an improvised melody. These skills require not only understanding of algorithm and recursion, but also of aesthetics. Baggi concludes that for these reasons, engineering education would only benefit from inclusion of music and musicology into its curriculum.

Music and Mathematics Integration Practice

The literature addressing the actual practice of music and mathematics integration includes example exercises for the classroom. Johnson and Edelson (2003) presented several activities to integrate music and mathematics. They remarked that language, music, art, and mathematics are “multiple sign systems” (p. 474) that increase our ability to express what we know in multiple ways and they hoped the activities presented will help students learn mathematics in challenging and enjoyable ways. Moreover, An and Capraro (2011) in their book provided a comprehensive connection between mathematics and music through 43 musical instrument designing activities and 12 music composition activities for elementary and middle school students to learn mathematics through interdisciplinary approaches.

While primary school integration has a focus on musical performance, at the university level, musical theory and psychoacoustics are more applicable to the level of mathematics studied. In his college textbook David Wright (2009) covers diatonic and chromatic scales, intervals, rhythm, meter, form, melody, chords, progressions, equal and mean tone temperament, just intonation, overtones, timbre, and formants. The mathematical concepts covered include integers, rational and real numbers, equivalence relations, geometric transformations, logarithms, sequences and series, groups, rings, modular arithmetic, periodic functions, and numerical integration. The physics

of sound is also discussed. The ways in which music and mathematics are intertwined are seemingly endless.

The practice of integrating music and mathematics in the classroom has also been tested quantitatively. According to Courey, Balogh, Siker, and Paik (2012), the integration of academic music with mathematics instruction – specifically for teaching the concept of fractions to third-graders – can have a positive impact on learning. Their study examined the effects of an academic music intervention on conceptual understanding of music notation, fraction symbols, fraction size, and equivalency. The link between music and mathematics in this application is that they both offer a semiotic means of objectification, one physical, the other abstract. Music instruction involving clapping rhythms functioned as a semiotic game grounded in Vygotsky's concept of a zone of proximal development. It allowed students to make meaning of fractions in a physical way. The gesture of clapping a rhythm served as a concrete symbol whose counterpart in the abstract can be represented by a mathematical fraction. Thus the students learned the concept of fractions with a concrete model before tackling it in the abstract. The authors found that students in the experimental group (who received music instruction with mathematics) outperformed students in the comparison group (who only receive mathematics instruction) in posttests involving fractions. Moreover they found the gains to be greater from pretest to posttest by the experimental group. The authors conclude that integration of music and mathematics can be beneficial to the students' learning, and that finding other connections between the two disciplines in the classroom may both improve students' mathematics performance and save music instruction in our schools.

In addition to quantitative studies, a fair amount of the literature documents qualitative studies. Still and Bobis (2005) present a case study of a primary school teacher who integrates mathematics and music in his classroom. The authors wanted to find out why some teachers utilize integration as a strategy. Their case study involves interviews, observations, and documentation collected over a three week period, and focuses on one third-grade class in Sydney, Australia. The teacher had a musical background and an appreciation for mathematics. The collected research data was organized into four themes: a typical lesson, style of teaching, impact on students, and degrees of integration. Typical lessons brought together elements common to both mathematics and music presented in story form. Additionally, through the course of the day the students would sing scales and songs, chant and dance while reciting multiplication tables, and play recorder in a call-response format with the teacher. The concept of time in particular was covered during the three weeks of the case study. The style of teaching was aimed to educate the whole person by thinking, feeling, and doing to create deep learning and significance. Additionally the teacher's method was to give the students experiences that lead them to discover new concepts. The impact on students was positive: they were excited to solve mathematics problems that came from the story, and they

gained understanding of the importance of time in music performance, not just mathematics. The teacher admits that, considering the age of his students, the level of integration between mathematics and music is not particularly deep. But with the foundation established, the level of integration could occur at deeper levels as the students got older. In conclusion, the authors claim this research raises some questions about teaching mathematics through an integrated approach. In particular: do teachers need expert knowledge in both content areas? Overall, the authors seem optimistic that integration strategies will help make the classroom more enjoyable for the students, and will improve their learning.

Methods

Overview

There were two research questions in this study. First: to what extent does the integration of the music-related mathematics activity Get the Math in Music improve students' academic performance during a review of ratio, proportion, and cross multiplication? Second: to what extent does participation in the Get the Math Activity improve students' attitudes towards the subject of mathematics in general? I was seeking both quantitative and qualitative answers. The general methods I used were based in part on those used in a study by Ben-Chaim et al. (2007) which measured knowledge gains and attitude shifts of pre-service teachers after receiving a treatment on proportional reasoning which involved activities with real world applications.

The quantitative instruments I used consisted of a pretest, a posttest, a second posttest, and a survey. The tests used problems adapted from the McDougal Littell 2007 edition *Algebra I* textbook and the Get the Math in Music activity. The survey was modeled after one used in a study by An, Ma, and Capraro (2011), which tested for gains in pre-service teachers' interest in mathematics after receiving a music integration treatment. The qualitative instrument was semi-structured interviews with questions modeled after those used in the study by Ben-Chaim et al. (2007).

This quasi-experimental study (Trochim, 2006) compared the gains in academic performance and positive attitude of two groups of high school students during a review of ratios and proportions in a remedial geometry course. During the semester, as part of an introduction to similarity, both groups were presented a one lesson review of ratios and proportions. Two weeks before this review all students took a pretest. During the review, both groups discussed ratios and proportions, but with different examples. Group B worked on problems with the treatment: an online activity called "Get the Math in Music." Group A received normal instruction and worked on two problems unrelated to music: calculating the student-teacher ratio at their school, and calculating if a person had enough gas to go from Portland to Bend. At the end of the lessons, the students in both groups received a posttest to measure their

improvement. To be equitable, a week after the posttest, Group A also received the treatment. Group A then took a second posttest as another measure of the effectiveness of the treatment. After all students received the treatment both groups completed a survey asking whether the Get the Math in Music activity improved their attitude towards mathematics. Lastly, after all tests and surveys were completed, a subset of students took part in semi-structured interviews to add insight and explanations to the results.

The treatment Get the Math in Music was the independent variable. It involved using ratios and proportions to solve *music-related* story problems. Two dependent variables were measured. One was the level of improvement in solving problems involving ratio, proportion, and cross multiplication. This was measured by comparing pretest to posttest scores, as well as posttest 1 to posttest 2 scores for Group A. Another dependent variable was the students' attitude towards mathematics. It was measured by a survey questionnaire using a Likert scale for responses. The survey questions asked all students about their attitude towards mathematics and about whether doing problems with music-related applications changed this attitude. Lastly, semi-structured interviews were conducted by me with a subset of the participants during the week following the lesson. These interviews focused on learning why the results of the tests and surveys were what they were. A diagram of this study is provided here in Table I:

Table 1
Quasi-Experimental Design

	Two weeks prior	Day 1	Day 2	The week following
N_a	O_A	O_B	X, O_C , O_D	O_E
N_b	O_A	X, O_B , O_D		O_E

Note: N_a = non-randomized study group A; N_b = non-randomized study group B; X = Get the Math in Music treatment; O_A = pretest; O_B = posttest 1; O_C = posttest 2; O_D = survey; O_E = student interviews

Participants

This study involved two remedial geometry classes taught by two different teachers at a suburban school in Northwest Oregon. The total sample size was 43 students. Each pre-selected class remained intact instead of participants being randomly assigned to one of the two groups. These groups were chosen with the consultation of the mathematics faculty at the school. The criterion was that both groups needed to be evenly matched in academic performance and that their teachers were willing to let their classes participate in the study. These sections consisted of students who had failed geometry during the preceding semester. The demographic of the student body at the school contained a wide range of ethnic backgrounds: 44% White, 25% Hispanic, 14% Asian, 1% Pacific Islander, 5% of mixed race, 10% Black, and 1% Native American. The majority of these students were from a low socio-

economic status (74% receive free/reduced lunch) and lived in neighborhoods close to the school.

Treatment

The treatment involved taking part in a short online activity called “Get the Math in Music.” The activity was developed by me in 2010 for WNET, a PBS affiliate in New York City. It may be found via the following web link: <http://www.thirteen.org/get-the-math/the-challenges/math-in-music/introduction/20/>. Get the Math in Music involved setting up proportions and using cross multiplication to solve them. The task of creating and solving proportions was done in the context of music production, where two rappers were trying to adjust the tempo of a drum track so that it would match the tempo of a particular instrumental audio sample. The drum track was computer generated and its tempo was set in beats per minute (BPM). By finding the BPM of the instrumental sample, the students were able to adjust the tempo of the drum track accordingly.

The Get the Math in Music activity began with a video which introduces the rappers and the problem at hand. The rappers discussed how they feel mathematics is important in music and shared their own stories of how their love of music coincided with an appreciation of mathematics. Then the problem of finding the BPM was posed to several students visiting the recording studio. The students in the video broke into teams of two and discuss how they would go about solving the problem.

After the introductory video, Get the Math in Music continued with a computer activity which guided the students through the problem and solution. The students were first given the duration and were asked to count the number of beats in the instrumental audio sample. Then they calculated the BPM of the instrumental sample by setting up either of the following equations and solving for BPM:

$$\frac{\text{number of beats in the instrumental sample}}{\text{duration of the instrumental sample in seconds}} = \frac{\text{BPM}}{60}$$

or

$$\frac{\text{number of beats in the instrumental sample}}{\text{BPM}} = \frac{\text{duration of the instrumental sample in seconds}}{60}$$

If the students had difficulty setting up the problem, a hint screen was provided. After choosing a value for BPM, a mix of the drum track and instrumental sample were played back. If the student had chosen the correct BPM, the mix sounded correct – the two parts were in synch. If they chose the incorrect BPM, the drum track sounded out of synch with the instrumental sample. Additionally, if they chose the incorrect BPM, a more detailed hint screen was provided. Once the students had completed this task successfully, they were given a second challenge of the same design but with the opportunity to choose from several different drum tracks and instrumental samples. The

students in both groups completed the entire activity in approximately 40 minutes.

Group A took part in normal class instruction taught by me. The lesson involved solving two problems. First, given how many teachers and students there are at this high school, what is the student-teacher ratio? Second, a person wants to drive to Bend from Portland. Their gas tank holds 12 gallons and is $\frac{3}{4}$ full. Their car gets 20 miles per gallon. The route is 150 miles via US 26, and 185 miles via OR22. Does the person have enough gas to get there? How do you know? By which route? What fraction of a tank should it read on the fuel gauge for each route? Students offered answers with explanations to these questions. The concepts and usage of ratios and proportions were reviewed.

Both groups received instruction that involved mathematics problems based on real world applications. The major difference was that the group receiving the treatment solved these problems in the context of music production while the group receiving regular instruction worked in non-musical contexts.

Instruments

The instruments used measured both quantitative gains in academic performance and positive attitude, and qualitative reasons for those gains. The quantitative instruments used were a pretest, a posttest (posttest 1), a second posttest (posttest 2), and a survey. The qualitative instrument used was semi-structured interviews. Details of each instrument are as follows:

Pretest, posttest 1, and posttest 2. The pretest, posttest 1, and posttest 2 were all of similar difficulty and each had four problems. Three problems in each test were adapted from the section quizzes in McDougal Littell's 2007 edition textbook *Algebra I*. The fourth problem in each test was adapted from the problem presented in the Get the Math in Music activity. Complete pretest, posttest 1, and posttest 2 questions are provided in Appendix A.

The pretest, posttest 1, and posttest 2 assessments were used to test my first hypothesis and answer my first research question. If the gains in subject knowledge between pretest and posttest were significantly greater for Group B than for Group A, then we might be able to attribute those gains to the implementation of the treatment. Additionally, if Group A showed greater gains from the first posttest 2 to posttest 2 than from pretest to the first posttest that might also support the claim of the effectiveness of the treatment.

Survey. The survey contained questions similar to those in An et al. (2011). It consisted of eight questions regarding the student's interest in mathematics and music, respectively. The answers were provided using a five point Likert scale. Response choices were: strongly agree, agree, neutral, disagree, and strongly disagree. The complete list of survey questions is provided in Appendix A.

A significant threat to the validity of the survey is apathy. Since it is a survey using a Likert scale, the student might presume (correctly) that they will

not receive a grade for their responses. In this case, it is possible that students won't be motivated to submit truthful answers. To guard against this I explained to students that the accuracy of their answers was important and beneficial to them because ultimately my study was concerned with making mathematics more enjoyable for them. If it is true that most students in a remedial geometry class do not enjoy learning mathematics, I anticipated their cooperation after telling them the goal of this study.

Interviews. Lastly, the semi-structured interviews I conducted posed several open-ended questions modeled after those used in Ben-Chaim et al. (2007). Among the questions, the students were asked if they enjoyed the Get the Math in Music treatment more or less than the regular instruction. They were also asked to explain what they liked or did not like about the music activity. The complete list of interview questions is included in Appendix A. The interviews were conducted after both groups received the treatment and after all quantitative assessments were completed.

At this stage in the study, after everyone had received the treatment, the distinctions between groups no longer existed and the interview questions were identical for all participating students. The primary purpose of the interview was to better understand why each student performed as they did. I wanted to learn in what way if any the Get the Math in Music activity helped or hindered their performance.

An important threat to validity to be concerned about in the interviews was a selection-instrumentation threat (Trochim, 2006). The students may say they liked the music activity just to please the interviewer. To mitigate this, at the outset of the interview, the importance of honesty in their responses was reiterated to the student being interviewed. The interviewer explained that cooperation and honesty are of the utmost importance, and that this study's ultimate goal was to make learning mathematics more enjoyable for the student.

Threats to Validity for All Instruments. Construct validity (Trochim, 2006) is a major concern since the Get the Math in Music activity is delivered online in a format that might be more appealing to students than a textbook. If students learn the subject matter better after the treatment, it is possible that this is due to Get the Math in Music being an online tool, or to the activity giving audio feedback for wrong answers, or to the students disliking their textbook in particular. It would not be because of the construct I wish to test: the application of mathematics in music. It is difficult to mitigate this threat. I theorized different ways to reduce this threat, but with each new solution, a new construct threat appeared. Ultimately the best way to deal with this threat is to find other mathematics-music integration studies that benefited students to show that activities like Get the Math in Music are part of a bigger body of evidence illustrating the effectiveness of using music-related real world examples while teaching mathematics.

Procedure

This study occurred over the course of several weeks at a high school in Northwest Oregon. It centered on one lesson reviewing ratios and proportions. The lesson was taught by the same teacher (i.e., myself) to two pre-selected geometry classes considered to be evenly matched in academic performance by the mathematics faculty at the school. Specifically, the students in these two groups had failed geometry in the preceding semester. These classes were to cover the same material in the same order as the preceding semester. One section served as Group A. The other served as Group B.

The groups did not receive geometry instruction on the same days. The school used an A/B “block” schedule. Group A had class on A days while Group B had class on B days. I took this into account when deciding upon the sequence of events in this study in attempt to minimize social interaction threats.

Two weeks preceding the start of a unit on similarity, all students took the pretest. Then on the first day of the unit, Group A received normal instruction and took the posttest. The next day, Group B received the treatment, took the posttest, and completed the survey. One week later Group A received the treatment, took posttest 2, and completed the survey. Another week later, after I examined the results of the tests and surveys, a selection of students were given interviews. Interviewee selections were made to include students who improved, students who did the same, and students who did worse from one assessment to another.

The goal of the interviews was to add depth to the understanding of the results from the tests and survey. These interviews were conducted by me rather than by the teacher to minimize bias. The majority of interview questions were open-ended. For example, one question was: did you prefer the Get the Math in Music treatment to the regular class instruction and why? This question was given to allow the students to expand upon their answers. I documented the students’ answers with notes containing paraphrase and quotes. The complete interview notes are included in Appendix C.

Data Analysis

Not all students returned signed consent forms. Of the 43 students who participated, 29 submitted signed consent forms. Therefore $N = 29$. All test scores and survey responses were entered into an Excel spreadsheet. Paired sample t -tests of test scores were done in Minitab with the consultation of an expert. Survey response data mean, median, and mode values were calculated in Excel.

To answer the first research question (i.e., to what extent does the integration of Get the Math in Music improve students’ academic performance in a remedial geometry review of ratios and proportions), a paired sample t -test was used to find out if Group B had statistically significantly greater gains from pretest to posttest than Group A. Another paired sample t -test was used to find

out if Group A showed significant performance gains after receiving the treatment compared to when they received normal instruction.

To answer the second research question (i.e., to what extent does participation in the Get the Math activity improve students' attitudes towards mathematics), survey responses from all participating students were tallied to determine if a majority of students enjoyed mathematics more after receiving the Get the Math in Music treatment. In particular the results of the fourth survey prompt (i.e., you like mathematics more now that you have used it in an activity related to music, like Get the Math in Music) informed the answer to this question.

Lastly, the interview notes were evaluated in order to better understand the thinking of those students interviewed, and to determine if a majority of those students enjoyed mathematics more after receiving the Get the Math in Music treatment. I first analyzed the responses to groups of questions based on what information those questions targeted. Then I made multiple passes over the notes looking for recurring themes and noting them with reference to supporting student responses.

Results

To what extent does the integration of Get the Math in Music improve students' academic performance in a remedial geometry review of ratios and proportions? To analyze this data I used a paired sample *t*-test of score gain by group. The test showed that greater improvement from pretest to posttest with Group B (P -Value=0.048). Group B received the treatment between pretest and posttest. On average this improvement was about 1 point. The table 2 shows these results:

Table 2
Comparison of Pretest to Posttest Gains by Group

Group	<i>n</i>	<i>M</i>	<i>SD</i>	<i>p</i>	95% CI
A	17	0.41	1.06	0.048*	-1.835, -0.008
B	12	1.33	1.23		

Note: A Two-Sample t-Test was used. n = number of participants. M = mean. SD = standard deviation. CI = confidence interval. A total of 4 points was possible on each test. Consequently the maximum gain or loss possible between tests was 4 points.

I also used a paired sample *t*-test to see if Group A showed larger gains between the first posttest and posttest 2 (after they received the treatment) compared to between pretest and posttest. This test showed no significant difference in gains. The table 3 illustrates these results:

Table 3
Comparison of Pretest and Posttests Gains for Group A

Tests	<i>n</i>	<i>M</i>	<i>SD</i>	<i>p</i>	95% CI
Pre to post 1	17	0.41	1.06	0.870	-0.784, -0.666
Pre to post 2	17	.47	1.01		

Note: A Two-Sample *t*-Test was used. *n* = number of participants. *M* = mean. *SD* = standard deviation. *CI* = confidence interval.

A total of 4 points was possible on each test. Consequently the maximum gain or loss possible between tests was 4 points. Note that most students in Group A showed no gain from posttest to posttest 2. A mean gain of 0.41 from pretest to posttest was very close to the mean gain of 0.47 from posttest to posttest 2 for this group. Neither of these gain values were close to Group B's mean gain of 1.33 between pretest and posttest.

Interviews

Students interviewed were split on whether they preferred regular instruction over the Get the Math in Music activity. Of those interviewed, five students preferred the activity and four preferred regular instruction. Several of the students who preferred the activity said they like it because it was "different," and not necessarily because it involved music.

Several students indicated their level of academic performance is primarily determined by their mood on any given day. For example student D said, "Sometimes I like it [*mathematics*], sometimes I just don't want to do it." Student B said, "I probably didn't care that day for the first two tests." Student O said "I was being lazy for the first two tests."

Questions 1 and 2 of the interview sought to know if the student already had an affinity for mathematics or music. Only one person, Student B, included music among an activity or topic that interests him on Question 1. For Question 2, only one person, Student S, said mathematics was her favorite subject, but she specified not geometry. Questions 3 and 4 sought to learn about the student's attitude and abilities with mathematics. Only one person, Student D, said he enjoyed mathematics (Question 3). Five participants, Students B, G, O, X, and AA, said they did not enjoy mathematics. Only one person, Student CC, said he was good at mathematics while four students, Students B, G, W, and AA, said they were not.

Questions 5 and 6 sought to know about the student's attitude towards the treatment. In response to Question 5, six students (B, D, S, X, AA, CC) said they enjoyed the activity, one (G) said it was alright, and two (O, W) did not care for it. Those interviewed were split five to four over whether they preferred the treatment to regular instruction. Five (B, G, S, X, CC) said they preferred the treatment. Four (D, O, W, AA) preferred regular class.

Question 7 was an open-ended self-evaluation. It sought to learn what students attributed their performance to. Responses revealed that several

students interviewed admitted they may or may not try on any given day (B, O). Question 8 was tied to the students' responses for survey questions 3 and 4. It sought to find out how strongly the treatment improved the learning, if at all. Student D's response revealed that he may or may not try on any given day which is consistent to the results above for Question 7. Several students (D, G, S, AA) said they just did not like mathematics. Several students (G, O, W, X) also said that for them the use of music to teach mathematics was no big deal.

Discussion

Some evidence found in the data supports the hypothesis that using a music-related activity like Get the Math in Music is more effective than normal instruction in fostering better academic performance. The correlation ($p = 0.048$) of Group B with greater gains from pretest to posttest may indicate that the treatment was effective. On the other hand, no other data supports this. The treatment was not statistically correlated ($p = 0.870$) with improving Group A's scores between posttest and posttest 2. This reason, along with the mixed reaction to the treatment as documented by the survey and interviews, makes it hard for me to feel confident that teaching with a music-related activity like Get the Math in Music is any more effective than normal instruction, even with adolescents, at improving academic performance in mathematics.

Furthermore, the evidence does not support or refute the second hypothesis that students like mathematics more after taking part in the Get the Math in Music activity. Survey question 4 specifically asked students if they liked mathematics more as a result of taking part in the Get the Math in Music activity. The average response was neutral ($M \approx 2$ on a Likert scale where 2 indicates "neutral").

The average of a neutral response to the first five questions on the survey which measured student interest in mathematics, along with interview data showing approximately half of those interviewed do not enjoy mathematics, suggested that there was a widespread apathy among the students in these sections when it came to learning mathematics. The activity alone did not change this apathy. Interviews showed that many students liked the activity, but not necessarily because it was related to music, and not enough to make them start liking mathematics.

Survey questions 6-8 showed that music was important to most if not all students. These findings were consistent with those of North and Hargreaves (1999) regarding the nearly universal gravitation of adolescents towards music. On the survey, most students strongly agreed that they liked music and that they listened to it regularly. Ironically, in the nine interviews, only one student actually mentioned music as one of his interests.

The assertion in the literature that proportional reasoning is one of the most difficult concepts in mathematics to teach and to learn (Lamon, 2007; Vasquez et al., 2013; Ben-Chaim et al., 2007) was also supported. The

participants had all studied ratios and proportions several times before (i.e., in middle school, in Algebra 1, and in the first semester of Geometry) and yet the majority struggled on the pretest. The average pretest score was less than 50%. Furthermore, even though all 4 problems on each test were of approximately the same level of difficulty, very few students got all four questions right on any of the tests.

Future studies would benefit from having more than four points of assessment to understand the level of student comprehension. The steps to solving the problems could be subdivided and assessed to see greater nuances of student understanding. Also a time-series repeated measure design might be a better way to analyze the data than using t-tests since two posttests take place at different times.

In sum, teaching mathematics to adolescents with music-related activities might still be an effective strategy. This research was not able to reliably conclude one way or another on that point. Several conclusions of this research support existing claims: adolescents love music and many participants struggle with proportional reasoning. Further study on a larger scale and in a general education setting would be helpful for determining more conclusively if music-related activities pose some advantage to high school mathematics students.

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Appendix A: Instruments**Pretest**Name _____ Date _____ Period _____
Assessment 1

Answer each question as best you can. Please show your work!

- 1) Holly baked 12 cookies with 4 ounces of raisins. Using the same ingredient ratio, how many cookies could she bake with one ounce of raisins?
- 2) Solve for t and then check by substituting your solution into the original proportion.
 $32 / t = 24 / 3$
- 3) You just rode your bike for 50 minutes and burned 600 calories. How many calories did you burn per minute?
- 4) An audio sample of music has a duration of 9 seconds. You count 12 beats within that sample. How many beats per minute is the music?

Posttest 1Name _____ Date _____ Period _____
Assessment 2

Answer each question as best you can. Please show your work!

- 1) Polly baked 4 cakes with 12 eggs. Using the same ingredient ratio, how many cakes could she bake with 21 eggs?
- 2) Solve for y and then check by substituting your solution into the original proportion.
 $\frac{15}{3} = \frac{25}{y}$
- 3) You just ran for 30 minutes and burned 570 calories. How many calories did you burn per minute?
- 4) An audio sample of music has a duration of 8 seconds. You count 10 beats within that sample. How many beats per minute is the music?

Posttest 2

Name _____ Date _____ Period _____
Assessment 3

Answer each question as best you can. Please show your work!

- 1) Holly baked 20 cookies with 5 ounces of raisins. Using the same ingredient ratio, how many cookies could she bake with one ounce of raisins?
- 2) Solve for t and then check by substituting your solution into the original proportion.
 $64 / t = 24 / 3$
- 3) You just rode your bike for 60 minutes and burned 540 calories. How many calories did you burn per minute?
- 4) An audio sample of music has a duration of 12 seconds. You count 16 beats within that sample. How many beats per minute is the music?

Survey

Name _____ Date _____ Period _____
Survey

Respond to each statement by circling A, B, C, D, or E accordingly.

- 1) You like mathematics.
A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Disagree
- 2) Mathematics is of more interest to you when it involves solving problems in the real world.
A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Disagree
- 3) You like mathematics when it involves solving problems related to music, like in the Get the Math in Music activity.
A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Disagree
- 4) You like mathematics more now that you have used it in an activity related to music, like Get the Math in Music.
A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Disagree
- 5) There are other uses of mathematics in the real world, in activities besides music, which you would prefer to study.
A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Disagree
- 6) You like music.

- A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Disagree
- 7) You play or listen to music regularly.
A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Disagree
- 8) You consider music to be a big part of your life.
A. Strongly Agree B. Agree C. Neutral D. Disagree E. Strongly Disagree

Interview Questions

Name _____

- 1) What sort of activities/topics interests you? For example, do you like nature, science, sports, fashion, cooking, etc.?
- 2) What is your favorite subject in school?
- 3) Do you enjoy mathematics? What do you like or dislike about it?
- 4) Do you consider yourself good at mathematics?
- 5) Did you enjoy the Get the Math in Music activity? Why?
- 6) Which did you prefer: the Get the Math in Music activity or regular in class instruction? Why?
- 7) Why do you think your test score improved between pre and posttests? (if it did)
- 8) Can you tell my about your answers to 3 and 4 on the survey? (look at surveys)

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