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# High School Students' Perceptions of the Relationship between Music and Math

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*While there is little doubt that engaging in musical or mathematical activities stimulates brain activity at high levels and that increased student involvement fosters a greater learning environment, questions remain about whether musical ability and mathematics performance are related. This study took a qualitative approach that allowed 24 high school students to share their direct experiences with music and mathematics, as well as their perceptions of how the two fields are related. Participants were divided into four groups based on school music participation and level of mathematic achievement. Using a multiple intelligence lens, this study addressed the following question: How do students perceive the fields of music and mathematics relating to each other? Interestingly, most of the students saw math as a foundation for musical ability, which suggest a different direction than most previous studies. The musical element of rhythm seemed to have the most mathematical connection. This implies several possibilities for educators, including encouraging students in both areas of study to recognize the connections between the two, if not particularly the influence of one over the other. Additionally, teachers in both fields may begin more collaborative efforts to support the learning in both content areas. Future studies include looking at the specific perceptions of students based on ethnicity, gender, and SES status, as well as exploring the motivation of students in both music and mathematics.*

Since the time of Pythagoras, philosophers, educators, and researchers have theorized that connections exist between music and mathematics. From intervals based on perfect ratios to more recent advances in neuroscience showing increased activation in the brain during musical and mathematical performance, these theoretical connections have gained and lost prominence in the literature. With current advances in brain mapping technology and a greater understanding of how the brain works, it is possible to explore these connections. Given these findings, it is important for educators to continue to explore the possible connections between mathematics and musical learning, especially given the common perception that music influences mathematics learning, when in reality the influences are less clear. It is important for educators of both music and mathematics to build on possible connections as a way of contributing to students' overall learning and capacity to contribute as learned citizens.

Numerous studies that have attempted to answer questions of linkage have failed to provide a definitive answer (Baillet, Mosher, & Leahy, 2001; Caterall & Rauscher, 2008; Helmrich, 2010; Southgate & Roscigno, 2009). Both research and practical applications have identified correlations between music and mathematics ability when addressing brain activity (Spelke, 2008; Szirony, Burgin, & Pearson, 2008); however, correlation does not equate to causation.

While there is little doubt that increased student involvement in either activity stimulates brain activity at high levels and fosters greater learning (Johansson, 2006), questions remain about whether musical stimulation actually improves mathematics performance. Conversely, little evidence suggests that those highly gifted in mathematics will be equally successful in musical study or show any desire to study music (Gardner, 2006).

The contradictory results in the research lead to much confusion and misunderstanding concerning musical and mathematical experiences and the relationships/influences between them. Many myths about a music/math connection have circulated in the media and among the general public, often based on incomplete or misunderstood research. For example, Rauscher and Shaw's (1998) study of college students' improvement on a spatial reasoning test after listening to ten minutes of Mozart's *Sonata for Two Pianos in D Major* (K.488), later dubbed the "Mozart Effect," generated considerable attention after its initial release. Working on the premise that music stimulates multiple regions of the brain, thereby also stimulating regions associated with spatial reasoning, the researchers posited that the temporary effect of listening to music organizes the cortex to better process spatial-temporal activities. Authors noted that students performed at high levels on a single mathematics test with Mozart music in the background. As a further test in a later study, Ivanov and Geake (2003) report observing a Mozart Effect in 76 elementary students, twenty who took private music lessons and the remaining 56 having no outside music experience, who participated in a Paper Folding Task (PFT) while listening to the music of both Mozart and Bach. They found that students with prior music experience outperformed students with lower levels of music experience in mathematics paper folding tasks. Pietschnig, Voracek, and Forman (2010), however, countered these claims based on a meta-analysis of 39 published and unpublished Mozart Effect studies that examined the spatial performance of over 3,000 subjects. Their findings show a small effect size and limited support for the effect of listening to Mozart as a means of promoting mathematics learning.

Supporters of the connections between music experiences and mathematics prowess encourage increased student involvement in school music programs (Sousa, 2006) for the purposes of raising mathematics test scores. Others caution that music should be studied for music's own sake, rather than to enhance the learning of other subjects or increase test scores (Kassell, 1998; Reimer, 1999). Anecdotal evidence showing higher mathematics test scores on standardized testing of musicians over non-musicians, while intriguing, only scratches the surface of this debate (Helding, 2010; Johnson & Memmott, 2006; Kinney, 2008; Klinedinst, 1991).

While correlational evidence suggests some students with advanced musical skills also show strong results on certain mathematics assessments (Fitzpatrick, 2006; Helmrich, 2010) it is unclear if and how these two strengths are connected. Gardner's (1983) theory of multiple intelligences (MI) attempted to address the developmental aspects of both sets of skills. While Gardner's views on the linkage between intelligences have evolved over the years since the initial publication of his theory, he originally claimed that these intelligences were not related, although they may share certain characteristics. "Music is a separate intellectual competence, one that is also not dependent upon physical objects in the world…. But … it is equally important to note the important and integral links that obtain between music and other spheres of intellect" (p. 122). Gardner notes, for example, that "certain musical abilities may be closely tied to spatial capacities" (p. 123) due to their position in the right hemisphere of the brain. Gardner maintained a theoretical position that musical and mathematical intelligences were independent, though later in his career he conjectured that similar cognitive operations may be used in both fields.

Numerous critiques of MI theory surfaced after the first publication of Frames of Mind (Gardner, 1983). Klein (1998) claimed there are several major issues with the entire concept of intelligences, arguing that the MI theory makes "three paradoxical claims": that (1) there are several relatively independent, coherent, content-specific cognitive modules called intelligences; (2) these intelligences interact, operating on one another's contents; and (3) each intelligence consists of sub intelligences that can operate independently. MI generates ambiguity because "one does not know whether to expect that the intelligences will act independently or interactively, nor whether the sub intelligences of any intelligence will act coherently or independently" (Klein, p. 105). A number of other critics (Hunt, 2001; Willingham, 2004) identify issues with MI theory, including concerns with the criteria used in identifying the intelligences, a lack of empirical evidence in measuring each of the intelligences, and an overall belief that some of intelligences, such as musical and bodily-kinesthetic, are merely talents in some individuals. While Gardner has moved on to new areas of inquiry, several researchers have continued to examine the math/music connection; specifically, the question of whether one intelligence may affect another (Helmrich, 2010; Sousa, 2006; Spelke, 2008). However, the question of *students*' perceptions of such linkages and how their experience in one domain influences the other has not been explored.

While numerous studies about multiple intelligences, developmental cognitive neuroscience, and motivational theories have identified anecdotal linkages between students' music and mathematic performances (Helding, 2010; Johnson & Memmott, 2006; Olson, 2010; Zatorre, 2003), none has involved a study of students' own perceptions of such connections. Such perceptions are important missing pieces to making meaning of any perceived or actual connections between the fields. Understanding students' perceptions can guide educators to examine the value of content students are expected to acquire while in school and perhaps lead to new and innovative ways to teach material.

## Music and Mathematics in Educational Settings in the Literature

The study of the cognitive connections of musical and mathematical thinking remains a topic of great interest among researchers. Most studies are uni-directional, examining whether and how music experiences influence mathematics learning. Few studies explore the opposite, that learning mathematics influences musical ability. In addition, most studies are correlational or circumstantial rather than experimental in nature. In spite of these research limitations, across time, researchers continue to suggest that music study influences mathematics learning.

Shore (2010) found that "Students who maintained membership in their middle and high school orchestras and bands performed better in math during their senior years. This result was even more pronounced for children from low-income homes" (p. 58). Further, Shore noted that the one-to-one setting of private music lessons appears to help children develop higher levels of attention to details, which may transfer out of the musical setting. Musical study "typically involves moving from more simple melodies to more complex musical compositions over time, engaging memory and mental stretching repeatedly" (p. 59). Shore suggested that the increase in focus due to the increasing complexity of the music fosters the development of cognitive skills in language or mathematics, and that developmentally appropriate sequences of learning support greater capacity in neural pathways, which are used for not only musical but for all areas of cognitive development.

However, it is important to note the difference between musical learning and using music as a memory aid. Teachers will often use music in drills, linguistic activities, and spelling lessons; however, Kassell (1998) contends that to use music in teaching mathematics, "the concept must be transferred back to mathematics if genuine understanding is to take place. Without making the translation back into mathematics, Gardner says that the student will never really think mathematically about the mathematical concept" (p. 30). Gardner (2000) also cautioned against the over-simplification of connections of intelligences, suggesting that trivial examples are often used to show connections. "'Let's sing our times tables children!' says the teacher, and the observer claims that musical intelligence has been used to teach mathematical thinking" (p. 188).

**Linkage Theories**

Most literature related to music and mathematics linkages emerges in two fields of study: cognition and neuroscience. Cognitive approaches examine related skill development in music and mathematics and in their relationship to one another. Near transfer theories are theories that attempt to connect the cognitive aspects of music and mathematics through shared cognitive skills. Črnčec, Wilson, and Prior (2006) define near transfer theory as:

> …musical instruction and spatiotemporal reasoning tasks require related cognitive skills. Learning that occurs during music instruction, therefore, may transfer to other tasks. For example, learning to read musical notation and understand spatial relations on the keyboard requires visuo-spatial skills. (p. 584-585)

This is consistent with Hetland's (2000) findings that suggest, "Two kinds of theories have been proposed to explain why various types of music instruction might enhance performance on spatial tasks: 'neural connections' theories and 'near transfer' theories" (p. 180). Neural theories refer to those that suggest specific regions of the brain are utilized for both musical and spatial tasks, while near transfer theories are based on cognitive connections between related skills in both music and spatial abilities. The following sections focus specifically on cognitive studies that look at correlational linkage between music and math, standardized testing correlations, and studies that involve multiple intelligences.

**Standardized Testing**

A number of studied pointed to the correlation between participation in musical groups and mathematics competencies on standardized tests. Kinney (2008) found increased mathematics test scores for musicians over non-musicians in a Midwestern urban setting using state tests administered in the sixth and eighth grades. Based on the test scores, Kinney found band students outperformed their non-musical counterparts in both sixth and eighth grade math proficiency tests, and instrumental musicians scored the highest of the music students, with choral students showing no significant differences in scores. These results align with Klinedinst's (1991) conclusions that high levels of reading performance, math performance, and scholastic ability have strong ties to success in performance-based achievement among beginning fifth-grade instrumentalists. Catterall, Chapleau, and Iwanaga (1999) also found that in tracking 25,000 students over a 10-year period, students involved in music had higher standardized test scores than their non-music counterparts regardless of socioeconomic status (SES). Fitzpatrick (2006) used Ohio Proficiency Test (OPT) results to compare musicians and non-musicians of various SESs. The OPT measures student performance in fields such as citizenship, math, science, and reading. Students who continued their elementary instrumental music training into high school outperformed their non-musical peers at similar SES levels at each grade level. Further, the scores of music students at low SES levels showed the highest gains. These correlational studies do not represent cause, but suggest that musical performance relates to or somehow influences achievement in mathematics.

Helmrich (2010) explored the effect of musical training on analytic processes, such as those used in algebra, looking at the scores of musicians and non-musicians included among those of over 6000 students taking the Maryland Algebra/Data Analysis High School Assessment. The findings remained consistent across each of the areas of study: the students with musical training outscored the non-musician group, with instrumental musicians out-scoring their choral counterparts. The average passing rate of instrumental musicians was 90.62, while students with choral training had an average passing rate of 81.51. The group of students with no musical training posted an average of 75.03. While these studies show a correlation between mathematical competency, as measured on state standardized tests, and formal music study, Helmrich cautioned that many additional factors may be involved. He noted specifically that highly motivated students who naturally possess greater academic talent might gravitate to formal music classes in schools, suggesting that their own intrinsic motivation would manifest itself in other areas. Alternately, the nature of musical study may support natural creativity, problem solving, and diversity of thinking that are all essential for mathematics study, and specifically for algebra. The skills needed to decode musical notation may align with skills seen in solving algebraic equations. The dedication required to practice a musical passage repeatedly might create a needed work ethic, essential to completing complex mathematical problems.

While these studies have found very specific correlations between music and mathematics, none can identify the specific cause of their findings. Strong correlations have been found concerning music students' increased ability in cognitive aspects of math, specifically logical and spatial areas, over non-musicians, as is seen in many studies relating to standardized test results. While many researchers may imply a direct linkage, where music supports mathematics skills, too many confounding elements prevent a clear statement of causality.

## Methodology

Previous studies that explored the possibility of musical and mathematical connections have focused on factors such as brain mapping or standardized testing. No study to date has examined students' perceptions of the connection or influence of one subject over the other, in spite of their involvement in and experience with both music and mathematics.

**Purpose**

This paper focuses on the students' own perceptions of connections between music and mathematics. The purpose of this study was to explore 24 high school students' perceptions of the relationship between music and mathematics learning. The data from this study were taken from a larger study that explored student perceptions of music and mathematics, based on high school experiences as well as their lives outside of school, through a multiple intelligence lens. Two main research questions guided this study:

1. How do students perceive the fields of music and mathematics relating to each other?
2. If they perceive a connection, what do they see as the source of this connection?

However, several interview questions were presented to students, regarding their own experiences and perceptions of differing connections.

**Setting**

The setting for this study was a north Texas high school in one of the fastest growing areas in the U.S., in a suburban city of over 136,000 residents. The district currently has three high schools, with a total high school population of approximately 7,500 students. The studied campus is the oldest of the three schools and has a student population of approximately 2000 students (approximately 60% white, 24% Hispanic, and 13% African American).

**Population and Sample**

The population for the study consisted of students in the senior class graduating in 2014. The senior class began the 2013-14 school year with 498 students. Of these, 244 were male and 254 female. Students self-reported their races as 56% White, 25% Hispanic, 13% African-American, and 6% other. The students varied in levels of school music participation in school ensembles, as well as mathematic performance based on the Exit Level Texas Assessment of Knowledge and Skills (TAKS) scores from the spring of 2013.[1] For the purpose of this study, students who participated in a school music organization during their senior year were identified as *high-level* school music participants. Students not enrolled in a school music organization during their senior year were identified as *non-music* participants.

Based on the definitions of school music and non-school music participation and mathematics TAKS success levels, the population was divided into four categories: Music/Commended, Music/Passing, Non-music/Commended, and Non-music/Passing. Due to the disparity between participation in mathematics (mandatory 100% participation), and music participation (voluntary/audition based), the information was used to stratify a sample of 24 students, six in each of the four classified categories of music and mathematics high and low levels.

Selection of potential participants for the study resulted from a multi-layered examination of music participation and mathematics TAKS scores. Initially, all school music students' names

[1] The high school Exit TAKS report a scale score, with 2100 showing a passing or met standard rating, and a score of 2400 or higher earning the commended performance rating. Commended Performance is defined as "high academic achievement; considerably above state passing standard; thorough understanding of the mathematics TEKS curriculum" (TEA, 2006, p 17-18).

were included in a spreadsheet. The junior mathematics TAKS scores for each student were added to the sheet. Based on the TAKS scores from their junior year, all students participating in music programs were divided into groups of high (2400+) (Music/Commended) and low (2100-2400) (Music/Passing) levels of mathematics performance. Additional information including musical medium, race, and gender was added to the spreadsheet for each student. The lack of black students in orchestra, and the much higher percentage of Asian students in all music groups that existed in the student population, precluded these subgroups from inclusion in the study. A sample of six white male/female students and six Latino male/female music students was included in the Music/Commended and Music/Passing groups.

A matching sample was selected from the non-music student population. The makeup of the non-music participant sample mirrored the racial and gender makeup of the school music participation groups. Again, TAKS scores defined mathematics level; however, additional filters first selected Hispanic students. Random selection then occurred from the number of commended Hispanic students not involved in music programs. From that list, male and female students matched the music groups. The process was repeated to complete the math-passing list of students. From there, white student selection continued in a similar manner to complete the Non-music/Commended and Non-music/Passing groups. Once they were identified, students and parents were contacted and provided with informed consent forms. All six of the invited students accepted the invitation to participate in the study and returned all required consent forms, for a sample of 24 students from the class of 498 seniors. Figure 1 shows the makeup of the sample.

Figure 1. *Sample of Students*

| Music Commended (*n* = 6) | Music Passing (*n* = 6) |
|---|---|
| 3 Male / 3 Female | 3 Male / 3 Female |
| 3 White / 3 Hispanic | 3 White / 3 Hispanic |
| 2 Band / 2 Choir / 2 Orchestra | 2 Band / 2 Choir / 2 Orchestra |
| Non-Music Commended (*n* = 6) | Non-Music Passing (*n* = 6) |
| 3 Male / 3 Female | 3 Male / 3 Female |
| 3 White / 3 Hispanic | 3 White / 3 Hispanic |

## Design

This study is a case study of twenty-four students who participated in music and mathematics learning at various levels. The data for the study were obtained through three interviews, employing the Seidman (2006) interview protocol of building upon previous interview data in subsequent interviews. Students chosen to participate in the study were involved in three individual interviews, lasting approximately 45-60 minutes total for each student. During the course of interviews, participants shared their histories and experiences with music and mathematics, their perceptions of the relevance of mathematics and music in their lives, and their perceptions of the interconnection of mathematics and music in their lived experiences. All interviews occurred on the campus, generally in the library, outside of the music classrooms, or in one of the administrative offices, and were typically held before or after school. While the interviews followed certain protocols, such as a specific list of interview questions for all

students, the questions were purposely open-ended, with a semi-structure format, to allow for an in-depth response. The related questions from the protocol are listed below.
First Interview

- Was music/math an important part of your family activities?
- What are your earliest memories of music/math as a child?

Second Interview

- Do you have any musical or math experiences or recognitions you would like to share?
- How important is music? Math?
- There are some theories that suggest there is a connection between music and mathematics. What is your initial reaction to that idea? Do you have experiences that support or oppose that view?

Third Interview

- Do you have any additional thoughts about the notion that music and math might be connected?
- What other information would you like to share regarding your experiences in music/math?

The interview methodology allowed the participants to direct their own stories (Seidman, 2006). Students were asked about their perception of connections between math and music at both their first and last interview, to note any change in student attitudes.

**Data Analysis**

The researchers based data analysis on an interpretive phenomenological analysis (IPA) approach (Smith & Olson, 2008), where the experiences and meanings perceived by the participants guided the researchers in making sense of their own perceptions of the data. The IPA approach unfolds on two levels; on one, participants are exploring the meaning of their experiences; on the other, the researcher is observing the participants as they explore their world. The process requires analyzing each transcript through multiple readings to identify themes, and to compare these themes across transcripts. In reporting the findings, "Care is taken to distinguish clearly between what the respondent said and the analyst's interpretation or account of it" (Smith & Olson, 2008, p. 76).

The data analysis plan included transcribing each interview, uploading transcriptions into NVivo 10 for coding, and looking first for relevant or constant themes in each transcript and then later for themes between members of the same group. Miles and Huberman (1994) refer to codes as "tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study" (p. 56). For this study, the researchers manually entered codes, with a separate code for each question, so that student responses were first coded question by question. From there, secondary codes developed from the content of the transcripts based on emerging themes via a line-by-line analysis. This included, for example, grouping positive responses to a single question using a secondary code, while the negative responses required a different code.

From there, a tertiary level of coding looked at important words or phrases within the positive or negative responses.

After the initial coding to each question began to clarify the experiences of individual students, it became necessary to compare experiences of students, both within their categorical groups and across groupings (Music/Commended, Music/Passing, Non-music/Commended, and Non-music/Passing). Cross comparisons included those between both music groups and both math groups to seek commonalities between the disciplines. Miles and Huberman (1994) define the purpose of studying multiple cases as seeing "processes and outcomes across many cases, to understand how they are qualified by local conditions, and thus to develop more sophisticated descriptions and more powerful explanations" (p. 172).

## Findings

### Music/Commended

All six of the Music/Commended students expressed some belief that both music and mathematics played an important role in family activities when they were children. Three of the students referred to older siblings previously being involved in music as a factor leading to their own involvement. One mentioned the parental expectation that she learn to read sheet music. Students in this group referred to the importance of music at family functions, particularly listening to live music. Mathematically, three of the students mentioned doing math with parents or siblings as a part of family activities. One noted that, "My mom would have us do… math in the store with her, when we were looking at how much something was per ounce, versus a different size… of the exact same thing." Another student reported that there was a history of advanced math work, "My sister…went through the same math classes that I did...being two years ahead of everybody...taking calculus and statistics her junior and senior year…we've always been great at math and able to figure problems and stuff."

Five of the Music/Commended group felt there was a connection between music and mathematics, while one of the group was unsure of a relationship between the two. The students cited several ways they perceived this connection, as well as anecdotal descriptions of musicians with strong math skills who they knew. The student who was unsure gave perceptions both for and against such a connection.

Some students suggested that musical study relates to brain development. One felt that listening to a "variety of types of music… knowing all of them, hearing all of them makes your brain develop in different areas." Another offered, "It's more like the relation of your brain and how well it's able to apply I guess, but of course I think that maybe math and music have their own styles and ways of thinking." Yet another student simply suggested, "It helps our brains grow," although he could offer no further detail.

Three Music/Commended students reported a belief that mathematical skills influenced musical ability. These beliefs were related to counting, rhythm, and musical structures. One noted, "I think there is something between math and rhythm… like if you're better at math, you can decipher rhythm, because you know how to subdivide it." Another student simply suggested, "You have to know the basics of math to go into music." A third student suggested math is used in music, "Especially when you're solfeging [using musical syllables to indicate certain pitches] and stuff, it makes the intervals really easy… you have to know math to actually count out the measures and stuff… there is a lot of math involved in that."

The final suggested connection related to the experiences of the students in music who showed success in math classes. One student offered the belief in such a connection based on the idea that, "All of my [band] friends that I know are really good at math or they are good enough to do at least … well." The second band student also suggested such a connection, "Especially with knowing a lot of people in the band… there's a lot of them that are really high up in the math stuff." Somewhat related, one student offered the perception, "I guess people that happen to be good at music... maybe are just more intellectual in general maybe...and just math happens… they happen to be good at it."

The student who remained unsure of any connection wavered on the idea of brain connections. The student did, however, challenge the idea that all music students were strong at math, saying "There's a lot of people that are really good at music, and really good at reading music, and not that good at numbers… and other people that are really good with numbers... can't read a bit of music." This student noted that non-musicians "still understand music and can still hear and they like music." The student also suggested that while not all students excel at every "specific math... they still understand the key parts of it that other people don't... or some aspects of it that other people don't... and maybe not, may be not... be good in algebra II but they're really good in geometry." In the final interview, this student offered, "I do think there's a little bit of a connection... maybe not as strong as some people think, but I do think there is one."

**Music/Passing**

Early experiences of the six Music/Passing students showed music played a role in all of their family activities. Many students in this group had additional musical experiences beyond school music participation. Both orchestra students played additional instruments beyond their choice for school, including guitar, bass, drums, and mandolin. These two planned to major in music related fields, with one majoring in voice. The vocal students had additional experiences with guitar and piano. One of band students played piano violin, and flute and also sang in a choir. The remaining band student talked about the importance of music and dancing at family functions.

Mathematically, two students reported doing math work with their parents as a daily activity. One student recalled, "My dad likes to do construction and all that…and he uses math for like measurements, to calculate everything, and he also uses it for like budgets… to figure everything out." Four of the students remember playing math games, either at school or in the home: "We used to always do the things with the M&M's... where you count the M&M's… stuff like that...in elementary school." Another recalled, "Counting and playing with the little blocks they had for us in kindergarten… I like to learn by doing things… so my first memory with math was hands on."

Four of the Music/Passing students agreed that a connection between math and music existed, while two saw no connection. Three of the students citing a connection suggested that math influences counting, meter, and rhythmic aspects of music, while one offered a belief that the study of music improves mathematics skills. For those students suggesting that math influences music, one noted "There's a connection with time, with rhythm and everything I believe… because a lot of music is based off … of equations and different things… but what I was saying with time… different rhythms and everything... very mathematical." This student went on to note, "the way you have to read music… just made me recognize patterns in that, and recognize patterns in math, and it just all correlated with each other." A second student suggested, "You need math for numbering measures, counting time and all that kind of stuff." The third student noted the relationship of math supporting music:

> Music is part of math... or math is part of music I should say, not the other way around… especially with counting... even feeling it... beat … counting can get complicated in music… Counting in 9/8 time and 5/8... counting… is a big part of my experience as a musician... They kinda intertwine… because in music you're always counting… you know… there's a connection between music and math.

The student believing music influenced math offered that a parent had taught her, "If I work on music that my math skills will be much better… and considering I was very slow at reading and writing, but I was a GT [Gifted and Talented] math student when I started piano, it kinda made me a believer."

The remaining two students could not see a connection between music and math. One simply stated, "I guess I don't really see it, because they're so different… not really." The other student similarly noted, "I don't think there is… personally... I don't really see how people see that… I mean it's music, so it's like notes and rhythms ... I don't really see how that has to do with math." Neither student changed their opinion about connections in their final interview.

**Non-music/Commended**

The six Non-music/Commended students revealed that musically, many of them listened to music as children, but only two responded that music was a major part of their family activities. One noted, "I have a cousin who has his own group, and it's always been a part… like taking lessons for piano and singing." The other student reported listening to Disney soundtracks and singing along. Other students reported listening to music recreationally. Mathematically, the students reported that math was valued; however, for five of the students, it was not a routine part of family activities. One student commented, "My parents think it is an important thing but they don't… like make me do math outside of school or anything." Only one student recalled doing math as a part of family activities, saying "My mom, she taught me at an early age how to do like subtraction and addition and everything."

Two students in the Non-music/Commended group felt a connection did exist between music and math, while the remaining four were unsure about a connection. The students who perceived a connection suggested that mathematical ability supports musical ability. One student noted:

> Math is all about equations and repetitions and getting things down, and I guess that could be music, because you have to know the notes and when to play them, and like the order, so I guess that could connect... they kinda like both symbols, and stuff.

The second student simply suggested, “I mean math has some part  in music, um… not quite sure exactly what, but it just… you think about it, math and music just go hand in hand a little bit.”

The remaining students felt unsure about a connection. Two suggested that listening to music helped them with homework. One noted:

> I just listen to music when I do math homework... I listen to something relatively calm... nothing too energetic... kinda like country music… Maybe it just helps… it maybe makes doing the math not so bad… it also helps tune out all the other things around you, because it kinda … for me it’s kinda in the background, so I... it helps me almost focus more… I don’t hear the things going on around me.

A second student did not easily see a connection but did mention later, “I know like whenever I’m doing math, I concentrate better when I’m listening… to music, very softly, but with an upbeat rhythm, so I can stay positive, stay focused, and so I cannot get sleepy and [can] stay up. Another student expressed ambivalence about a connection, because of not “really know[ing] how music works.”

Two students had mixed thoughts about the possibility that musicians do better in mathematics. One noted, “I don’t know... I’ve heard before that people that study music do well in math... I guess it doesn’t synch with me, because I’m like not good with music, but I’m good in math.” The other student originally did not see a connection, but later remarked:

> I think they are too opposite… but once I think about it, some people are really smart, like in math like [they] got 5’s on the AP Calculus BC exam... they are all like musicians… so they all play like an instrument... so there might be a connection… because it might trigger some part of your brain, that … works with music and math at the same time… but I don’t really know the science behind it

This group of students stayed consistent with their perceptions in two different interview sessions, with answers supporting previous responses.

**Non-music/Passing**

Most of the six Non- Music/Passing students reported that music played a minimal role in family activities. Families listened to music on TV, in the car, or at church; however, little additional effort to increase music listening was reported. One student did report that listening to music was important in some ways, saying “If my family’s ever down we would like turn on music and cheer up basically… it’s a part of my family and my childhood.” Additional early memories of music include listening to different genres in elementary music class and playing the recorder.

This group reported that their family's math activities included doing math homework as well as some practical applications. Two students reported active math activities with their families. One noted, "My dad would take care of me and he would like have me sitting down and have me do math problems." A second student talked about the importance of practical math skills learned at an early age, "I grew up having to realize a budget was always something you had to have in life and so I kinda grew up knowing that... I should know basic math." Early math memories included elementary math class, such as flash cards, in-class competitions, and practical applications of counting money.

Students in this group had differing perceptions of a connection between music and mathematics, with three agreeing and three disagreeing. Those that did perceive a connection suggested it was related to common skills in both fields. One noted, "I can see how that would make sense… because there are a lot of numbers in it [music]…. Maybe beats per minute?" A second student suggested, "I'm sure it is true... I know learning music takes a lot of skill and practice and so does math." The final student suggested that musicians tended to perform well in math: "I agree... I feel like people who are in orchestra or any kind of thing like that are really smart at things like that, like with math things, I guess it runs together."

Those that disagreed felt that the two subjects were too different to be related. One noted, "I don't believe that… because like how could music be related to math… it doesn't make sense." In a later interview, however, this student did suggest, "Whenever people are trying to make a beat or like try to write it, they at least use a little bit of math to try to figure it out." A second student had a similar view: "That it doesn't really compare at all, because you don't do math in music." The third student was shocked that such a connection could be suggested, and countered, "I would say more reading or history would go with music" rather than math.

**Summary of Findings**

Students were asked about their initial reaction to the possibility of a connection between music and mathematics. Though the interview protocol did not specify a why or why not question, it did ask about student experiences that supported or refuted such a claim. Fourteen students (represented in all four groups) perceived a connection and five were unsure about a connection. Each of the students who thought there might be a connection provided comments that suggested some rationale for the connection, whether brain connections between music and math; connections between the cognitive aspects of math that supported musical meter, rhythm, and structure; or anecdotal evidence of musicians who were successful in mathematics. These perceived origins are discussed below. The five students who saw no connection generally stated a belief that music and math are two unrelated fields. The groups also began to show some patterns in their beliefs. The music groups included the highest percentage of students who perceived a connection. The students who saw no connection all came from the passing (rather than commended) math groups.

The perception of cognitive aspects of math supporting musical development was the most common response, as seen by the numerous statements referring to rhythmical elements in music and math. For the fourteen students that did perceive an obvious connection between music and mathematics, eight of them expressed a belief that mathematics fostered a stronger sense of musical rhythm, and therefore stronger math skills were related to enhanced ability in music. A word search in NVivo of interview data found that variations of the words “count” or “counting” appeared 23 times, and “rhythm” appeared thirteen times, in transcripts, in responses to the question about perceived connections between music and .mathematics. Further, this belief is the only one based on actual experiences of students, as the anecdotal evidence and suggested neural connections were based on conjecture.

## Discussion and Implications

While the students’ perceptions cannot be “supported” or “denied,” the idea that cognitive connections exist between musical and mathematical capabilities did emerge from their comments. The cognitive element most cited by the students had to do with rhythmic understanding of music, specifically counting. One of the most interesting aspects of this was a belief by many of the students that a stronger understanding of math supported this element of music.

Gardner (n.d.) notes, “Individuals who are mathematically talented often show an interest in music. I think that this linkage occurs because mathematicians are interested in patterns, and music offers itself as a goldmine of harmonic, metric, and compositional patterns” (para. 4, p. 12). This is of potential interest, as previous literature would suggest that those involved in school music would have the superior mathematic skills—especially those musicians in the commended math group. The student interviews revealed that students in this study had a variety of opinions regarding their own levels of mathematic ability.

The multiple references to counting and rhythms in the student responses suggest that the students see these as connecting elements. While most correlational studies have suggested that musical participation supports mathematics achievement, the findings in this study suggests that the students in the sample perceived the connection happening in the opposite direction as well, based on their perceptions that understanding of the mathematical elements in musical rhythm are being supported by their outside mathematical instruction. Obviously, with such a small sample, it is impossible to determine if this belief is common, but it warrants further investigation with a larger population. If these perceptions are more prevalent beyond the sample, teachers in both fields may want to begin to collaborate to find ways to support one another.

### Limitations

This study has several limitations. The small sample size makes it impossible to generalize, as do the student self-reporting and personal perceptions that serve as data. The study included students from only one high school; students from other campuses and areas may have other experiences. The sample selected may not reflect the entire student population, although stratification of sampling was used to match the sample as closely as possible. Additionally, students may have had different musical experiences from those found in school music programs. As the music students sampled were determined only through their current participation in school band, choir, or orchestra during their senior year, students who participated in private musical study, such as piano lessons, or are part of outside musical groups were not identified in the music group. Students who participated in school music groups earlier in their education experience may also have been excluded from identification in the musical participation sample.

The populations who participated in the study were limited to White and Hispanic students, due to the lack of matching students in all three musical performance groups, thus diminishing the implications across all racial groups. The difficulty in including diverse students may be based in part on the expense of participation in instrumental music. Where choir students may have been found among all populations, band and orchestra students were limited to those with adequate income to support participation. In addition, music is an elective in the school, and there are limited placement opportunities for participation in music at the high school level. In contrast, of course, all students have a number of math courses required for graduation, although a less diverse student population often comprises the upper level math courses.

**Future Research**

Using student interviews, this multiple case study provided an insight into the mindset of students currently involved in music and mathematics classes. This study did not explore the differences in perceptions between males and females or between the white and Hispanic students. These factors were balanced in each of the four groups to give the best possible comparison between the categories but were not specifically addressed in the research questions. In this study, gender played no role in the distinction in responses. However, ethnicity coupled with SES showed signs of distinction, warranting additional study of hegemony, whereby Hispanic and low SES students were limited in their participation in music groups and higher-level mathematics. While this was not the focus of the particular research questions for this study, the larger study did expose these patterns reflecting SES and ethnicity trends in music classes and upper math classes. Further research would be valuable, both to explore student perceptions of music and mathematic connections, but also to examine access to music programs for low SES and minority students, along with whether and how schools can remove barriers to music courses. Regardless of any possible or perceived benefits to mathematics, access to the arts to all students only served to better those students by experiencing music.

Further, it may be worth exploring stronger partnerships between music and math teachers. Co-teaching similar elements of music and mathematics with interchangeable terms, and using both numeric and musical notation examples, may reinforce basic underlying skills associated with both elements. This follows Gardner's (2000) recommendations of using multiple modes of entry when teaching concepts: "One can find at least seven powerful entry points to diverse concepts. These opening gambits help to introduce important and challenging topics" (p. 188). The use of mathematical-logical, spatial, and musical approaches may lay a foundation for a multiple intelligence methodology in teaching mathematics. However, it is important that musical elements such as counting, proportions, and pattern recognition maintain their fidelity toward the musical education of the students involved. This may be accomplished by using authentic musical examples, rather than those contrived solely for such an exercise. These could include exploring Pythagorean formulas for identifying musical ratios, such as the octave or Perfect Fifth, or using twentieth century atonal music to explore complex musical patterns. These atonal patterns can be inverted or transposed in the same way geometric figures are on graphs. To achieve this, teachers in both content areas would have to understand and be willing to create the connections for students in order for transfer of learning to occur.

Students that failed the Math TAKS test were excluded from the sampling. Interviews with students from this group would provide valuable information on the perception of any connection or lack thereof between math and music. As most prior literature suggests a natural mathematic ability in musicians, talking with school musicians who struggled with the math assessment might provide a unique perspective into the experiences of these students.

A final direction to consider is level of individual motivation of students regarding the two fields. No interview questions directly addressed the motivational factors relating to music or mathematics. Level of involvement and motivation plays a role in student academic performance, as it relates to performance on standardized measures as well as musical prowess. It is possible that participation in school music programs attracts highly motivated students. These students may already exhibit high levels of mathematics proficiency before they begin formal music training. Marzano (2003) reports the achievement gains in students with high motivation far exceeds those with lower motivation levels, citing a link between motivation and achievement, "if students are motivated to learn the content in a given subject, their achievement in that subject will most likely be good. If students are not motivated to learn the content, the achievement will likely be limited" (p. 144). Longitudinal studies may track early math aptitude and look at music involvement.

Such studies would need to address all levels of students and their involvement in music and mathematics, including those students who participate in non-school related music activities, as well as those with a wide variety of math experiences. One area to address may include perceived access to music programs; for example, if students perceive barriers such as financial constraints. Likewise, what barriers are perceived by all students regarding access to upper level math classes.

Looking at student success as measured by any specific metric would be greatly improved by adding the element of the student's own perceptions of that level of success. In combining both elements, we are able to see a more holistic picture. While students' perceptions, again, are only perceptions; they are often overlooked as researchers study school settings. We miss valuable insight into school phenomenon by overlooking the perceptions of the students most involved. This group of 24 students contributed valuable information regarding the possibility of musical and mathematical linkage, from a firsthand perceptive. Their perceptions of possible sources of musical and mathematical connections regarding provide insights that can lead us to new questions and new discoveries.

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