EXPERIENCES AND PERCEPTIONS OF STUDENTS IN
MUSIC AND MATHEMATICS

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Since the time of Pythagoras, philosophers, educators, and researchers have theorized that connections exist between music and mathematics. 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, several questions remain to determine if musical stimulation actually improves mathematic performance.

This study took a qualitative approach that allowed 24 high school students to express their direct experiences with music and mathematics, as well as their perceptions of how the two fields are related. Participants were divided into four equal groups based on school music participation and level of mathematic achievement, as determined by their performance on the Texas Assessment of Knowledge and Skills (TAKS). Students participated in a series of three interviews addressing their experiences in both music and mathematics, and took the Multiple Intelligences Developmental Assessment Scales (MIDAS). TAKS data and MIDAS information were triangulated with interview findings. Using a multiple intelligence lens, this study addressed the following questions: (a) How do students perceive themselves as musicians and mathematicians? (b) What experiences do students have in the fields of music and mathematics? (c) Where do students perceive themselves continuing in the fields of music and mathematics? and (d) How do students perceive the fields of music and mathematics relating to each other?
Contrary to most existing literature, the students who perceived a connection between the two fields saw mathematics driving a deeper understanding of the musical element of rhythm. Not surprisingly, students with rich backgrounds in music and mathematics had a higher perception of the importance of those fields. Further, it became readily apparent that test data often played a minimal role in shaping student perceptions of themselves in the field of mathematics. Finally, it became apparent from listening to the experiences of high school students, there are many growth areas for schools in order to meet the needs of their students.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>EXPERIENCES AND PERCEPTIONS OF STUDENTS IN MUSIC AND MATHEMATICS</td>
<td>1</td>
</tr>
<tr>
<td>Theoretical and Philosophical Rationale for the Study</td>
<td>1</td>
</tr>
<tr>
<td>Music and Mathematics in Educational Settings in Related Literature</td>
<td>2</td>
</tr>
<tr>
<td>Standardized Testing</td>
<td>2</td>
</tr>
<tr>
<td>Setting</td>
<td>5</td>
</tr>
<tr>
<td>Population</td>
<td>5</td>
</tr>
<tr>
<td>Sample</td>
<td>6</td>
</tr>
<tr>
<td>Design</td>
<td>7</td>
</tr>
<tr>
<td>State Testing</td>
<td>8</td>
</tr>
<tr>
<td>Interviews</td>
<td>8</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>9</td>
</tr>
<tr>
<td>Findings</td>
<td>10</td>
</tr>
<tr>
<td>School Music Participation/Commended Math</td>
<td>10</td>
</tr>
<tr>
<td>School Music Participation/Passing Math</td>
<td>12</td>
</tr>
<tr>
<td>Non-School Music Participation/Commended Math</td>
<td>13</td>
</tr>
<tr>
<td>Non-School Music Participation/Passing Math</td>
<td>14</td>
</tr>
<tr>
<td>Summary</td>
<td>15</td>
</tr>
<tr>
<td>Discussion</td>
<td>16</td>
</tr>
<tr>
<td>Future Research</td>
<td>18</td>
</tr>
<tr>
<td>Conclusion</td>
<td>19</td>
</tr>
<tr>
<td>References</td>
<td>20</td>
</tr>
<tr>
<td>APPENDIX A. EXPANDED INTRODUCTION</td>
<td>22</td>
</tr>
<tr>
<td>APPENDIX B. EXPANDED REVIEW OF LITERATURE</td>
<td>38</td>
</tr>
</tbody>
</table>
APPENDIX C. METHODOLOGY ........................................................................................................... 56
APPENDIX D. EXPANDED RESULTS .................................................................................................. 80
APPENDIX E. EXPANDED DISCUSSION ........................................................................................... 123
APPENDIX F. INTERVIEW PROTOCOL ............................................................................................. 144
APPENDIX G. OUTLIERS .................................................................................................................... 148
APPENDIX H. INFORMED CONSENT FORMS ............................................................................... 152
APPENDIX I. STUDENT ASSENT ....................................................................................................... 156
APPENDIX J. TAKS SCORES OF SAMPLE COMPARED TO ALL STUDENTS AND ALL MUSIC STUDENTS .................................................................................................................. 158
APPENDIX K. DISTRICT APPROVAL FORM .................................................................................... 160
COMPREHENSIVE REFERENCE LIST ............................................................................................. 162
LIST OF TABLES

Table C.1. Student Body by Ethnicity ................................................................. 58
Table C.2. Percent of Student Body by Academic Risk Factor in 2012 ............... 58
Table C.3. Racial Percentage of Senior Class Member Participation in Music Performance Groups ................................................................. 60
Table C.4. School Testing Data .......................................................................... 61
Table C.5. Sample of Students .......................................................................... 62
Table D.1. MIDAS Ranges and Sub-scores for Each Group ................................. 95
Table D.2. MIDAS Score Based on the Mean for Each Group ............................. 96
Table D.3. Importance of Music and Math to Each Group’s Future ...................... 111
Table D.4. Student Agreement with a Connection between Music and Mathematics . 118
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.1</td>
<td>Exploring perceptions: interviews (<a href="http://www.qsrinternational.com/default.aspx">www.qsrinternational.com/default.aspx</a>).</td>
<td>73</td>
</tr>
<tr>
<td>D.1</td>
<td>MIDAS mean scores for all four groups.</td>
<td>96</td>
</tr>
<tr>
<td>D.2</td>
<td>Student’s self-reported perception of their level of music.</td>
<td>97</td>
</tr>
<tr>
<td>D.3</td>
<td>Student’s self-reported perception of their level of math.</td>
<td>97</td>
</tr>
<tr>
<td>D.4</td>
<td>Music’s importance in family activities (results based on the six group members responses to interview questions).</td>
<td>104</td>
</tr>
<tr>
<td>D.5</td>
<td>Math’s importance in family activities (results based on the six group members responses to interview questions).</td>
<td>105</td>
</tr>
<tr>
<td>D.6</td>
<td>Importance of participants’ future children studying music and mathematics.</td>
<td>112</td>
</tr>
<tr>
<td>D.7</td>
<td>Student agreement with a connection between music and mathematics.</td>
<td>119</td>
</tr>
</tbody>
</table>
EXPERIENCES AND PERCEPTIONS OF STUDENTS IN MUSIC AND MATHEMATICS

Theoretical and Philosophical Rationale for the Study

The study of music and mathematics, as well as the implications for possible connections between the two subjects, is a matter that has long been a source of debate among various learning theorists. While some groups hold rigidly that each subject functions completely independently of the other, others seek a connection between the two. Anecdotal evidence showing higher mathematics test scores on standardized testing of musicians over non-musicians only scratches the surface of this debate (Helding, 2010; Kinney, 2008; Johnson & Memmott, 2006; Cobb, 1997; Klinedinst, 1991).

While substantial evidence suggests some students with high skill in music also show high results on certain mathematic assessments, the actual cause of such a relation remains uncertain. Gardner’s Theory of Multiple Intelligence (MI) is one major theory that addresses the developmental aspects of both sets of skills. While Gardner’s views on the linkage between intelligences has evolved over the years since the original publication of the theory (Gardner 1983), the lack of empirical research still leaves unanswered questions of linkage between intelligences. While Gardner has moved on to new areas of research, several researchers have continued this line of questioning into the linkage of intelligences, specifically, the question is whether one intelligence may affect another (Helmrich, 2010; Rauscher et al, 1997; Spelke, 2008; Sousa, 2006). In particular, the question of the students’ perceptions of such linkage and how their experiences in both domains interact with one another remains unanswered.
The study of the cognitive connections of musical study and mathematical thinking remains a topic of great interest among researchers. Most studies are unidirectional, maintaining the assumption that music experiences influence mathematics learning. Few studies emphasize the opposite, that learning mathematics influences music learning. In addition, most studies are either correlational or circumstantial rather than experimental in nature. In spite of these research limitations, across time, authors continue to suggest that music study influences mathematics learning.

Shore (2010) found, “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 provide children with higher levels of attention, 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 suggest that this increase in focus and complexity of music fosters the development of cognitive skills such as language or mathematics and that developmentally appropriate sequences of learning support greater capacity in neural pathways and are used for not only musical development but for all areas of cognitive knowledge.

Standardized Testing

A number of studies pointed to the correlation between participation in musical groups and mathematics competencies on standardized tests. Kinney (2008) found
increased mathematics test scores in musicians over non-musicians in a Midwestern urban setting using state tests administered in the 6th and 8th grades. Based on the test scores, Kinney found band students outperformed their non-musical counterparts in both 6th and 8th grade math proficiency tests. Kinney noted that the instrumental musicians were the only group to score higher the other groups. Choral students showed no significant differences in scores. These results mirror Klinedinst’s (1991) conclusions that reading performance, math performance, and scholastic ability have strong ties to 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, particularly those in music, than the non-music counterparts regardless of socioeconomic status. Fitzpatrick (2006) used Ohio Proficiency Test (OPT) results to compare musicians and non-musicians of various SES’s. The OPT measures student performance in fields such as citizenship, math, science, and reading. Students who began and continued instrumental music training into high school outperformed their non-musical peers at like SES levels at each grade level. Further, the scores of music students of low SES levels showed the highest gains. These correlational studies do not represent cause but continue the supposition 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 among over 6000 students on the Maryland Algebra/Data Analysis High School Assessment (HSA). 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 passing rate of instrumental musicians was 90.62, while students with choral training had a passing rate of 81.51. The group of students with no musical training remained at a passing rate 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, specifically that highly motivated students who naturally possess greater academic talent may 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 mathematic 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 theses numerous studies have found very specific correlations between music and mathematics, none can identify the specific cause of their findings. Strong correlations have been found with regards to music students’ increases 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 authors may imply a direct linkage, where music supports mathematics, too may confounding elements prevent a clear statement of causality.
Setting

The setting for this study was a north Texas high school in one of the fastest growing areas in the US, in a suburban city of over 136,000 residents. The district currently has three high schools, with a total high school population of approximately 7500 students. The studied campus is the oldest of the three schools and has a student population of approximately 2,000 students, comprised of approximately 60% white, 24% Hispanic, and 13% African American students.

Population

The population for the study consisted of students in the 2014 senior class. 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 Exit Level Texas Assessment of Knowledge and Skills (TAKS) scores from the spring of 2013. 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 participation. Students not enrolled in a school music organization during their senior year were identified as low level of music participation.

Based on the definitions of school music and non-school music participation, and mathematics TAKS success levels, the population was divided into four categories: School Music Participation/Commended Mathematics (SMPCM), Non-School Music Participation/Commended Mathematics (NSMPCM), School Music Participation/Passing Mathematics (SMPPM), and Non-School Music Participation/Passing Mathematics
Due to the disparity between participation in mathematics (mandatory 100% participation), and music participation (voluntary/audition based), the information from Tables 3 and 4 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.

**Sample**

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 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+) (SMPCM) and low (2100-2400) (SMPPM) 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 were included in the SMPCM and SMPPM groups.

A matching sample was selected from the non-music student population. The makeup of the non-music participation sample mirrored the racial and gender make-up 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 NSMPCM and NSMPPM groups. Once they were identified, the researcher contacted students and their parents and gave them informed consent forms. Upon obtaining signed forms, participants began their involvement with the study. Figure 1 shows the makeup of the sample.

Six students in each category allowed for two each in the different music categories: band, choir, and orchestra. All six of the invited students accepted the invitation to participate in the study, for a sample of 24 students from the class of 498 seniors. All students selected agreed to participate and returned all informed consent forms.

Design

This study is a multiple case study. A single case study involves an in depth and detailed gathering of data from a single system, whereas a multiple case study compares several similar cases to one another in an attempt to create a better understanding of the specific phenomenon (Teddlie & Tashakkori, 2009; Glense, 2011; & Bryman, 2008). The use of 24 students in four sete groups allowed the opportunity to begin to draw commonalities not only within each of the four groups but also to make comparisons and contrasts between groups. The perceptions and experiences of each group of students were essential to answer the research questions; however, the comparisons between multiple groups led to the development of theories related to a deeper understanding of how these musical and mathematic experiences might affect the lives of the students.
State Testing

The Texas Assessment of Knowledge and Skills (TAKS) began in 2003, replacing the previous Texas Assessment of Academic Skills test. The TAKS tested students in grades 3-11 as part of federal compliance with the No Child Left Behind Act (NCLB) that mandates an accountability system for measuring student progress. The assessment measured student performance in reading, writing, mathematics, science and social studies. The 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).

Interviews

Students chosen to participate in the study were involved in three interviews, lasting a total of approximately 45-60 minutes. During the course of interviews, participants shared their histories with the two fields, their experiences, their perceptions of the relevance of mathematics and music, and their perceptions of the interconnection of mathematics and music in their lived experiences. All interviews occurred on the campus, generally in library, outside of the music classrooms or in one of the administrative offices and were typically before or after school. While the interview followed certain protocols, the questions were purposely open-ended to allow for an in-depth response and offer a semi-structured format. This allowed the participants to direct their own stories.
Data Analysis

The researchers based data analysis on an interpretive phenomenological analysis (IPA) approach, where the experiences and meanings perceived by the participants guided the researcher in making sense of their own perceptions. The approach with IPA is twofold; in one sense, participants are exploring the meaning of their experiences, while the researcher is exploring 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, the authors note, “Care is taken to distinguish clearly between what the respondent said and the analyst’s interpretation or account of it “(Smith and Olson, 2008, p. 76).

The data analysis plan included transcribing each interview, uploading transcriptions into NVivo 10 for coding, and looking for relevant or constant themes in each transcript, and later 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 researcher 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 versus a line-by-line analysis. This included, for example, grouping positive responses to a single question to a secondary code, while the negative responses appeared in 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 individuals, it became necessary to compare experiences of students, both within their categorical groups and across groupings; SMPCM, SMPPM, NSMPCM, NSMPPM. 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

The interviewer presented the statement that “there are some theories that suggest there is a connection between music and mathematics.” The students were asked, “What is your initial reaction to that idea? Do you have experiences that support or oppose that view?” Findings are reported by each group response.

School Music Participation/Commended Math

Five of the SMPCM group felt there was a connection between music and mathematics, while one of the group was unsure of a relationship between the two fields. The students cited several ways they perceived this connection as well as anecdotal instances of musicians with strong math skills. 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 they could offer no further detail.

Other students related the idea that math influences musical ability. A common idea here was 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 suggest math is used in music, “Especially when you’re solfeging 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 waivered on the idea of brain connections. The student did, however, refute the idea that all music students were strong at math, “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, maybe 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.”

School Music Participation/Passing Math

Four of the SMPPM 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. 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
complication 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 taught, “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 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.”

**Non-School Music Participation/Commended Math**

Two students in the NSMPCM group felt a connection did exist between music and math, while the remaining four were unsure of such a connection. The students who perceived a connection between the two suggested that mathematic ability supports music. 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 offered,

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 stay up. Another student expressed unsureness of 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 are 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 got 5’s on the AP Calculus BC exam... they are all like musicians...so they are 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-School Music Participation/Passing Math

Students in this group had differing perceptions of a connection between music and mathematics, with three agreeing and three in disagreement. Those that did perceive this connection suggested the connections 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.” Although this student did later 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 noted, “I would say more reading or history would go with music” rather than math.

Summary

Students had multiple perceptions about not only the possibility of a connection between mathematics and music, but also the root causes of such a connection. Fourteen students, from across all groups perceived a connection, while five students remained unsure of any connection. Five students perceived no connection.

For the 14 students that did perceive an obvious connection between music and mathematics, eight of the students expressed a belief that mathematics fostered a stronger sense of musical rhythm, thus higher math skills were related to higher ability in music. In reviewing interview transcripts, there are 36 references to counting/rhythm when students were asked about their perception of the relationship between music and math. This is contrary to most of the existing literature that attempts to draw a connection where music involvement supports mathematics ability.
The 19 students who either perceived a connection or remained unsure about a connection cited three primary beliefs about the origin of the connection: a) brain connections between music and math, b) connections between the cognitive aspects of math that supported musical meter, rhythm, and structure, or c) anecdotal evidence of musicians that were successful in mathematics. The five students that 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 only students who saw no connection both come from the passing math groups. Table 8 and Figure 9 address these findings.

Discussion

While the possibility of neuro-connections between the fields was not tested within the sample, and anecdotal evidence could not be supported or denied, the idea that cognitive connections existing between musical elements and mathematics did emerge. The cognitive aspect 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 the students that a stronger understanding of math supported this aspect of music.

Students from all groups expressed a belief that math supported rhythmic elements. Eight different students make this assumption of connecting math to music. A word search in NVivo also found that the word “counting” or some related variation appeared 23 times, and rhythms appears 13 times in responses to the interview question relating to the perception of such connection between music and mathematics.
While most correlational studies have suggested that musical participation supports mathematics achievement, this finding suggests that the students in the sample perceived an opposite connection, where mathematics concept understanding supports musical understanding. 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.

Gardner (2013) 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” (FAQ, What about the often noted connection between mathematical and musical intelligences?, ¶ 1). Students were asked about their ability to perceive patterns in both mathematics and musical selections. Mathematically, five of the six students in the SMPPM, NSMPCM, and NSMPPM groups reported they easily could spot patterns. In the SMPCM group, only four reported the ability to easily recognize patterns in numeric sequences. This is of considerable interest, as the previous literature would suggest that those in school music would have the superior mathematic skills, especially those musicians in the commended math group. The student interviews revealed that perceptions of students in this study were contrary to the findings of existing correlational studies.

Musically, all of the SMP groups reported that they easily recognized musical patterns. In the NSMP groups, the students who could identify patterns spoke about structural and formal elements, such as repetition of the chorus. Though an ability to identify patterns in no way represented a definitive connection between music and
math, where one influences the other, this is one shared element between the two fields.

If the students did show a natural tendency to gravitate toward algebra, it is possible that they viewed aspects of rhythm similar to linear equations. This could possibly explain the statements of students that they felt there were many elements of mathematics inside of music, specifically in rhythm. Algebra deals with three elements: variables, functions, and patterns. When viewed from this perspective, the connection seems to be students' perception as both math and music embody these similar elements. In spite of this, the data did not bear out that students perceived that one was directly related and/or influenced the learning of the other.

Future Research

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. However, 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. This theme was not fully developed in this study, but further research would be valuable.

Rhythm/meter/time instruction to beginning musicians could be another line of research. Since these are the elements that the students most readily identified as the source of a connection between music and mathematics, it would be a valued study to
explore if these musical elements are taught as a function of special relationships or as a linear element. This may influence student perceptions of any connection.

A final direction to consider is the involvement in any school activity on academic performance. Perhaps the level of involvement and motivation plays a role in student academic performance, as it relates to performance on standardized measures. Previous motivational studies in music often fail to address students directly. As testing is often used in correlational studies, it is critical to include the opportunity to allow students to express in their own words their experiences. Drawing conclusions solely from test data may misrepresent the phenomenon. The experiences and perceptions of the teachers and students provide an important piece of data to explaining any aspect of schools. Additional studies may investigate student involvement or measure levels of motivation in students; however, they should continue to utilize student perceptions as a data source.

Conclusion

Fourteen of the sample agreed that a connection did exist, while five remained undecided on the topic. From these nineteen student responses that suggested a connection could exist, a common belief emerged that they perceived that mathematical ability actually fostered musical behavior, especially in those related to counting, rhythm, and meter. This runs counter to the findings in the literature review; however, none of the cited studies addressed the actual student perceptions of the relationship between music and mathematics. This suggests that further study is warranted to determine if this finding is an isolated event or perhaps more common that originally believed.
References


APPENDIX A

EXPANDED INTRODUCTION
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, these theoretical connections have gained and lost prominence in the current literature. With current advances in brain mapping technology and a greater understanding of neuroscience, it is possible to explore these connections at a level unimagined by previous generations. However, the numerous studies that have attempted to answer questions of linkage have failed to provide a definitive answer (Caterall & Rauscher, 2008; Baillet, Mosher, & Leahy, 2001; Helmrich, 2010; Southgate & Roscigno, 2009).

Perhaps connections in the cognitive processes associated with music and mathematics work to develop each other. Alternatively, musical training may stimulate enough brain activity to improve functioning in other areas, such as mathematics. Through the stimulation of multiple cortical locations, when participating in musical instruction, regions of the brain associated with mathematical functions may see additional increases in activation (Helmrich, 2010; Jonides, 2008; Schlaug, Norton, Overy, & Winner, 2005). However, these conjectures fail to receive the overwhelming acceptance of current psychological or educational learning theory.

From a cognitive view, it is possible to identify several musical factors that contain mathematical elements, such as rhythm, subdivision of beats, and intervals, and to presume that strengthening these musical aptitudes would further strengthen their counterparts in a purely mathematical setting. The various cognitive studies of music and the brain address specific musical abilities and follow a traditional method of observation and testing of ability. These studies have typically focused on shared skills
related to music and math. More recently, brain mapping and Functional Magnetic Resonance Imaging (fMRI) of individuals who perform musical and mathematical tasks have become tools in such research. Researchers now explore in ways not imagined 20 years previously, regions and functions of the brain, such as effect of emotional attachments, long and short-term memory processing, and regions of the brain activated during specific tasks (Baillet, Mosher, & Leahy, 2001; Shibasaki, 2008; Singer, 2007).

Both research and practical applications have identified correlations between the two fields when addressing brain activity; however, correlation does not equate to causation. 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, several questions remain to determine if musical stimulation actually improves mathematic performance. Conversely, little evidence suggests those highly gifted in mathematics will be equally successful in musical study or show any desire to study music (Gardner, 2006b).

The contradictory results in the research lead to much confusion and misunderstandings concerning musical and mathematical experiences and the relationships/influences between them. Misinterpretation of research and the desire to find an easy solution to boosting math scores created many myths surrounding ideas that musical training boosts mathematical skills. One solution to combating these myths is to go directly to high school students who have had varying levels of measured success in both music and mathematics. A qualitative approach allows students in a school setting to express their direct experiences with music and mathematics, as well
as their perceptions of how the two fields are related.

Statement of the Problem

While numerous studies about multiple intelligence, cognitive development neuroscience, and motivational theories have identified anecdotal linkage between students' music and mathematic performances, none has involved a study of students’ lived musical and mathematical experiences. The current body of research has yet to address the perception of students and their own stories related to the two fields. Although brain scans and standardized test results provide some evidence of a connection, the key element of student experience offers a potentially rich field of missing information. Seidman (2006) describes, “Telling stories is essentially a meaning-making process. When people tell stories, they select details of their experiences from their stream of consciousness” (p. 7). These details of students’ experiences in mathematics and music are important missing pieces to making meaning of any perceived or actual connections between the fields. The need for further research to clarify the students lived experiences and their perceived connections between the study of music and mathematics is evident by the lack of existing research.

Purpose

The purpose of this study was to determine high school students’ perceptions of both music and mathematics over the course of their high school experiences as well as their lives outside of the school setting. The information gathered from student interviews was examined through multiple lenses: family culture and expectations, personal motivation, and the student’s own future goals. Further, this study explored how students perceived the fields of music and mathematics as a part of their future
educational, personal, and career goals. Finally, by triangulating student interviews, academic records, and self-reported multiple intelligence levels, students expressed their own perceptions of the relationship between musical and mathematical study.

Research Questions

The following questions guided the research:

- How do students perceive themselves as musicians and mathematicians?
- What experiences do students have in the fields of music and mathematics?
- Where do students perceive themselves continuing in the fields of music and mathematics?
- How do students perceive the fields of music and mathematics relating to each other?

Assumptions

It was assumed that all students had some experience or exposure to both music and mathematics, even those who did not participate in school secondary school music classes. It was assumed that students participated in elementary music classes and were exposed to musical experiences in society. It was further assumed that mathematic test data, provided by the state of Texas, was accurate and valid for placing students into groupings. Finally, it was assumed that students provided truthful answers to all interview questions and responded to the best of their ability on the MIDAS instrument.

Self as Researcher

As the researcher, I also held the role of a school counselor at the setting where the study was conducted. While every effort was maintained to avoid using any of my
position in the school to coerce student participation on the study, the existing relationship I had with some students did allow me to begin student interviews with an already existing level of rapport. Using Seidman’s (2006) model to create “respect, interest, attention and good manners” (p. 97) but never to “distort” (p. 97) responses was always a primary concern in my structuring of interviews and the actual questions.

Each student and parent I approached to participate was given full consent forms and as I explained the purpose of the study, I assured them that participation was not a requirement, and it would not be held against them in any way if they chose to not participate. Parents and students were made aware of the multiple intelligence assessment and the general content of the three interviews before they received consent forms. Three different parents thanked me for the opportunity to participate, stating that they believed it would be beneficial for their child to see their multiple intelligence results and to talk to a guidance counselor about their plans for after graduation. While it is important to acknowledge this dual role, I believe I was able to use it to increase the depth of student responses, rather than influence their answers.

Theoretical and Philosophical Rationale for the Study

The study of music and mathematics, as well as the implications for possible connections between the two subjects, is a matter that has long been a source of debate among various learning theorists. While some groups hold rigidly that each subject functions completely independently of the other, others seek a connection between the two. Anecdotal evidence showing higher mathematics test scores on standardized testing of musicians over non-musicians only scratches the surface of this
While substantial evidence suggests some students with high skill in music also show high results on certain mathematic assessments, the actual cause of such a relation remains uncertain. Gardner’s Theory of Multiple Intelligence (MI) is one major theory that addresses the developmental aspects of both sets of skills. While Gardner’s views on the linkage between intelligences has evolved over the years since the original publication of the theory (Gardner 1983), the lack of empirical research still leaves unanswered questions of linkage between intelligences. While Gardner has moved on to new areas of research, several researchers have continued this line of questioning into the linkage of intelligences, specifically, the question is whether one intelligence may affect another (Helmrich, 2010; Rauscher et al., 1997; Spelke, 2008; Sousa, 2006). In particular, the question of the students’ perceptions of such linkage and how their experiences in both domains interact with one another remains unanswered.

Multiple Intelligences

Psychologist Howard Gardner challenged the psychological world with the theory of Multiple Intelligences (MI) (Gardner, 1983). This theory was a radical change from accepted theories of the time that relied heavily on linguistic and logical ability to define intelligence. Gardner noticed exceptional abilities in other fields, as well as in unique populations, including prodigies, patients with brain damage, the gifted, and the savant. Gardner questioned the abilities of these populations and quickly concluded that other paradigms of viewing intelligence could explain these exceptional cases while traditional
theories could not. Although the prospect of MI caused controversy among psychologists, many educators gravitated toward the ideas presented in MI theory.

Born July 11, 1943, in New Jersey, Howard Earl Gardner began his academic career as a history major at Harvard University but later changed to cognitive psychology, in which he eventually earned his PhD. Gardner credits his early study of piano and love of the arts as catalysts in developing the premise of MI. As a graduate student studying developmental and cognitive psychology, he noticed the absence of the arts in these fields. In 1979, Gardner’s work with Project Zero and neurological research with Norman Geschwind eventually led to the Project for Human Potential, which aimed to study human potential. While writing a book on human cognition as defined by biological and behavioral sciences, Gardner began his research on what became MI theory. Gardner (2006a) stated,

> The theory of multiple intelligences is a synthesis of work in a number of disciplines, ranging from neuroscience to anthropology. The major claim... is that the human intellect is better described as consisting of a set of semi-autonomous computational devices, each of which has evolved to process certain kinds of information in certain kinds of ways. (p. 503)

Gardner made the distinction of referring to the human capabilities as multiple intelligences as opposed to gifts or abilities. Choosing the word intelligence placed MI Theory in opposition to the proponents of IQ testing. He theorized a multi-faceted set of autonomous intelligences (Gardner, 1983). Gardner’s theory of multiple intelligences challenged the accepted norm that all humans possessed a single general intelligence, or ‘g’ that relies on “a set of tests given to a specific population under specific conditions and analyzed in a certain way” so results often “vary according to the tests” (Gardner, 2006a, p. 503). The ‘g’ supports the Western perspective of intelligence.
In contrast, Gardner (1983) defined intelligence as “the ability to solve problems or to create products that are valued within one or more cultural settings” (p. xxiv). Further, Gardner (1983) established eight criteria to identify possible intelligences:

1) the potential for brain isolation by brain damage, 2) the existence of idiot-savants, prodigies and other exceptional individuals, 3) an identifiable core operation or set of operation, 4) a distinct developmental history, along with a definable set of expert “end-state” performances, 5) an evolutionary history and evolutionary plausibility, 6) support from experimental psychological tasks, 7) support from psychometric findings and 8) susceptibility to encoding in a symbol system. (pp 63-66)

Based on this list of criteria, Gardner’s originally proposed intelligences included linguistic, logic-mathematical, musical, spatial, bodily kinesthetic, interpersonal, and intrapersonal, with the later addition of naturalistic intelligence.

**Musical Intelligence**

Gardner indicated that of all the intelligences, music develops first, manifesting in the form of musical compositions, a deep understanding of musical elements or a natural ability in musical performance. His work shows that composition begins with ideas regarding musical tones, patterns or rhythms that crystallize. For those not gifted with the art of composition, the role of musical performer, interpreter or even listener, are related to those same skills in detecting patterns. Gardner defined the key elements of music: pitch as “sounds emitted at a certain auditory frequency”, rhythm as the “prescribed system” of grouping, and timbre as the “characteristic quality of a tone” (pp.104-105).

Musical competence in the form of performance begins at an early age. Infants are able to match pitch and melodic contour of musical ideas as well as imitate musical patterns. Musical ability expands in children, usually in the form of singing throughout
the early childhood years, until “most children in our culture have a schema of what a song should be like and can produce a reasonably accurate facsimile of the tunes commonly heard around them” (Gardner, 1983 p.109). As musical skills continue to develop, most children realize that to improve skills to the next level, serious practice must commence. Great dedication and strict standards can produce young students with exceptional skills.

**Logical-Mathematical Intelligence**

Gardner’s (1983) definition of logical-mathematical intelligence relied heavily on many of the observations made by Piaget. Through experiencing the world around them, young children begin to make sense of their surroundings and begin to determine patterns. While Gardner proposed the idea that different intelligences develop in a variety of ways, in the case of logical-mathematical intelligence, Gardner adopted Piaget’s model of moving from various stages toward formal operations, including the sensorimotor stage, preoperational stage, concrete operations, and formal operations.

Unlike many of the other proposed intelligences, logical-mathematical intelligence had undergone several years of psychometric testing, as it is one of the principal elements in IQ testing. This was a key criterion in establishing a formal intelligence by Gardner, as are the numerous documented cases of individuals with exceptional abilities in calculation. Additionally, the intelligence meets Gardner’s criteria in the existence of the savant and those with traumatic brain injuries (Gardner, 1993, 2006b). Both the logical and numerical aspects of the intelligence are highly valued across multiple cultures, and there is significant history of evidence documenting their existence (Gardner, 1983).
Gardner provided several examples to identify the characteristics of logical-mathematic intelligence, namely rapid ability of the individual to solve problems, and the non-verbal attribute of the intelligence. Addressing rapid problem solving, Gardner gave the example of scientists testing multiple hypotheses and rejecting or accepting them rapidly, even when compensating for numerous variables. (Gardner, 1993, 2006b).

Referring to the non-verbal nature of the intelligence, Gardner (2006b) noted that, “a solution to a problem can be constructed before it is articulated. In fact the solution process may be totally invisible, even to the problem solver” (p. 12).

Gardner and Hatch (1989) further described mathematical logical intelligence in terms of defining and identifying numeric patterns, and the ability to understand chains of reasoning. Through a combination of problem solving, pattern recognition, and following reasonable chains, Gardner described the mathematical-logical centered individual as one who seeks to solve difficult problems and finds delight in finding solutions to those issues. Gardner suggested that it is this logical ordering of events and reasoning that allows scientist to move forward with their theoretical perspectives.

Linkage between the Intelligences

Gardner’s own views on a linkage between the intelligences, specifically between music and mathematics, have varied and changed over time. Originally, Gardner remained very skeptical about drawing connections linking intelligences. Gardner noted that correlations or lack thereof between musical ability and mathematic ability might be due to cultural expectations of families, the motivation of a particular student, or to the personal drive of the students (Gardner, 2006b). Further, regarding the possible connections between music and mathematics, Gardner (1983) remarked, “evidently,
there is no problem in finding at least superficial links between aspects of music and properties of intellectual systems. My own hunch is that such analogies can probably be found between any two intelligences” (p. 126). Additionally, Gardner (2000) cautioned against over-simplification of connections of intelligences:

All too often the theory of multiple intelligences has been evoked to convey trivial examples or to present important examples in an offbeat or anecdotal way…”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)

However, Gardner (1983) did acknowledge certain points of musical intelligence as related to the other intelligences. “Music is a separate intellectual competence, one that is also not dependent upon physical objects in the world… it is equally important to note the important and integral links that obtain between music and other spheres of intellect” (p. 122). For example, Gardner noted certain connections between musical abilities and spatial capacities due to their relative positions in neurological studies. Gardner suspected a “sensitivity in mathematical patterns…characterized many composers, ranging from Bach to Schuman” (p.126). Gardner identified traits of talented mathematicians and their 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” (Gardner, 2013, The Structure of Intelligences and their Combinations, ¶ 10). Gardner does caution that this interest does not necessarily constitute a certain amount of skill in the field of music, as either a performer or critical listener. Further, Gardner noted that while research is quick to point to an increase in mathematic ability in musicians, it is rarely points to a reverse, “We do
not expect of randomly chosen musicians that they will be interested, let alone skilled in mathematics” (Gardner, 2006b, p. 75).

Gardner suggested that a single action may require multiple intelligences working together. In his example, Gardner (2006b) referred to playing the violin as requiring more than musical intelligence, “To become a successful violinist requires bodily-kinesthetic dexterity and the interpersonal skills of related to an audience” (p. 22). Similarly, many of the actions measured in schools may rely on multiple intelligences.

Gardner’s position has further changed as correlational and neurological research continues to bring new evidence to light. In the keynote address to the 2003 American Education Research Association Symposium, regarding linkage to the spatial elements of mathematics and geometry, Gardner noted, “To the extent that the so-called Mozart effect gains credibility, I might want to rethink the relation between musical and spatial intelligences” (Helding, 2010, p. 327). Additionally, changes in educational settings allow multiple intelligences to interact, prompting Gardner (2000) to note, “Brains do not exist in isolation. They exist in bodies, which in turn exist in culture” (p. 78). This prompted questions of the independence of the intelligences, to which Gardner (2013) replied:

There is no necessity that each intelligence be wholly independent of the others; and it may turn out empirically that certain intelligences are more closely tied together than are others, at least in particular cultural settings or on certain kinds of tasks or test (The Structure of Intelligences and their Combination, ¶ 2).

This change in Gardner’s earlier views of the connections between the intelligences leaves many questions unanswered, especially between the relationship of music and mathematics.

Definition of Terms

- A.C.T. – refers to the American College Test
• Advanced Placement (AP) - refers to a standardized test administered by the College Board in conjunction with enrollment in Advanced Placement classes
• fMRI - refers to Functional Magnetic Resonance Imaging, a technique for measuring brain activity based on electrophysiological changes in the brain
• g - refers to general intelligence in psychological literature
• GPA - refers to Grade Point Average
• MI - refers to multiple intelligences, a theory developed by Howard Gardner in 1983
• NCLB - refers to the No Child Left Behind Act, the 2001 reauthorization of the Elementary and Secondary Education Act of 1965
• S.A.T. – refers to the Scholastic Aptitude Test
• STAAR-refers to the State of Texas Assessment of Academic Readiness, a standardized assessment, given at the end of course, in reading, writing, math, social studies and science
• TAKS- refers to the Texas Assessment of Knowledge and Skills, a standardized assessment to measure student achievement in reading, writing, math, social studies and science
• TAKS Alt- refers to the altered form of the TAKS assessment given to students receiving special education services but remains on grade level
• TAKS-M- refers to the modified TAKS assessment given to students receiving special education services that is not on grade level
• TEA- refers to the Texas Education Agency
• TEKS- refers to Texas Essential Knowledge and Skills, the specific curriculum for courses mandated by the state of Texas
• UIL- refers to the University Interscholastic League, the governing body of Texas extracurricular competitions in academics, athletics and music

Limitations

This study has several limitations. 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 high music-achieving group. Further, this may have excluded students who participated in school music groups earlier in their education experience from identification in the high musical participation sample.

Another limitation existed in that the study included students from only one high school; students from other campus may have other experiences. Second, 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, the various musical experiences of students in elementary and middle school were not considered in the placement of students in the high music groups. Finally, students may have had different mathematic experiences with different math teachers.

Significance of the Study

This study fills an obvious gap in the literature related to musical and mathematical intelligence linkage. This study extends the research on multiple
intelligences and the relationships between them, particularly between mathematics and musical intelligence, by examining the self-described experiences of students who engage in both music and mathematics skills development and learning in schools. Through a series of interviews, students had the opportunity to share their stories and perceptions related to their musical and mathematical experiences. In sharing their stories, students provided a greater understanding of how they perceived the connections of music and mathematics in their everyday lives and their future interests in each discipline.

Summary

While some researchers have proposed a possible linkage between music and mathematical study, this hypothesis remains a source of contention among educators and researchers. Although anecdotal evidence appears in test scores and brain scans, no definitive answer currently exists. Further, no research has addressed the actual experiences of students as they study these fields. This study explored student’s perceptions relating to both music and mathematics.
There is a relatively small body of literature that addresses high school students’ experiences and perceptions of music and math. The few perceptual studies that exist focus on the perceptions of teachers and parents. Vitale (2011) found that in addressing the effects of music on cognitive skills, elementary students, parents, music teachers and other classroom teachers, all four groups, perceived a benefit of music, to not just math, but to all cognitive skills. The author suggests that responses indicate a belief that the “ancillary benefit that is not limited to one or two subjects, but rather all subjects, making this connection more democratic and equitable” (p. 332). However, students had difficulty in linking music to any other cognitive skill.

Rather, most literature related to music and mathematics linkages emerges in two fields of study: cognition and neuroscience. Cognitive approaches examine related skill development in both music and mathematics and their relationship to one another. Near transfer theories are those 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 literature review focuses specifically on cognitive studies that look at correlational linkage between music and math, standardized testing correlations, and studies that involve multiple intelligences.

Cognitive Learning in Music and Mathematics

Music Cognition

The field of musical cognition has grown from the field of psychoacoustics to now encompass the study of musical behavior, the function of music, organization of patterns, learning, and the emotional aspect aspects of music (Radocy & Boyle, 2004). Pearce and Rohrmeier (2012) define three factors in the cognitive study of music including the universality of music in humans, music’s role in ontogenetic development, and music’s engagement of cognitive, perceptive and emotional processes simultaneously.

The study of musical behaviors includes perceiving and performing music as well as the comprehension, enjoyment, and cultural appreciation of music. Musical perception includes the differentiation in pitch, rhythm, timbre, stress, spatial location, and dynamics in music (Krumhansl, 2000; Serafine, 1983; Gardner, 1983; Pearce & Rohrmeier, 2012, ). While these perceptions occur both during performance and during listening, they require complex processing and ordering of structures associated with each element.

Musical Cognition as Emotional Response
These relate to perception and musical performance, as well as responses associated with the comprehension, enjoyment, and cultural appreciation of music. Musical preferences began with the indoctrination of the specific culture. Certain tonal and rhythmic patterns become readily accepted while those from other cultures are rejected beginning with early exposure in infants. Emotional responses to music have been documented to show specific physiological responses as well provide emotional outlets, relieve stress, and change the emotional state of the listener (Stalinski & Schellenberg, 2012). Further, musical preference develops over time and with experience and exposure to music genres.

More recently, musical cognition has turned to the field of neuroscience to explore the role of the brain in processing musical information. Advances in brain mapping technology have allowed researchers to explore how the mind processes musical stimuli as well as the ways musical thinking activates regions of the brain. In the areas of cognitive, affective, and motor, responses, there is evidence of physiological changes in the brain when presented with various musical activities, from listening to analyzing and performing (Baillet, Mosher, & Leahy, 2001; Hodges, 2000).

Mathematics Cognition

Fluency in mathematical computation is a key element in developing further math skills. Fluency combines speed and accuracy to solve mathematical questions while allowing cognitive process to focus on comprehension versus the decoding process. Research identifies key elements of mathematical reasoning, such as fact fluency, speed of processing, analysis of word problems and strategy. Furthermore, access to working memory and long-term memory greatly influences the speed and accuracy of
mathematical reasoning. In addition, the ability to focus may influence the ability to answer mathematic problems (Ramos-Christian, V., Schleser, R., & Varn, M., 2008).

Fuchs et al. (2005) identified key elements of mathematical reasoning such as fact fluency, speed of processing, analysis of word problems, and strategy. Furthermore, access to working memory and long-term memory greatly influences the speed and accuracy of mathematical reasoning. As with all developmental skills, mathematical ability begins with early stages. The pre-mathematical functions develop within children as they experience more situations that require mathematical thought.

The emerging mathematical processes eventually become the cognitive foundation for more complex mathematical computations. Mathematics focuses on a symbol system and the interpretation of those symbols. (Rapp, 2009; Gallistel & Gelman, 2005). Instructional methods that rely heavily on auditory-sequential patterns often separate the actual meaning of the symbols from what they represent. Students who process information through auditory-sequential instruction easily follow this rationale through copying examples and memorizing patterns or rules to complete the next similar problem. Students who are visual-spatial learners often struggle with this concept. Conversely, tasks that require translating visual patterns would challenge auditory-sequential learners, as these modes of learning are hemispherical opposites with respect to brain processing areas.

The Relationship between Music and Mathematics in Educational Settings

The study of the cognitive connections of musical study and mathematical thinking remains a topic of great interest among researchers. Most studies are unidirectional, maintaining the assumption that music experiences influence mathematics
learning. Few studies emphasize the opposite, that learning mathematics influences music learning. In addition, most studies are either correlational or circumstantial rather than experimental in nature. In spite of these research limitations, across time, authors continue to suggest that music study influences mathematics learning.

Shore (2010) found, “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 provide children with higher levels of attention, 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 suggest that this increase in focus and complexity of music fosters the development of cognitive skills such as language or mathematics and that developmentally appropriate sequences of learning support greater capacity in neural pathways and are used for not only musical development but for all areas of cognitive knowledge. Additionally, Shore’s meta-analysis found music study was strongly correlated with improved motivation, higher-level critical thinking skills, and a more positive view of school.

Several correlational studies showed increases in mathematics knowledge and skills. According to Catterall, Chapleau, and Iwanaga (2002) “33.1 percent of low-SES students in orchestra or band performed at the highest levels in math, compared to only 15.5 percent of low-SES students who were not involved in music” (p. 70). Portowit, Lichtenstein, Egorow, and Brand (2009) found that private music lessons were
correlated with improvements in mathematics and language regardless of outside factors such as low socio-economic status (SES). As private music lessons usually involve a one-to-one setting between teacher and student, children demonstrate higher levels of attention in lessons. Musical study “typically involves moving from more simple melodies to more complex musical compositions over time, engaging memory and mental stretching repeatedly” (Shore, 2010, p. 59). Schellenberg (2004) found a small increase in general IQ by an average of 7.0 points in the music students over the 4.3 increase in the control group, as well as increases of sub-scores in students with private voice or piano lessons over control groups. Schellenberg suggested that these increases in focus and in the complexity of the music learned correlated with the development of cognitive skills such as language or mathematics.

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. While findings from the Mozart Effect studies remain unclear and have been difficult to reproduce, the study brought a great deal of media attention to the possibility of linkages (Weinberger, 1998). Rauscher (2002) noted that the intent of the original studies was never to create the media sensation associated with concepts such as music making people smarter and cautions against associating cause with correlation. Reimer (1999) cautions that while it can be
tempting for those in music education “to regard a rationale such as improved spatial-temporal reasoning as a gift handed to them on a silver platter…There will be potentially destructive effects if the gift is accepted without a thorough examination of the consequences of accepting it” (p. 42).

Though the Mozart Effect drew considerable criticism, many researchers continue to explore this concept. Schellenberg, Nakata, Hunter, and Tamoto (2007) propose that the Mozart Effect is a result of the arousal and mood hypothesis, a belief that changes in cognitive abilities associated with music listening are in fact a reflection of the listener’s mood or state of arousal. Ivanov and Geake (2003) report observing a Mozart Effect in 76 elementary students, 20 with private lessons and the remaining 56 with no outside music experience, who participated in a Paper Folding Task (PFT) while listening to the music of both Mozart and Bach. The researchers found that the PFT mean scores of both the Mozart group (6.29) and the Bach group (6.08) were significantly higher than the score of the control group (5.09). The untimed PFT asked students to “to imagine how a piece of paper, which has been folded several times and had a hole punched through the folded portion, will look when unfolded” (p. 408). Pietschnig, Voracek, and Forman (2010) counter these claims based on their 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 (d=0.37, 95% CI [0.23, 0.52]) for those exposed to the original Mozart sonata KV 448 and note that the results indicate a “rather strong evidence for publication bias for effect sizes of studies comparing samples exposed to the Mozart sonata and samples
exposed to no stimulus at all. Overall effects seem to be inflated and need to be adjusted downward” (p. 321).

Various studies examined linkages between musical achievement and spatial reasoning, intelligence, and verbal/literary skills. Increases in spatial reasoning remain the center of many theories relating music and mathematical ability. Črnčec, Wilson, and Prior’s (2006) meta-analysis of the research on the cognitive increases in children, as correlated to musical instruction, identified three predominant strands of research: (1) focused listening to certain types of complex music (2) music lessons; and (3) background classroom music. They found that active group music instruction did appear to relate to improvement in spatial ability. This effect appeared to be more related to individual music instruction, such as private lessons, and based on longitudinal studies, seemed to be most beneficial with younger children. They did note that the study of notation seemed to offer benefits to spatial reasoning, mirroring similar studies that examine the use of symbols as mathematical representations. These results conflict with Hetland’s (2000) meta-analysis of 15 studies related to musical study and spatial effects, where the author showed only a moderate effect (r=.37) in all studies, while accounting for bias, inequality in experimental groups, and overall quality of the study. The relationship between music and mathematics learning remains inconclusive.

Several studies have attempted to link music and math based on cognitive growth in students associated with musical study. Sousa (2006) looked specifically at arts education and its role in the cognitive, social, and emotional development of students, noting the rapid growth of neural pathways during childhood. Artistic activities associated with play, such as singing or movement, “engage all the senses and wire the
brain for successful learning. When children enter school, these art activities need to be continued and enhanced...The arts are not just expressive and affective, they are deeply cognitive” (Cognitive Growth, ¶ 1-3). These findings are similar to Brown (2001) suggesting that high levels of musical or artistic achievement allow for a mega-cognitive transfer of ability. The skills required for abstract thinking in music mirror the skills needed in other areas, although Brown cautions that, “The specialized skills of the arts do not have a monopoly on transfer” (p. 93). An, Ma, and Capraro’s (2011) study of pre-service teacher’s beliefs of teaching math through music found that after training on a mathematically based musical task, pre-service teachers had far greater confidence in the concept based on a pre-test-intervention- post-test model. Effect sizes were in the moderate to large range (.67–.80), “indicating that the intervention activity had a considerable educational impact on the pre-service teachers” (p. 240). Participants completed a musical composition lesson and were asked to answer specific mathematical questions based on the compositional rules given to them. The task was designed to explain, “Notes, intervals, scales, harmony, tuning, and temperaments are related with proportions and numerical relations, integers, logarithms and arithmetical operations, trigonometry, and geometry” (p. 237). Again, these studies identified certain correlation but no definitive causality.

Spelke (2008) found correlations between intense musical study and geometric thinking, primarily due to increases in neural connections through cognitive development. Mathematic thinking relies on three core systems of reasoning relating to (a) representing small exact numbers, (b) representing large and approximate numbers, and (c) representing geometric relationships and properties. While each of the core
systems is independent of the others, they “become linked over the course of human cognitive development, and the most important linkages emerge before children begin their formal education” (p. 19). While previous studies have explored linkages between music and IQ or other cognitive measures, they are dependent on a variety of abilities and factors. Spelke sought to isolate the effects of musical training on one of the three core mathematical systems by using tasks specifically designed to measure just those areas. In three separate studies, students with music training outperformed their non-musically trained peers on geometric tasks relating to core systems. The author further identified three aspects of the relationship between geometrical thinking and musical study: (a) it is not dependent on other factors such as intelligence, income, or academic ability, (b) it does not relate to other mathematical skills, such as numerical reasoning, and (c) it is not related to the study of all of the arts, as students with music and dance training outperformed students with theater, writing or visual arts training.

**Standardized Testing**

A number of studies pointed to the correlation between participation in musical groups and mathematics competencies on standardized tests. Kinney (2008) found increased mathematics test scores in musicians over non-musicians in a Midwestern urban setting using state tests administered in the 6th and 8th grades. Based on the test scores, Kinney found band students outperformed their non-musical counterparts in both 6th and 8th grade math proficiency tests. Kinney noted that the instrumental musicians were the only group to score higher the other groups. Choral students showed no significant differences in scores. These results mirror Klinedinst’s (1991) conclusions that reading performance, math performance, and scholastic ability have
strong ties to 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, particularly those in music, than the non-music counterparts regardless of socioeconomic status. Fitzpatrick (2006) used Ohio Proficiency Test (OPT) results to compare musicians and non-musicians of various SES’s. The OPT measures student performance in fields such as citizenship, math, science, and reading. Students who began and continued instrumental music training into high school outperformed their non-musical peers at like SES levels at each grade level. Further, the scores of music students of low SES levels showed the highest gains. These correlational studies do not represent cause but continue the supposition 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 among over 6000 students on the Maryland Algebra/Data Analysis High School Assessment (HSA). The HSA consists of 38 questions relating to algebra, probability, and data analysis. The test is part of state graduation requirements. The study explored relationships between music instruction and performance on the Maryland Algebra/Data Analysis HSA, while controlling for achievement, based on previous test results from the fifth-grade Maryland School Assessment (MSA) exam. The study also explored similarities between racial subgroups: African American and White. Finally, the study examined the relationship between middle school music participation and ninth-grade achievement scores in algebra. 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 passing rate of instrumental musicians was 90.62, while students with choral training had a passing rate of 81.51. The group of students with no musical training remained at a passing rate of 75.03. In looking at racial subgroups, the African-American instrumental students’ minimum score was 100 points larger than the control, with all African-American musicians outscoring the non-music African-American subgroup. Finally, instrumental musicians “scored the highest mean of the three groups, with the instrumental group’s mean score 9.33 greater than that of the choral group and 13.57 greater than the mean score of the neither-instruction group” (p. 568).

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, specifically that highly motivated students who naturally possess greater academic talent may 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 mathematic 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.

Johnson and Memmott (2006) explored the relationship between participation in high quality music programs and standardized tests scores. Using university music
faculty to identify elementary and middle schools with strong music programs, the researchers identified 4,739 student scores from regions in the north, south, east and western portions of the United States. The study compared the mean scores of students in music versus those not, finding that in highly respected instrumental and choral music programs, scores differed significantly, “These differences, represented by z-scores, indicate a magnitude of difference equal to 22% better English scores and 20% better mathematics scores for the excellent music programs” (p. 299). These findings mirror those of the Cobb (1997) ACT study that showed music students with higher scores in all sections of the test than their non-music counterparts.

Elpus (2013) explored the relationship of music participation and SAT scores of over 13,000 students using a set of variables that included test scores, and transcript analysis of all music credits earned. A first analysis showed that the music students outperformed their non-music peers by 37.3 points; however, when statistically controlling for demographics, academic history, and school attitudes, Elpus found these gains quickly diminished. Elpus suggested that this difference may relate to an omitted variable bias and question the validity of prior studies linking music participation to higher standardized test scores. Variable biases included higher SES levels and academic achievements of music students prior to testing and the ability of students to report their own level of musical involvement.

While thses numerous studies have found very specific correlations between music and mathematics, none can identify the specific cause of their findings. Strong correlations have been found with regards to music students’ increases 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 authors may imply a direct linkage, where music supports mathematics, too may confounding elements prevent a clear statement of causality.

*High School Students’ Perceptions of School*

A final element of the related literature is the role of student interviews in giving voice to high school students’ lives and their experiences. Though no other studies could be identified that explored the perceptions and experiences of high school students in both music and mathematics, a small body of literature addressed certain perceptions of high school students in math or music separately.

In most cases, institutional review boards require additional permissions to conduct research on minors. The studies conducted in the United States all reported obtaining informed consent by parents (Gao, 2012; Kuntz, 2011; Parker, 2011). Two of the studies used interviews with students (Kuntz, 2011; Parker, 2011) while the remaining two used an assessment tool, such as a survey to determine student perceptions (Gao, 2012; Deniz, 2010). Although the two studies using survey instruments did produce findings related to student experiences, they did not allow students to address their perceptions in their own words.

The survey-based studies identified student perceptions of and beliefs about the researched topics. Gao (2012) explored student’s perceptions of assessments in mathematics, using an adapted questionnaire based on the Student’s Perceptions of Assessments Questionnaire. Two hundred forty-eight students responded and reported an overwhelming belief that they felt a strong connection between math assessments and lesson planning on the part of their teachers, but also that they had no say in the
assessment planning process. In regards to their perspectives of student accommodations, 73% of the students reported a perception that their individual needs were not always met. Student responses varied greatly on their perception of the availability of multiple opportunities to complete tasks.

Deniz (2010) explored the results of 100 students, 32 from a general high school and 68 from a music high school in Istanbul. Using the Piers Harris Children’s Self Concept Scale, the author determined that students at the music high school had a significantly lower self-concept than students at the general high school. Deniz proposes that this may be related to a belief that the students in the music high school feel less prepared to achieve success in other academic subjects. Additionally, male students reported a higher self-concept mean than their female counterparts. While these studies provide information on student perceptions, they fail to give students an opportunity to address questions in their own words.

The remaining two studies offered an interview format that allowed the researchers to gather the specific responses to questions by individual students. Parker (2011) asked students to express their beliefs about music making, and established four common themes from the participants. The study used the responses of 18 participants who completed 40-minute interviews. Participants then reviewed the transcriptions of interviews. The four themes that developed were that (1) music making is an experience for that created feelings in the participants, (2) musical knowledge is related to interpersonal knowledge, (3) music expresses feelings, and (4) musical performance creates an enlightened experience. One of the declared purposes of the study was to
specifically address the use of the student’s voices when considering musical philosophies.

Kuntz (2011) used focus groups to establish common themes and elements among high school band students’ musical activities outside of the school day. This study reported the experiences of 14 students from three focus groups, each representing rural, suburban, and urban schools. The specific focus of the interviews was on out of school musical activities available to current music students. Students reported community events, listening to music with friends, and various groups as ways they participated in music. Further, family influences were a major factor in musical involvement and the desire to continue music beyond high school. The researcher notes that focus groups provided a greater opportunity for interaction between participants than survey collection. The researcher further created codes to group themes that emerged from interviews. The major themes that appeared were school music activities, outside of school activities, the emotional outlet of music, and musical participation beyond high school.

Data analysis models differed greatly in both categories of studies. Standardized responses allowed for in-depth statistical analysis of results. Individual student responses found in interviews allowed the researchers the opportunity to code, group, and interpret each response to gain meaning. Each study provided a different avenue for including high school students’ information, perceptions and experiences in the research. While Likert based surveys do offer some opportunities for students to provide feedback, the interview models provide the opportunity for students to express specific
beliefs or experiences in their own words. The original purpose of the research appears to guide the specific methodology for collecting student responses.

Summary

Numerous studies have attempted to link mathematic ability and musical training through both cognitive and neuro-scientific models. The review of literature provides several studies that have found at least correlational connections between music study and mathematics; however, none show conclusive data supporting this linkage. Increases in test scores of musicians may easily be due to factors other than musical study. Unquestionably, there are certain skills required to perform both mathematic and musical tasks, and some of these skills do overlap; however, improvement in one set of skills may not translate to both fields of study. Finally, the chapter reviewed literature that examined high school student’s perspectives. The literature does support the need for further study.
The purpose of this study was to determine high school students’ perceptions of their musical and mathematical experiences in both school and other aspects of their lives. The study addressed the following research questions.

- How do students perceive themselves as musicians and mathematicians?
- What experiences do students have in the fields of music and mathematics?
- Where do students perceive themselves continuing in the fields of music and mathematics?
- How do students perceive the fields of music and mathematics relating to each other?

Additionally, the following assumptions were in place during this investigation.

1. All students in the school have some experience in both music and mathematics. These may include participation in school music programs at the elementary level, family events involving music, or outside music sources, such as religious events. In addition, students are exposed to music through media sources.

2. Mathematics state test data collected are accurate and valid.

3. Students will provide truthful answers to all interview questions and any battery of assessments.

Setting

The setting for this study was a north Texas high school in one of the fastest growing areas in the US, in a suburban city of over 136,000 residents. The district currently has three high schools, with a total high school population of approximately 7500 students. The studied campus is the oldest of the three schools and has a student
population of approximately 2000 students, comprised of approximately 60% white, 24% Hispanic, and 13% African American students. Table C.1 shows the ethnic make-up of the campus, district and Texas in 2012.

Table C.1

*Student Body by Ethnicity*

<table>
<thead>
<tr>
<th></th>
<th>Campus</th>
<th>District</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>African American</td>
<td>13.40%</td>
<td>12.70%</td>
<td>14%</td>
</tr>
<tr>
<td>White</td>
<td>59.20%</td>
<td>60.10%</td>
<td>33.30%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>23.90%</td>
<td>22.90%</td>
<td>48.60%</td>
</tr>
<tr>
<td>Native American</td>
<td>0.50%</td>
<td>0.50%</td>
<td>0.40%</td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>3%</td>
<td>3.70%</td>
<td>3.70%</td>
</tr>
</tbody>
</table>

Source: www.Texastribune.org

A majority of students met state standards on the Texas Assessment of Knowledge and Skills (TAKS) test, and the campus was rated Academically Acceptable in 2012 due to performance of student sub-groups. The campus had a 22% economically disadvantaged population, and 24% of the population met the Texas criteria for being at-risk. The campus completion rate for students to graduate in four years was 96.2%. Table C.2 identifies risk factors for student graduation in 2012.

Table C.2

*Percent of Student Body by Academic Risk Factor in 2012*

<table>
<thead>
<tr>
<th></th>
<th>Campus</th>
<th>District</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economically Disadvantaged</td>
<td>22.10%</td>
<td>26.90%</td>
<td>59%</td>
</tr>
<tr>
<td>At Risk</td>
<td>24.40%</td>
<td>26.50%</td>
<td>47.20%</td>
</tr>
<tr>
<td>Limited English Proficient</td>
<td>5%</td>
<td>9.80%</td>
<td>16.90%</td>
</tr>
</tbody>
</table>

Source: www.Texastribune.org
Population

The population for the study consisted of students in the 2014 senior class. 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 Exit Level TAKS scores from the spring of 2013. 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 participation. Students not enrolled in a school music organization during their senior year were identified as low level of music participation.

For the study, mathematics scores from the primary administration of the Exit Level Texas Assessment of Knowledge and Skills (TAKS) or Texas Assessment of Knowledge and Skills – Altered (TAKS- ALT) test from the 2012-2013 school year determined the level of mathematics achievement. Hereafter, both TAKS and TAKS-ALT are referred to as TAKS. The criterion for placement in the high mathematics group was earning a commended score in mathematics; 2400 or higher. Students earning less than a 2400 but greater than the passing standard of 2100 were considered as part of the low mathematic achievement population.

With the stratified selection, some of the students that met the appropriate criteria were my own counseling students. As students are divided by last name, I am responsible for approximately one-fifth of the senior student population. To meet the racial, gender and appropriate math levels outlined, for each of the groupings, it was necessary to include the entire student population, including my portion of the senior
class. Additionally, I knew many of the students outside of my alpha portion, simply from interaction with them at other school activities. To ensure fidelity, I approached each student randomly selected and their family in the same way, by explaining the purpose of the study, providing informed consent paperwork, and ensuring them that participation was voluntary.

Based on the definitions of school music and non-school music participation, and mathematics TAKS success levels, the population was divided into four categories: School Music Participation/Commended Mathematics (SMPCM), Non-School Music Participation/Commended Mathematics (NSMPCM), School Music Participation/Passing Mathematics (SMPPM), and Non-School Music Participation/Passing Mathematics (NSMPPM). Due to the disparity between participation in mathematics (mandatory 100% participation), and music participation (voluntary/audition based), the information from Tables C.3 and C.4 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.

Table C.3

*Racial Percentage of Senior Class Member Participation in Music Performance Groups*

<table>
<thead>
<tr>
<th></th>
<th>White</th>
<th>Black</th>
<th>Hispanic</th>
<th>Asian</th>
<th>Am. Ind.</th>
<th>2 or More</th>
<th>Eco. Dis</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>55.9</td>
<td>12.88</td>
<td>24.67</td>
<td>2.62</td>
<td>0.87</td>
<td>3.06</td>
<td>26</td>
</tr>
<tr>
<td>All Music</td>
<td>70.59</td>
<td>5.88</td>
<td>11.76</td>
<td>7.35</td>
<td>2.94</td>
<td>1.47</td>
<td>13</td>
</tr>
<tr>
<td>Band</td>
<td>82.14</td>
<td>3.57</td>
<td>7.14</td>
<td>3.57</td>
<td>0</td>
<td>3.57</td>
<td>4</td>
</tr>
<tr>
<td>Choir</td>
<td>63.33</td>
<td>10</td>
<td>13.33</td>
<td>6.67</td>
<td>6.67</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Orchestra</td>
<td>55.56</td>
<td>0</td>
<td>22.23</td>
<td>22.23</td>
<td>0</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Band/Choir</td>
<td>100*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table C.3 represents the percentages of students in each racial or economical grouping by campus and musical participation. The campus percentages are listed first followed by the musical percentages. *Only one student was involved in both band and choir, thus 100% in the white category.

Table C.4

School Testing Data

<table>
<thead>
<tr>
<th></th>
<th>N=</th>
<th>Met Standard</th>
<th>%</th>
<th>Mean Score</th>
<th>Commended Mean</th>
<th>% Commended</th>
<th>Non-Commended Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>458</td>
<td>411</td>
<td>89.96</td>
<td>2307.46</td>
<td>2495.55</td>
<td>34.06%</td>
<td>2245.26</td>
</tr>
<tr>
<td>All Music</td>
<td>68</td>
<td>63</td>
<td>92.65</td>
<td>2401.79</td>
<td>2535</td>
<td>55.88%</td>
<td>2274.84</td>
</tr>
<tr>
<td>Band</td>
<td>28</td>
<td>27</td>
<td>96.43</td>
<td>2461.04</td>
<td>2549.63</td>
<td>67.86%</td>
<td>2280.75</td>
</tr>
<tr>
<td>Choir</td>
<td>30</td>
<td>26</td>
<td>86.67</td>
<td>2342.04</td>
<td>2524.3</td>
<td>43.34%</td>
<td>2242.85</td>
</tr>
<tr>
<td>Orchestra</td>
<td>9</td>
<td>9</td>
<td>100%</td>
<td>2419.8</td>
<td>2532.8</td>
<td>55.56%</td>
<td>2303</td>
</tr>
<tr>
<td>Band/Choir</td>
<td>1</td>
<td>1</td>
<td>100%</td>
<td>2407</td>
<td>2407</td>
<td>100%</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Sample

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 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+) (SMPCM) and low (2100-2400) (SMPPM) 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 were included in the SMPCM and SMPPM groups.

A matching sample was selected from the non-music student population. The makeup of the non-music participation sample mirrored the racial and gender make-up 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 NSMPCM and NSMPPM groups. Once they were identified, the researcher contacted students and their parents and gave them informed consent forms. Upon obtaining signed forms, participants began their involvement with the study.

Table C.5

Sample of Students

<table>
<thead>
<tr>
<th>School Music Participation/Commended Mathematics (SMPCM)</th>
<th>School Music Participation/Passing Mathematics (SMPPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Students</td>
<td>6 Students</td>
</tr>
<tr>
<td>3 Male/3 Female</td>
<td>3 Male/3 Female</td>
</tr>
<tr>
<td>3 White/3 Hispanic</td>
<td>3 White/3 Hispanic</td>
</tr>
<tr>
<td>2 Band/2 Choir/2 Orchestra</td>
<td>2 Band/2 Choir/2 Orchestra</td>
</tr>
<tr>
<td>Non-School Music Participation/Commended Mathematics (NSMPCM)</td>
<td>Non-School Music Participation/Passing Mathematics (NSMPPM)</td>
</tr>
<tr>
<td>6 Students</td>
<td>6 Students</td>
</tr>
<tr>
<td>3 Male/3 Female</td>
<td>3 Male/3 Female</td>
</tr>
<tr>
<td>3 White/3 Hispanic</td>
<td>3 White/3 Hispanic</td>
</tr>
</tbody>
</table>
Six students in each category allowed for two each in the different music categories: band, choir, and orchestra. All six of the invited students accepted the invitation to participate in the study, for a sample of 24 students from the class of 498 seniors. All students selected agreed to participate and returned all informed consent forms (Appendix H and I).

**Design**

This study is a multiple case study. A single case study involves an in depth and detailed gathering of data from a single system, whereas a multiple case study compares several similar cases to one another in an attempt to create a better understanding of the specific phenomenon (Teddlie & Tashakkori, 2009; Glense, 2011; & Bryman, 2008). The use of 24 students in four separate groups allowed the opportunity to begin to draw commonalities not only within each of the four groups but also to make comparisons and contrasts between groups. The perceptions and experiences of each group of students were essential to answer the research questions; however, the comparisons between multiple groups led to the development of theories related to a deeper understanding of how these musical and mathematic experiences might affect the lives of the students.

Case studies involve a narrative or description of a specific person, group of people, or event. Researchers use multiple sources of data, such as interviews, document analysis, behaviors, or any other related data that better explains a particular phenomenon. This study relied on student interviews, multiple intelligence scores, and state math assessment results to explain student perceptions and experiences in both music and math.
Data Sources

The study employed multiple data sources to determine each student’s perception of music and mathematics and the relationship of these to him or herself as a participant/non-participant in music and mathematics TAKS tests. Data were derived from a series of interviews, student self-reporting through a multiple intelligence assessment (MIDAS), document collection in the form of student transcript examination, and analysis of student performance in several mathematic assessments, as well as musical performance. The researcher determined levels of musical performance by current placements in ensemble levels and specific interview questions aimed at individual musical achievements. These data sources created a case for each student’s experiences and perceptions of their lived experiences as both musicians and mathematicians.

Interviews

During the fall of 2013, students participated in a series of three interviews guided by an interview protocol (Appendix F); however, student responses led to additional questions. During the course of interviews, participants shared their histories with the two fields, their experiences, their perceptions of the relevance of mathematics and music, and their perceptions of the interconnection of mathematics and music in their lived experiences. Students’ levels of musical achievement and music participation outside of the school were determined, as well as their current placements, if any, in school music ensembles, as well as University Interscholastic League (UIL) scores from outside judging, solo and ensemble awards, and current chair placements or rankings in ensembles.
Demographic Data

Additional data sources, for creating student profiles, included demographic data and student standardized test scores. These test scores include the Exit Level math TAKS scores.

Exit TAKS

The Texas Assessment of Knowledge and Skills (TAKS) began in 2003, replacing the previous Texas Assessment of Academic Skills test. The TAKS tested students in grades 3-11 as part of federal compliance with the No Child Left Behind Act (NCLB) that mandates an accountability system for measuring student progress. The assessment measured student performance in reading, writing, mathematics, science and social studies. The 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).

Further, TEA (2006) defined the following characteristics of students who achieve a commended performance score:

1. Are fluent readers with a rich math vocabulary
2. Consistently exhibit persistence, endurance, and stamina
3. Enjoy math and are confident about their math skills
4. Consistently retain and apply prior math knowledge
5. Have strong problem-solving skills (e.g., use a variety of strategies, distinguish between essential and extraneous information, apply necessary skills, consistently justify answers and check solutions for reasonableness)
6. Demonstrate strong abstract thinking skills and can reason algebraically (e.g., transferring between variables and numbers)

7. Can consistently visualize geometric shapes and solids

8. Have a thorough understanding of complex measurement concepts

9. Make connections among math concepts

10. Have a thorough understanding of quadratic functions

11. Have a thorough understanding of systems of linear equations

12. Consistently identify and use the appropriate formulas to solve problems

13. Can easily represent equations and functions in multiple ways

14. Can solve problems with or without a graphing calculator (pp. 17-18)

For the purpose of this study, a commended performance on the first attempt of the EXIT TAKS is the indicator for placing students in the high mathematics group.

Multiple Intelligences Developmental Assessment Scales (MIDAS)

The MIDAS was used as a data source to determine students' perceptions of themselves across the eight multiple intelligences. For the purposes of this study, only the mathematics and music components were examined, although the entire battery was administered. MIDAS (Shearer & Luzzo, 2009; Shearer, 2012), a web-based assessment consists of 119 items 26 subscales, and when scored, produces a personal, perceptual profile based on Gardner’s eight intelligence. The assessment consists of three types of questions: Questions assessing frequency or amount of time spent on an activity, questions seeking an evaluation on performing an activity, and questions seeking level of interest in certain activities (Shearer, 2013).

Shearer (2012) describes the MIDAS as unique due to its being “carefully designed as a structured interview where respondents could describe their skills and abilities in both quantitative and qualitative terms. Each question is written to describe
specific behaviors associated with core cognitive components of the target intelligence” (p. 132). Scored items range from 0 to 4. Certain items score not only on a primary scales, but on a secondary or even tertiary scale. The main and sub-scores are shown as simple percentages based on the total number of items with a range being reported as “0 – 19%= Very Low; 20% - 39% = Low; 40 – 59%= Moderate; 60% - 79%= High; and 80% - 100= Very High” (Shearer, 2012, p. 132).

The MIDAS profile provides both main scale scores and sub scores for all eight intelligences defined by Gardner; however, for the purposes of this study, only musical and mathematical intelligences were used. Shearer (2012) describes the main scales as “Your general overall intellectual disposition which includes your skill, involvement and enthusiasm for these areas. These scores are indicative of which intelligences you will generally use with ease (or difficulty) to solve problems or create products” (p. 45). Subscales contain specific items and “Are provided to give descriptive information rather than as precise units of measurement” (p. 48). Shearer describes these main scales and specific subscales as:

**Musical**

To think in sounds, rhythms, melodies and rhymes. To be sensitive to pitch, rhythm, timbre and tone. To recognize, create and reproduce music by using instrument or voice. Active listening and a strong connection between music and emotions.

1. Musical Ability: awareness of and sensitivity to music, rhythms, tunes and melody
2. Instrument: skill and experience in playing a musical instrument
3. Vocal: a good voice for singing in tune and along with other people
4. Appreciation: actively enjoys listening to music
Logical-Mathematical

To think of cause and effect connections and to understand relationships among actions, objects or ideas. To calculate, quantify and classify. It involves inductive and deductive reasoning as well as critical and creative problem-solving.

1. Problem solving: skill in organization, problem solving and logical reasoning; curiosity and investigation
2. Calculations: ability to work with numbers for mathematical operations such as addition and division

Spatial

To think in pictures and to perceive the visual world accurately. To be able to think in three-dimensions and to transform one’s perceptions and re-create aspects of one’s visual experience via imagination. To work with objects effectively.

1. Imagery: use of mental imagery for observation, artistic, creative, and other visual activities
2. Artistic Design: to create artistic designs, drawings, paintings or other crafts
3. Construction: to be able to make, build or assemble things (pp. 135-136)

Both main and subscales are each given both a rating, such as very low, low, moderate, high, or very high; and a numerical score. Numeric scores served as the primary sources of data for reporting.

Reliability and Validity

Multiple studies have looked at the validity and reliability of not only the MIDAS, but also translations of the MIDAS to Spanish, Bahasa, Chinese, Turkish and Korean. Looking specifically at the MIDAS, Shearer (2013) identified the “mean Alpha reliabilities for the seven scales in four studies range from .76 to .87…indicating…that the questions for each scale are answered consistently by respondents around a common
theme” (p. 124). These findings correlate with similar findings from additional studies. Wiswell, Hardy, and Reio (2001) found reliability coefficients ranging from .85-.90 on the MIDAS scales. Shearer (2005) found correspondences between the main scale, and two of the Spatial Reasoning subscales, with an Alpha reliability range of .79-.89. Shearer (2007) found a correlation ranging from .77-.92 on test-retest of the MIDAS, as well as an inter-rater reliability of 40% on exact agreement, and 80% + or – one category. Beyond inter-test reliability, Shearer (2006a, 2006b) found moderate correlations between MIDAS sub-scores and the Ohio State Math Achievement test (r = .58) and correlations between the reading and writing sub-scores and the Ohio State reading test.

The growing interest in multiple intelligence has led to translations of the MIDAS into several languages. Wu (2004) cautions “It is believed that the MI model has universal meaning. However, when it is applied to appraisal and teaching, cultural and social factors have to be taken into account” (p. 183). Initial studies show promising results related to the validity and reliability of the translations. Wu (2007) found strong correlations with the C-MIDAS Chinese and the original English. Yoong (2201) also found strong correlations with the MIDAS-BH Bahasa translations with 644 Malaysians, showing Alpha ranges of .72-.91. Similarly, the K-MIDAS Korean translation found correlations among student groups and sub-scores (Kim, 2007). Pizarro (2004) also found an Alpha=.81 in a study of 429 Chileans on the Spanish translation of the MIDAS. İflazoğlu Saban, Shearer, Kuşdemir Kayıran, and Işık (2012) found internal consistency had a “Cronbach’s alpha of .96” (p. 659) and found that test-retest produced similar results after a four week period for the retest. These results seem to support the
multicultural aspect of multiple intelligences and their assessment through use of the MIDAS instrument.

Data Collection Procedures

The primary sources of data were a series of student interviews and the collection of related data from multiple intelligence profiles and TAKS test scores. These multiple points of data provided the opportunity to triangulate findings. In addition, research memos written during data collection and analysis aided in the organization of collection and analysis.

Time Frame

During the spring of 2013, the school district and UNT IRB granted approval to conduct research (See Appendix K) The researcher identified students and placed them in appropriate groups in August 2013. This allowed time for a) TAKS score delivery to the campus, b) student schedules to be finalized showing music ensemble participation and current math course selection, and c) obtaining informed consent of adult students and the minor students and their parents if they were under the age of 18. (See Appendix H and I) Approximately 25% of the students were of age at the time of the study, and were able to give their own consent. For the remaining students, the researcher made parent phone calls to explain the study and seek consent. Students returned all forms to the researcher. Students not meeting testing criteria, such as those not taking TAKS or TAKS Accommodated, were excluded from the population. After the researcher placed students into their respective groups of School Music Participation /Commended Mathematics, Non- School Music Participation/Commended Mathematics, School Music Participation/Passing Mathematics, and Non-School Music
Participation/Passing Mathematics, random samples of six students from each sample were contacted and invited to participate in the study. Upon the receipt of written consent, the researcher secured existing demographic data, test scores, and course history from the district student information management system. Initial interviews began during the fall of 2013, Final interviews concluded by October of 2013.

**Interviews**

Students chosen to participate in the study were involved in three interviews, lasting a total of approximately 45-60 minutes total. The first interview lasted approximately 10 minutes and an additional 20 minutes to complete the MIDAS instrument, the second interview lasting approximately 10 minutes, and the final interview approximately 5 minutes. 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 before or after school. Some students had a release period or served as office aides and were interviewed at these times. The orchestra teacher suggested that the four students in their program complete their interviews during the class period, during the warm-up. Many of the students chose to do the interviews in one of the administrative offices, while others preferred that the researcher meet them after their last class due to their after school commitments. The researcher digitally recorded interviews and later transcribed to Microsoft Word documents for further analysis. While each interview followed certain protocols, the questions are purposely open-ended to allow for an in-depth response and offer a semi-structured format. This allowed the participants to direct their own stories.
Participants completed the on-line MIDAS via an iPad. The researcher entered the student identifying number and password and explained the directions. Students then completed the remaining questions, with most taking approximately 20 minutes to complete. Participants received MIDAS profiles at the beginning of the second interview.

The researcher based data analysis on an interpretive phenomenological analysis (IPA) approach, where the experiences and meanings perceived by the participants guided the researcher in making sense of their own perceptions. Smith and Olson (2008) define IPA as an attempt to:

Explore in detail how participants are making sense of their personal and social world...and is concerned with an individual's personal perception or account of an object or event, as opposed to an attempt to produce an objective statement of the object or event itself. (p. 53)

The approach with IPA is twofold; in one sense, participants are exploring the meaning of their experiences while the researcher is exploring 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, the authors note, “Care is taken to distinguish clearly between what the respondent said and the analyst’s interpretation or account of it “(p 76).

NVivo 10

NVivo 10 software was used to analyze the transcribed interview data. NVivo 10 is a product of QSR International that allows researchers to import and code documents, videos, pictures, websites, and other data sources. Miles and Huberman (1994) suggest that primary concerns when selecting software for analysis should
include coding, memoing/annotation, data linking, search and retrieval, conceptual/theory development, data display, and graphics editing. QSR International (2012) offers this description:

Qualitative research software like NVivo, helps people to manage, shape and make sense of unstructured information. It doesn't do the thinking for you; it provides a workspace and tools to enable you to easily work through your information. With purpose built tools for classifying, sorting and arranging information, qualitative research software gives you more time to analyze your materials, identify themes, glean insight and develop meaningful conclusions. (What is Qualitative Research Software?)

The model of analysis provided by QSR International allows researchers to import transcripts, create codes, analyze and code themes, write memos, and create visuals. Figure C.1 shows this model.

![Figure C.1. Exploring perceptions: interviews (www.qsrinternational.com/default.aspx).](image)

The NVivo software allowed the researcher to group the student responses to each question for closer analysis. This made it easier to look for similarities or differences in answers to each question within members of each of the four groups.
Once each group response was analyzed, it became possible to compare the responses among the four groups.

A second feature of NVivo allowed the researcher to search each node, looking for common words or phrases among all responses. Results of word counts may appear as statistical analysis or a graphic representation. This feature was especially useful in assigning meaning to responses. When certain words or their synonyms appeared numerous times in response to a single question, this was taken as an indication that meaning should be assigned to these phrases. This was especially true in the response to a direct question about student perceptions of the connection between music and math, where several responses mentioned different aspects of a relationship to rhythm, counting, and mathematics.

Student Interviews

The data analysis plan included transcribing each interview, uploading transcriptions into NVivo 10 for coding, and looking for relevant or constant themes in each transcript, and later 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 researcher 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 versus a line-by-line analysis. This included, for example, grouping positive responses to a single question to a secondary code, while the negative responses appeared in a different
code. From there, a tertiary level of coding looked at important words or phrases within the positive or negative responses.

When recurring answers in student responses occurred, the researcher used analytic memos to note emergent themes or streams of thought. The memos noted the various trends of the four groups (SMPCM, SMPPM, NSMPCM, and NSMPPM) in response to different questions as well as emerging themes from student responses. This included the levels of agreement of each group to specific questions and common phrases or key words found in their responses. These memos helped make connections between the separate stories of students within the same categories. Organizing common experiences, beliefs, and perceptions of students in the same category played an important role in developing a better understanding of the experiences and perceptions of students in both music and mathematics.

After the initial coding to each question began to clarify the experiences of individuals, it became necessary to compare experiences of students, both within their categorical groups and across groupings; SMPCM, SMPPM, NSMPCM, NSMPPM. 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).

TAKS

The scale score of the MATH TAKS served as the primary factor for determining students’ assignment in the four categories. After students were placed in each group,
the TAKS data supplied additional information in regard to comparisons between groups. First, mean TAKS scores were compared among the four groups, showing differences and similarities between the groups. Secondly, in comparing sample means to the student population, it became apparent that the samples provided an accurate representation of the performance of the student body on the Math TAKS. Finally, the sub-scores for the 10 objectives were analyzed, looking for emerging patterns of math performance of each of the four groups.

Using individual student score reports, the researcher transferred the mean score and the individual objective scores to spreadsheets for further analysis. Filtering results allowed for organizing of data by each of the four groups. Additionally, a simple formula converted the raw objective scores to percentage for comparisons. All data were converted to tables and visual representations in the form of graphs that are presented with the findings.

**MIDAS**

MIDAS data were collected for each participant and used in building a profile for each person and each group. Based on the results of the individual participants, the researcher transferred main scores and sub-scores from individual students to a master spreadsheet for analysis. Using a variety of filters in the spreadsheets, it was possible to obtain specific scores for each group. The spreadsheet also allowed creation of tables and graphs that provided a visual representation of similarities and differences in each of the four groups. These tables and graphs are provided in the results section.

The researcher provided the main scale scores of Musical, Spatial and Mathematical-Logical intelligences in both a range and mean for each of the four
groups. Mean scores were then translated to the MIDAS range of scores, of low, moderate, or high, for each group. The mean and group ranges were also provided for the sub-scores under Spatial and Mathematical Logical intelligences.

Interview questions from the second interview related to three specific aspects of multiple intelligences: musical, mathematical-logical, and spatial. The responses to each of these intelligences were compared to actual MIDAS scores in the corresponding areas. Additionally, one portion of the student interview questions focused on the student’s reaction to MIDAS scores and his or her belief in the accuracy of the individual results. The student’s response to his or her MIDAS scores added validity to any attempts to triangulate individual scores to interview questions.

**Triangulation**

Bryman (2008) defined triangulation as “using more than one method or source of data in the study of social phenomena” (p. 379). This study relies heavily on triangulating data from student interviews, multiple intelligence profiles, and TAKS scores. Each of these elements supports the others in building a profile of school music participants and non-school music participants and their perceptions of connections between music and mathematics. As mentioned previously, several studies examined single academic factors and failed to provide any definitive answers. Using these data to support students’ perceptions and their self-reported multiple intelligence profiles provided an understanding of students’ perceived connectivity.

**TAKS and MIDAS**

TAKS data and MIDAS scores were aligned using a system of spreadsheets. Using a system of filters, each group’s data presented itself to view connections. Of
particular interest was comparing the algebraic objectives of the TAKS student performance on the Mathematical-Logical intelligence and related sub-scores to the MIDAS. Similarly, the geometric objectives of TAKS and Spatial Intelligences results of the MIDAS provided an alignment between the two sources, by student, within, and across groups. The data analysis resulted in the creation of tables and graphics that showed profiles of individuals’ and groups’ perceptions of themselves as mathematicians.

**Combining Interview and Assessment Data**

Students’ interview responses were triangulated in multiple ways: TAKS/MIDAS alignment and directly with MIDAS. Several interview questions addressed a specific interest or preference and were interrogated using the NVivo 10 software that allowed for ease in grouping responses by each of the four groups to each different aspect of MIDAS or TAKS results. One of the primary forms of triangulation came in comparing student interview responses to their perceptions of themselves as musicians and mathematicians. Mathematical perceptions were triangulated to their performances on the TAKS and MIDAS in both mathematical-logical and spatial intelligences. Student perceptions of themselves as musicians were also triangulated to MIDAS results on musical intelligence. A second example was in comparing the student responses on their preference toward algebra or geometry to both their performance on the specific objects in the TAKS and their results on the MIDAS in Mathematical-Logical and Spatial Intelligences.

**Summary**

This chapter first identified the population of the particular school and community
of the study and then outlined the methodology used in participant selection and recruitment. Next, the researcher identified the specific sources of data, including student interviews, academic data, and multiple intelligence profiles. After explaining the method of obtaining each of the sources of data, the chapter then outlined the data analysis plan and explanation of the software used and theoretical rationale used.
APPENDIX D

EXPANDED RESULTS
The purpose of this study was to determine students’ perceptions of both music and mathematics over the course of their high school experiences as well as their lives, outside of the school setting. Specifically, the research questions were:

- How do students perceive themselves as musicians and mathematicians?
- What experiences do students have in the fields of music and mathematics?
- Where do students perceive themselves continuing in the fields of music and mathematics?
- How do students perceive the fields of music and mathematics relating to each other?

Through triangulating student interviews, TAKS scores, and their own self-reported multiple intelligence levels (MIDAS), certain themes appeared regarding the student’s experiences and perceptions. Students from various levels of music participation and mathematic achievement levels, expressed, in their own words, their perceptions of the relationship between musical and mathematical study. The study focused on balanced groups of high school students, at various levels of school music participation and TAKS mathematics achievement, as well as ethnicity and gender. Student were classified into four categories: school music participation/commended mathematics (SMPCM), school music participation/passing mathematics (SMPPM), non-school music participation/commended mathematics (NSMPCM), and non-school music participation/passing mathematics (NSMPPM) based on enrollment in school music programs and standardized testing measures, described earlier.

Analysis from data sources that included interviews, a multiple intelligence survey (MIDAS), and TAKS scores, revealed trends in the four groupings of students. Academic and testing data tended to resemble previous research that showed higher scores in the mathematic subjects for the active music group compared to those of the
student body; however, the multiple intelligences data showed mixed results in the preferences of the four groups. See Appendix J. In combining these data with student interview results, several themes emerged from 24 high school students regarding their perceptions of music and mathematics. Results are presented based on each research question and the responses of each of the four groups. Tables and figures appear at the end of each summary section.

How Do Students Perceive Themselves as Musicians and Mathematicians?

To answer this question, the data came from both student interviews and their responses to the MIDAS. Of particular interest were interview questions relating specifically to student perceptions of music and math and the importance of each. The MIDAS responses are given both numerically and rated using the following scale: 0 – 19%= Very Low; 20% - 39% = Low; 40 – 59%= Moderate; 60% - 79%= High; and 80% - 100= Very High.

School Music Participation/Commended Math

Interviews

Four of the SMPCM group characterized themselves as being at a high level of musicianship, while the other two felt they were average. Five of the six were involved in additional musical activities outside of their school music participation. Three of these students were learning additional instruments, such as guitar and piano, while one was active in both choir and additional musical productions. The fifth student wrote and produced music in addition to working as a DJ. The final student enjoyed playing, but saw music as something to enjoy while in high school.
Mathematically, four characterized themselves as at a higher level; with two feeling they were average, or simply a high school mathematician. Most of the students described their mathematic ability based on the difficulty of math classes, especially those who had completed or were currently enrolled in AP math classes. Only one self-described difficulty in mathematics, and that was a previous experience in Pre-Calculus; however, this student noted that otherwise math flowed naturally.

When asked about the importance of music in their lives, five responded that music was very important, two going so far as to state, “Music is my life.” Another noted that music “kinda shapes how I think about some things and how I look at some stuff.” A different student described the importance of music as, “There’s always music going through my head, and sometimes in class I’ll hum a little bit or something…there’s always music somewhere in my life.” The final member of the SMPCM group described music’s importance to life as less important that other aspects. This student described music’s importance as “not a whole lot… Just... I enjoy playing…that’s about it.”

Mathematically, the SMPCM group viewed the importance of math at different levels as well. One student noted math’s importance as “A good deal...I really enjoy it and I’m good at it.” Similarly, another described it as, “I like math...I’ve always liked math… and I’ve always been good at it, so...I've always been able to excel in those math classes.” A third student described math’s role in family relationships, “I do a lot with my dad, and like calculating things, cause we’re very precise people, like it has to be perfect.” One student described math as less important than music, but notes, “It’s still important in its own way...Not just applying it to counting change or anything, or using math...it’s more like being able to develop in your mind and have some sort of
logic foundation.” A final thought came from the student who described his/her interaction with both music and mathematics as:

For some reason my brain is always doing some sort of math problem, like I’ll be singing on one hand, and on the other I’ll be looking at something and trying to figure out …what mathematical equation that would go with or how… I wonder how someone would mathematically thought that up.

When asked how they used math outside of the school day, the SMPCM students had a variety of responses. Three referred to using math in a work situation or related to money. One used math as a time management tool, while another claimed to have no use for math outside of school. The final student’s answer, “I like to take the fake math people do and check it” referring to statistical figures provided in advertisements.

MIDAS

The MIDAS data revealed the SMPCM group had score ranges of 48-82 in their Music Intelligence, 29-65 in Spatial Intelligence, and 39-62 in the Mathematical Logical intelligence. The mean scores were 64.5, 51, and 52.2 respectively, giving them a high score in Musical Intelligence, and moderate scores in Spatial and Mathematical Logical on the MIDAS scale.

The sub-scores for Mathematical Logical Intelligence were School Math 50-92, Everyday Math 30-73, and Everyday Problem Solving 25-92. The means were 73.5, 48.3, and 58.5, giving overall scores of high for School Math and moderate for Everyday Math and Everyday Problem Solving on the MIDAS scale. For Spatial Awareness the mean sub-score was 53.2 or a moderate on the MIDAS Scale. Five of the six students indicated a preference for algebra over geometry in their interviews. Their MIDAS data revealed a slightly higher mean score in the Mathematical Logical scores.
Triangulation

The combined elements of the interviews, TAKS data, and MIDAS scores point to certain patterns. Musically, three students considered themselves at a high level while the other three considered themselves at a moderate level. This aligns with MIDAS findings, as the range of 48-82 indicates students scoring in both moderate and high ranges. Mathematically, the group was identified as all having commended performance scores in mathematics. However, during interviews four stated a belief that they had high math ability while two stated only average ability, whereas MIDAS scores indicate individual scores in the low to moderate range. In triangulating MIDAS scores to algebra preference, Mathematical-Logical scores aligned with the group’s stated preference to algebra over geometry. The triangulation of the data indicated some discrepancy across sources, particularly in mathematics. Mathematically, the TAKS scores would indicate higher levels of student performance than the students’ own perceptions of their abilities; however, the MIDAS results indicated a slightly lower MI score in mathematical-logical thinking.

School Music Participation/Passing Math

Interviews

Five of the SMPPM group rated themselves as at a high level of musicianship, while the sixth described themselves as fair. Five of the six were in top performing groups at their school, with one choir student in both the varsity choir and varsity jazz choir. One student performed with a several musical groups outside of the school, and two students planned to major in fields related to music, audio engineering, and music production.
Mathematically, three rated themselves at a higher level, with the other three self-describing as fair or average. Again, most of the students related their mathematic ability based on the difficulty of math classes. Two specifically referred to themselves as a high level because of AP math enrollments. Three of the students were enrolled in Foundations for College Math, which is equivalent to an on level collegiate algebra class, and the remaining student was enrolled in Pre-Calculus.

Two of the students felt math was very important, one felt it was somewhat important, and one acknowledged the importance and applications, but did not “really care for it.” One of these students specified the need for a daily use of math, related to personal finance. The final two students, who plan to enter music related fields, noted that while math was important, it was less important than music. The two students who reported higher beliefs in the importance of math plan to enter medical related fields.

When asked about the importance of music, the SMPPM group had a wide variety of responses. Two noted that though they enjoy it now; they did not plan to pursue music beyond high school, beyond some personal playing of music. Two noted that music was important to them in a therapeutic measure, in that it changed their mood and provided a calming effect. One specifically noted that, “when I’m having trouble with my day... [it is] relaxing.”

The final two described music’s importance in detail. These students both planned to major in music related fields, audio engineering and music production. The engineer saw this as a combination of the fields of music and mathematics; however, believed that music was the primary focus:

Oh... it’s all I do... it’s work...I’m in two bands...I practice every day, cello, the guitar and all the other instruments...I’ve got a home studio at my house, and my
dad plays drums, and my brother plays bass, so we play all the time together. Music is...probably the biggest thing on my life...my primary interest.

The student majoring in music production was an orchestra student who planned to audition and major in voice. This student went on to describe music as one of the defining factors of life:

It’s a big part of my life... so I think it’s like really up there with, you know, like, just everything. As an athlete would refer to their sport, for me it’s like my music, so it’s pretty up there. I definitely want to continue with music...in college, like continuing to do orchestra, play instruments, just have music attached.

When asked how they use math outside of the school day, four of SMPPM students referred to using math in relation to money or in a work situation. One used math to complete homework, while another claimed to use math “everywhere.”

MIDAS

The MIDAS data revealed the SMPPM group had score ranges of 63-79 in their Music Intelligence, 30-75 in Spatial Intelligence, and 38-86 in the Mathematical Logical intelligence. The mean scores were 68.5, 49, and 56.7 respectively, giving them a high score in Musical Intelligence, and moderate scores in Spatial and Mathematical Logical on the MIDAS scale.

The sub-scores for Mathematical Logical Intelligence were School Math 33-83, Everyday Math 20-90, and Everyday Problem Solving 50-92. The means were 59.7, 55.8, and 68, giving overall scores of moderate for School Math and Everyday Math, and a high in Everyday Problem Solving on the MIDAS scale. For Spatial Awareness the mean sub-score was 53.2 or a moderate on the MIDAS Scale. All six students revealed a preference for algebra over geometry in their interviews. Their MIDAS data revealed a higher mean score in the Mathematical Logical scores.
Triangulation

In comparing the interviews, TAKS data, and MIDAS scores, the SMPPM group showed a higher perception of themselves as musicians and a slighter lower perception of themselves as mathematicians than the SMPCP group. Musically, four students considered themselves at a high level while the other two considered themselves at a moderate level. This does align with MIDAS findings were individual ranges of 63-79 indicate students scored in the moderate to high ranges. Mathematically, the group all had passing performance scores in mathematics. In interviews, three stated a belief that they had high math ability while the other three stated only average ability, whereas MIDAS scores indicated individual scores were in the moderate range, ranging from 38-86 in Mathematical-Logical. The wide range of MIDAS scores accounted for the range of student perceptions found in the interviews. In triangulating MIDAS scores to algebra preference, Mathematical-Logical scores also aligned with the group’s stated preference for algebra over geometry.

Non-School Music Participation/Commended Math Interviews

The NSMPCM students had a wide range of perceptions regarding themselves as musicians and mathematicians. Musically, the group rated themselves much lower. Three students rated themselves as low, while two rated their music ability as non-existent. One stated, “I wouldn’t consider myself a musician whatsoever.” Another student self-rated as average. This student had prior school music experience from middle school and outside of school musical experiences.
Mathematically, four of the group rated themselves as very high, often referring to the mathematic ability based on the enrollment in AP math classes. One noted, “I’m taking calculus, isn’t that as high as you can go?” Another student self-rated as average, and the last student self-identified as having low mathematic ability. The student with this latter response was the only student not taking a math class in the senior year.

Regarding the importance of music, most of the group expressed feelings that music was important to them. Five specifically expressed an importance of music listening. One noted, “I really like music, and I listen to it a lot, so it’s pretty important... in the past I played music, I guess... I mean I used to play a couple of instruments... I played guitar, and drums.” A second student expressed the ways music was a part of many aspects of life:

I listen to it every day... all throughout the school, I do it when I get home, when I’m cleaning or something, or when I’m doing home-work... before I go to my game... I pump myself up with it, so... I know it’s not as big as other people’s lives, but it’s a big part of my life... even though I can’t play it.

Other students referred to the way music is important to them without being involved in the making of music, “I think it’s pretty important... I don’t play any instruments... but I think it’s just important to everything.”

While not all students agreed to music’s importance to themselves, they acknowledged music’s role in the lives of others. One noted, ” I think that... to me... it’s not very important, other than to... just listen to it, but I understand that to other people it’s... a very important aspect of life... it’s how they express themselves.” A second remarked that, “It’s important... but not a priority.” A third student mentioned music as relaxation, but also a distraction:
Music...I think it's important to a lot of people... for me it's more like a relaxation...I just listen to it to relax, I don’t really like to listen to it when I’m doing homework, because I can’t do both at the same time.. I either listen to the lyrics or do my homework.

Another student noted that music, “Influences many different people...so it’s a big part of my life.”

When asked how they approach music, three of the group responded that the lyrics were the primary connection they made to determine if they enjoyed the music. One student referred to the “beat.” Further questioning revealed that this expression referred to a faster tempo. The final two could offer no explanation as to what made a specific piece of music better than another, other than it gave them “the chills.”

The NSMPCM group reported that math was of high importance. A common element was the importance of math in everyday activities, as seen in, “I think math is very important, because you use math in almost everything you do...and...everyone should know math.” Another student describes math’s importance, by stating that math is needed, “just for everything.” Even if they did not enjoy the study of mathematics, students recognized the importance of the subject, “I definitely see the use of it, and the importance of it...I don’t really enjoy of it a lot, but I see the importance of it, so I do it, and put effort into it.” Four students referred to the importance of math for college or to its being directly related to their future majors. One noted, “It's like very important, because that’s what I’m going to focus on in college and stuff.” Another related, “I want to do something math related, like engineer, so I put more effort into math.”

When asked how they use math outside of the school day, five of the NSMPCM students referred to using math related to money or in a work situation. The remaining student used math to complete homework.
MIDAS

The MIDAS data revealed the NSMPCM group had score ranges of 11-63 in their Music Intelligence, 21-94 in Spatial Intelligence, and 49-74 in the Mathematical Logical intelligence. The mean scores were 39.7, 58, and 62.7 respectively, giving them a low score in Musical Intelligence, a moderate score in Spatial, and a high score in Mathematical Logical on the MIDAS scale.

The sub-scores for Mathematical Logical Intelligence were School Math 63-92, Everyday Math 35-80, and Everyday Problem Solving 50-92. The means were 79.8, 58.3, and 70.2, giving overall scores of high for School Math and Everyday Problem Solving, and a moderate in Everyday Math on the MIDAS scale. For Spatial Awareness the mean sub-score was 63.3 or a high on the MIDAS Scale.

Triangulation

When comparing the interviews, TAKS data, and MIDAS scores, the NSMPCM group showed a lower perception of themselves as musicians than the SMP groups. Musically, only one considered him or herself at a moderate level while the other five considered themselves at a low level. This aligns with MIDAS findings where individual ranges of 11-63 indicated students scoring in the low to moderate ranges.

Mathematically, the group all had Commended performance scores in mathematics; however, in interviews, only two stated a belief that they had high math ability while the other four stated only average ability. The MIDAS scores indicated individual scores ranging from 49-74 in Mathematical-Logical and a range of 21-94 in Spatial. The wide range of MIDAS scores, including moderate Spatial and high Mathematical-Logical scores may account for the range of student perceptions found in the interviews. The
TAKS and MIDAS scores indicated a higher level of mathematics than reported in student interviews.

When comparing algebra/geometry preference, student interviews revealed that three students preferred algebra while two preferred geometry, with one undecided. This triangulated with both Spatial and Mathematical-Logical Intelligences, which the MIDAS revealed as moderate; however, there was a slightly higher mean score for Mathematical-Logical. This could account for the slight preference in algebra.

*School Music Participation/Passing Math*

Interviews

Students in the NSMPPM group described their level of musicianship as low, and stated they experienced music through listening only, although two had prior middle school choir experience. Most expressed that they felt music listening was important to them. One noted, “Music is important...because I like to listen to music, but to learn about music and study it and all that isn't too important.” Three of the students also noted they relate instrumental music study as a sign of music importance,

I mean it’s not like that important, but when you're listening to it, it is... like I always have my headphones on... I always have music in my head... like even if I am taking a test...or doing work... like it helps me concentrate...so like that’s how important it is to me...but not like playing an instrument.

Two students also noted that music affects emotional responses, “I feel like some people express their way through music, as a strong feeling, and I don’t disagree with that at all, if something motivates you and keeps you who you want to be, I encourage it.”

When asked how they approached music, three of the NSMPPM group responded that the tempo or being “up-beat” was a primary factor in determining if they
liked a new piece of music. One felt that the artist was a major influence in the decision. That student and one other also noted the importance of the “background music” or use of specific instruments in a song. The final student was unsure how to determine if he or she liked a new piece of music.

Regarding math’s importance, two of the students rated themselves at a high level of math, with three rating themselves as moderate, and the final student as low. Two felt it was essential to their future careers. One student planned to pursue engineering, the other agricultural business, and noted, “Math to me would have to be one of the higher priorities for my future job.” Other students acknowledged math’s importance in their daily activities. Two noted that math is their favorite subject, and they believed “it can take me somewhere in the future.” When asked how they used math outside of the school day, all of the NSMPPM students referred to using math related to money or in a work situation.

MIDAS

The MIDAS data revealed the NSMPPM group had score ranges of 25-50 in their Music Intelligence, 25-63 in Spatial Intelligence, and 32-63 in the Mathematical Logical intelligence. The mean scores were 35.2, 41.7, and 45.7 respectively, giving them a low score in Musical Intelligence, a moderate score in Spatial, and a moderate score in Mathematical Logical on the MIDAS scale.

The sub-scores for Mathematical Logical Intelligence were School Math 25-83, Everyday Math 25-70, and Everyday Problem Solving 33-58. The means were 35.2, 41.7, and 45.7, giving overall scores of low for School Math and moderate scores for
Everyday Math and Everyday Problem Solving on the MIDAS scale. For Spatial Awareness the mean sub-score was 44.2 or a moderate on the MIDAS Scale.

Triangulation

The interviews, TAKS data, and MIDAS scores of the NSMPPM group showed a lower perception of themselves as musicians than the SMP groups. Musically, all six considered themselves at a low level, which aligns with Low MIDAS. Mathematically, the group all had passing performance scores in mathematics; however, in interviews, there was a wide range of perceived math levels. Three students reported that they felt high levels of mathematics, two reported a moderate ability level, and one reported a low perception. The MIDAS mean scores in both Mathematical-Logical and Spatial indicated moderate scores; however, the individual ranges indicated scores in low, moderate and high ranges in each intelligence. This may account for such a large range in perceived math ability. Additionally, four of the six students preferred algebra to geometry. This aligned with the group’s four point mean difference, favoring to mathematical-logical intelligence over the spatial intelligence score.

Summary

Students in the sample perceived themselves as having connections to both music and mathematics. Musically, students not involved in school music, value listening to music as an important aspect to their lives, while the active musicians valued their own musical performance. Three students in NSMPPPM and one from the SMPCM shared a belief that only instrumental music study qualified as musical study.

Mathematically, students from both groups saw an importance to mathematics in education and daily lives. Even those students that had a dislike of the subject saw the
daily value of mathematics. Students with a great interest in mathematics tended to regard the levels of mathematics in association with levels of math classes they were taking. Students in all groups referred to the number of AP math classes they had taken or were currently enrolled in when expressing their perceived level of mathematics.

Tables D.1 and D.2 provide a comparison of MIDAS ranges, and the MIDAS scoring system in each category. Figure D.1 shows a comparison of mean scores for each group in Musical, Spatial and Mathematical Logical Intelligences. Figures D.2 and D.3 show the students self-reported perceptions of their own levels of music and math. Students in the music groups showed a higher level of musical intelligence than the non-music groups. For Mathematical Logical Intelligence and Spatial Intelligence, the NSMPCM group outperformed the others, with the SMPPM having the second highest score in the Mathematical Logical Intelligence, and the SMPCM group with the second highest score in Spatial Intelligence.

Table D.1

**MIDAS Ranges and Sub-scores for Each Group**

<table>
<thead>
<tr>
<th>MIDAS Range</th>
<th>SMPM</th>
<th>SMPP</th>
<th>NSMPM</th>
<th>NSMPPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music</td>
<td>48-82</td>
<td>63-79</td>
<td>11-63</td>
<td>25-50</td>
</tr>
<tr>
<td>Spatial</td>
<td>29-65</td>
<td>30-75</td>
<td>21-94</td>
<td>25-63</td>
</tr>
<tr>
<td>Spatial Awareness</td>
<td>25-70</td>
<td>10-95</td>
<td>15-100</td>
<td>25-65</td>
</tr>
<tr>
<td>Mathematical Logical</td>
<td>39-62</td>
<td>38-86</td>
<td>49-74</td>
<td>32-63</td>
</tr>
<tr>
<td>School Math</td>
<td>50-92</td>
<td>33-83</td>
<td>63-92</td>
<td>25-83</td>
</tr>
<tr>
<td>Everyday Math</td>
<td>30-75</td>
<td>20-90</td>
<td>35-80</td>
<td>25-70</td>
</tr>
<tr>
<td>Everyday Problem Solving</td>
<td>25-92</td>
<td>50-92</td>
<td>50-92</td>
<td>33-58</td>
</tr>
</tbody>
</table>
Figure D.1. MIDAS mean scores for all four groups.

Table D.2

*MIDAS Score Based on the Mean for Each Group*

<table>
<thead>
<tr>
<th>MIDAS Range</th>
<th>SMPCM</th>
<th>SMPPM</th>
<th>NSMPCM</th>
<th>NSMPPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Spatial Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Spatial Awareness Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Mathematical Logical Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>School Math High</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Everyday Math Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Everyday Problem Solving</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Note: MIDAS scoring based on the mean score for each intelligence and sub-score.
What Experiences Do They Have in the Fields of Music and Mathematics?

Students shared in interviews the variety of experiences they had in both music and mathematics. The interview data are organized by each group category and
represent a study of their lived experiences, rather than their vicarious experiences detailed in TAKS and MIDAS scores. Early family experiences were most the most common musical experience. These included singing songs with family, listening to music, and church experiences. Most students in the SMP groups also reported school music experiences of either older siblings or their parents. Mathematically, the students reported early experiences from home and school. Students from all groups reported working with their parents on homework or using math in a practical sense such as when shopping. Many students also had early memories of school math, such as flash cards or math games.

School Music Participation/Commended Math: Interview Findings

SMPCM students expressed that 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 involvement. One mentioned the parental expectation that they learn to read sheet music. Students in this group referred to the importance of music at family functions, particularly 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.”

For many, an early musical experience was an important experience. The
orchestra students referred to the day when they picked instruments in elementary school as one of their most importance musical memories. Other students remembered favorite songs from church or listening with family members. One student referred to early memories of singing with a piano teacher.

The SMPCM group had very little in the way of mathematic recognitions. One listed receiving the highest math TAKS score in 4th grade, while another just referred to doing “really well in those [math] classes.” Musically however, this group listed several accomplishments. Five of the group members were in the top performing ensemble for their discipline. Additionally, four students had previously earned the highest rating at the district solo and ensemble festival, while another four had earned places in the All-City or All-Region competitions for their disciplines. One student was selected to take the AP Music Theory class and had earned state recognition for piano performances. Five of the SMPCM group took private music lessons at some point, with several taking additional piano lessons beyond their school music discipline.

_School Music Participation/Passing Math: Interview Findings_

Early experiences of the SMPPM 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 have additional experiences with guitar and piano. One of band students played piano, violin, and sang in a choir beyond playing the flute. The remaining band student talked about the importance of music and dancing at family functions.
Family members often served as catalyst in introducing musical interest. One student reported that a mother “always wanted me to play an instrument.” Another reported, “My whole family on my mom’s side has done music...she forced me to do piano, but I love it... I quit... but I do love it...and it’s really relaxing for me.” A third student referred to a long family tradition of music, “My great grandpa played...instruments like guitar and he like sung, and then that went to my grandpa, and then to my grandpa to my mom, and then to me, so that’s like kinda where I got it from.” Other students reported that music and dancing were a part of family gatherings or of church meetings. One student mentioned the role of a father played in developing the child’s musical interest, “We would go and work in the garage with him and I would listen to music with him... got introduced to some hard rock...like what I like now.”

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.” One recalled math experience in class in 3rd grade,

The first time I thought I loved math and would love to do something with it was when I was in the 3rd grade and...I had this exam...and I did like so good on it and I thought I was the best mathematician out there...so yeah I wanted to do something with it.

Another student noted, “I did GT math in 5th grade...it was like algebra and I loved it.”
Five of the SMPPM group listed no special recognitions in math. The one recognition listed was being placed in Gifted and Talented (GT) math in elementary school. Musically, five members were in the top ensemble for their discipline, and four had received the highest ratings at the district solo and ensemble festival. None of the students had previously placed in the All-City or All-Region competition. One student was involved in the school AP Music Theory program. Five of the students were currently or had previously taken private lessons. One student also listed as a recognition performing with their own personal band at several "shows."

*Non-School Music Participation/Commended Math: Interview Findings*

The 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, "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, “My mom, she taught me at an early age how to do like subtraction and addition and everything.”

Earliest memories of math focused on school activities, such as learning multiplication tables. Several students noted an early interest and aptitude for mathematics. One noted,

I remember being the smartest kid in my 5th grade class… I remember I’d always have my hand up and stuff… and I liked math up until I got into pre-cal… and I
was just like...uh what is this... but I finally finished that so...yeah I was actually really interested in math when I was little.

Other students noted that math came very easily to them, "I guess I don't remember much, because I never struggled with it...I just kinda did it and moved on." For five of the students, their earliest music memories included just listening to music, although two students listed specific instances of listening. One referred to early memories of Christmas music, and another to a "classical music CD" that was played when going to sleep. One student mentioned music at family activities, “My cousin...since I was little, I remember him playing in a band and when I reached the age of 11, he used let me sing a few songs, at like parties with him.”

Mathematically, two students were involved in the Math Olympiad, and won recognition there. One student also identified as being GT in math. The students in the NSMPCM group listed no musical recognitions. One student however had studied private piano and mentioned performing as a singer in her family’s band at paid performances but did not consider this a recognition as much as a family activity. Two students reported being involved in middle school band. One student “played the trombone in 6th and 7th grade...and just didn’t enjoy it whatsoever.” The other played euphonium all three years of middle school but reported not having time to continue in high school.

Non-School Music Participation/Passing Math: Interview Findings

Most students reported that music played little 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 reported that listening was important to family activities “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.

The NSMPPM group reported that their family’s math activities included doing homework and 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.

Mathematically, one student had received an award in physics. The remaining students reported no other recognitions for mathematics. The students in the NSMPPM group listed no musical recognitions. Three students reported being involved in middle school music programs, two in choir and one in band for less than two months.

Summary

Early experiences and family expectations appear to have shaped musical and mathematic experiences. The school music participants show more active music experiences, both in school and in their home life, than the non-school music students. These active experiences included music lessons, and piano experiences. Figures D.4 and D.5 show the students’ perceptions of the importance of music and math in their family activities, based on student responses in the first interview to the direct questions: Was music/math an important part of your family activities? Student
responses were coded to align with three codes: High Importance, Some Importance, and Low Importance based on student responses. In this case, students in the Passing Math groups reported higher levels of math importance in their family lives than their commended counterparts initially reported, however, subsequent interview questions revealed a more detailed description of interaction with the family in music and math, especially in regards to mathematic involvement. Several students, from all groups initially reported little involvement in mathematical activities in their family lives; however, when asked about early memories of mathematics, they reported early family interactions. This is also true for responses related to musical activities. Differences in responses may be related to the more specific nature of questions regarding earliest memories of music and math. It is interesting to note that students initial perceptions do not align well with responses to more detailed questions that revealed most early memories of the two fields occurred in the family setting, perhaps suggesting that musical or mathematic activities were so common to the point that they did not seem to have specific importance.

Figure D.4. Music’s importance in family activities (results based on the six group members responses to interview questions).
Where Do They Perceive Themselves Continuing in the Fields of Music and Mathematics?

These findings related not only to the immediate student goals but also their future lives. Interview questions revealed how both music and mathematics played into future careers as well as plans for engaging their own families in both music and mathematics. The first interview question addressed this importance of education, as a litmus test for gauging student responses.

All students from all four groups agreed on the importance of education, citing the need for education to further their careers. Questions in the final interview addressed the students’ future goals, how they saw music and mathematics playing into their futures, and finally whether they would want to encourage children of their own to study music and mathematics.

*School Music Participation/Commended Math*
The School Music Participation/Commended Math group had very diverse plans for their futures. Five of the six planned to attend college, with one entering a trade field. Of the college-bound students, one was undecided, three looked to math related fields such as computer science, actuary sciences and accounting, one was considering social work, and the final one was considering either music education or a career in forensic science.

Four of the college-bound students planned to continue some form of musical study, either through participation in collegiate band or choir or their own private study; however, the fifth noted not “really see[ing] a place for it… I think I enjoy it now.” The student entering a trade field planned to continue work in music production and as a DJ as a part time job. Of the remaining college-bound students, only one professed a clear desire to continue music beyond college, "I definitely want to keep learning, and be in a choir…when I’m older, and definitely in college…no matter which college I go to, I want to be in a choir…music will always be a big part of my life."

Mathematically, the group all recognized the importance of continual study of mathematics. Three specifically listed it as very important due to its relating to their majors. The student seeking to become a social worker professed a great love of mathematics, but noted, “As much as I love it…I’m not going into that field.” The possible education/medical student saw the need for mathematic coursework in either field. The trade student was most interested in carpentry and saw great value in mathematics.

As far as the study of music and mathematics for their future children, all six students saw an importance and wanted their future children studying both. Four of the
six rated mathematics as very important, with the other two saying that it was important to know; although one did say it was less important than the study of music. One student specifically mentioned that it is important that their student be “Advanced...I want my kids to be smart.” All six agree that they would wanted their children to study music, citing their own interest and experiences in music as primary reasons. One student noted that “There is a day and age where I won’t be able to do it [play] anymore, or I don’t want to do it anymore...and I want to hear stuff [music] in my house.”

School Music Participation/Passing Math

The School Music Participation/Passing Math group had more detailed plans for their future goals. All six planned on college, with two seeking medical degrees, one in an undecided engineering field, one looking to enter education as a social studies teacher, and two seeking careers related to music, one in music production the other in audio engineering. Two of the students specifically mentioned plans to continue into graduate programs, one relating to veterinarian medicine, the other into either genetics or forensic anthropology.

As far as continued involvement in music, the two students entering medical fields saw little room for music in their plans. The audio engineer and music production students saw music as a major part of their lives, with course work relating to music study. The political science/education majors would like to participate in colligate level choir, while the student interested in genetics and forensic anthropology saw music as a way to stay calm and to “help stay relaxed” but had no plans for any additional formal study.

Four of the students saw math as very important and related heavily to their
fields of study. The education major stated only the desire to take basic courses needed for graduation, and the music production major saw math as not as important as the study of music. The audio engineer noted the equal importance of music and math in this chosen field, "Music is definitely in that, and there is a lot of math, which some people don’t realize… um…when you’re dealing with compression and levels and all that…complicated stuff...so they both play an intrinsic role."

All members of the SMPPM group saw great value in having their own children study both music and mathematics. All students agreed that mathematic study was important and related to every day needs. Musically, while all participants wanted their children to study, they had different opinions related to at what level. While two wanted to expose their children early so they could be a part of their own musical lives, they would leave it to the children to decide; one was adamant that he/she would “force them to learn something...probably piano.” One student who referred to wanting children to play an instrument suggested that the social aspect of band was one of the most important aspects this individual had taken from the band experience. Another student referred to the importance of studying music because it is related to academic gains, “Music makes you improve in school… makes you a little bit smarter.” When questioned further, the student was unsure of why, just that this statement had been heard from various people and some teachers.

*Non-School Music Participation/Commended Math*

Students in the Non-School Music Participation/Commended Math group had diverse fields of study. Three students looked specifically at engineering, with one set on mechanical engineering, and the other two undecided in area of expertise. The
remaining three students planned to major in art, accounting and physical therapy. The accounting major and one undecided engineer specifically mentioned plans for graduate school. Two of the NSMPCM group also reported that they would be playing colligate level girls’ soccer and had signed contracts with their schools. The soccer decision was a major part of their school selection.

In regards to music in their chosen fields, none of the NSMPCM group foresaw music as playing a role in their future goals. Two specifically saw no place for music, while two mentioned that music would remain important for them only as a form of enjoyment or relaxing. The final two mentioned music as a hobby, with one reporting the possibility of choosing to learn another instrument in addition to the previously self-taught guitar and drums.

Four of the group saw math as playing a large role in their future coursework. The mechanical engineering student specifically mentioned the importance of math in regards to calculus and physics. The art major saw very little math in the future, stating that only need one math class would be needed for their major. The physical therapy major did not foresee much math and instead thought the focus would be on science.

In regards to plans for their children, all six of the NSMPCM group expressed the importance of studying mathematics. The mechanical engineer specified the importance of children continuing the family tradition. Four of the group felt that musical study would be important, and could offer some benefits. These benefits included a sense of responsibility in the form of caring for an instrument, the ability to express themselves, and the opportunity to find something that they might enjoy.
Non-School Music Participation/Passing Math

The Non-School Music Participation/Passing Math students had a much wider variety of career options. Additionally, three of the students expressed an uncertainty and provided several possible majors. Two students expressed clear desires to continue to four-year schools and major in engineering and agricultural business. A third student expressed a desire to complete an Associate’s degree in graphic design. The three remaining students provided possible options that included sports management or marketing, forensic science or photography, and animal science or counseling.

Musically, the NSMPPM group overall did not see music as having a major role in their futures. The one exception was the graphic design major, who considered the need to add music to video productions. Of the remaining five students, two saw music as remaining only for listening and enjoyment, one saw music as a means to help focus while studying, and the remaining two saw no place for music.

The NSMPPM group had mixed perceptions of the role of math. Two saw it as a requirement for at least some classes in their possible majors, while two saw it as a major piece of the major. Of the remaining two students, one saw it having some importance, but not “a huge impact,” while the final student saw math as playing a role after degree completion to help with preparing “taxes and writing checks.”

Concerning the importance of music and mathematics to their future children, five of the six believed it was very important to study mathematics. The sixth specified it would be important if the child showed an interest in mathematics. Musically, two of the NSMPPM group did not see any importance to studying music, while two others would like their children to study if they show an interest. The remaining two wanted their
children to study some music at an early age, and later decide if they would want to continue.

Certain obvious trends appear in looking at the responses of the four groups. While a majority of students saw an importance of mathematics for their immediate future, only those students heavily involved in music foresaw it as a greater importance to their plans. Table D.3 shows the breakdown by each group of how the students reported their perceptions of themselves continuing in the fields of music and mathematics. Five SMPCM, four SMPPM, zero NSMPCM, and one NSMPPM students identified as believe music played an important role to their future. For students believing math was important to their future, all six of the SMPCM and four in each of the remaining groups saw importance.

Table D.3

<table>
<thead>
<tr>
<th></th>
<th>SMPCM</th>
<th>SMPPM</th>
<th>NSMPCM</th>
<th>NSMPPM</th>
</tr>
</thead>
<tbody>
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<td>Music</td>
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<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Math</td>
<td>6</td>
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</tr>
</tbody>
</table>

The majority of all students showed math relating to future career plans. Even those not seeing an immediate relationship, did acknowledge a need for mathematics. While the music groups showed a higher likelihood of music connection to career or college coursework, many of the non-music groups mentioned a desire to continue to enjoy music in a non-professional setting.

Related to the idea of continuing music and mathematics is the desire for the students' future families to continue the study of the two fields. Figure D.6 reveals 23 of
the 24 participants believed it to be important for their children to study mathematics. The one student who did not agree gave the condition that it would be important if their children showed an interest in the field of mathematics. All music students agreed that it would be important for their children to study music, while four of the six in both the NSMPCM and NSMPPM groups expressed that desire.

![Figure D.6. Importance of participants’ future children studying music and mathematics.](image)

*Figure D.6. Importance of participants’ future children studying music and mathematics.*

**How Do They Perceive the Fields of Music and Mathematics Relating to Each Other?**

Student interviews served as the primary data for this question. In the second interview, the interviewer presented the statement that “there are some theories that suggest there is a connection between music and mathematics.” The students were asked, “What is your initial reaction to that idea? Do you have experiences that support or oppose that view?”

*School Music Participation/Commended Math*

Five of the SMPCM group felt there was a connection between music and mathematics, while one of the group was unsure of a relationship between the two fields. The students cited several ways they perceived this connection as well as
anecdotal instances of musicians with strong math skills. 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 they could offer no further detail.

Other students related the idea that math influences musical ability. A common idea here was 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 suggest math is used in music, “Especially when you’re solfeging 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 waivered on the idea of
brain connections. The student did, however, refute the idea that all music students
were strong at math, “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, maybe 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.”

School Music Participation/Passing Math

Four of the SMPPM 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. 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 complication 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 taught, “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 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.”

Non-School Music Participation/Commended Math

Two students in the NSMPCM group felt a connection did exist between music and math, while the remaining four were unsure of such a connection. The students who perceived a connection between the two suggested that mathematic ability supports music. 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 offered,

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 stay up. Another student expressed unsureness of 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 are 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 got 5’s on the AP Calculus BC exam… they are all like musicians…so they are 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-School Music Participation/Passing Math

Students in this group had differing perceptions of a connection between music and mathematics, with three agreeing and three in disagreement. Those that did perceive this connection suggested the connections 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.” Although this student did later 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 noted, “I would say more reading or history would go with music” rather than math.

Summary

Students had multiple perceptions about not only the possibility of a connection between mathematics and music, but also the root causes of such a connection. Fourteen students, from across all groups perceived a connection, while five students remained unsure of any connection. Five students perceived no connection.
For the 14 students that did perceive an obvious connection between music and mathematics, eight of the students expressed a belief that mathematics fostered a stronger sense of musical rhythm, thus higher math skills were related to higher ability in music. In reviewing interview transcripts, there are 36 references to counting/rhythm when students were asked about their perception of the relationship between music and math. This is contrary to most of the existing literature that attempts to draw a connection where music involvement supports mathematics ability.

The 19 students who either perceived a connection or remained unsure about a connection cited three primary beliefs about the origin of the connection: a) brain connections between music and math, b) connections between the cognitive aspects of math that supported musical meter, rhythm, and structure, or c) anecdotal evidence of musicians that were successful in mathematics. The five students that 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 only students who saw no connection both come from the passing math groups. Table D.4 and Figure D.7 show the breakdown of each group’s perceptions.

Table D.4

<table>
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<tr>
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<th>NSMPCM</th>
<th>NSMPPM</th>
</tr>
</thead>
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<tr>
<td>Agree</td>
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<td>4</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Unsure</td>
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<tr>
<td>Disagree</td>
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</tr>
</tbody>
</table>
Additional and Unexpected Findings

A deeper examination of the data revealed additional observations regarding the groups’ experiences and perceptions. Some of these observations relate to the socio-economic status of students as related to parental education level, while others relate to additional experiences in school music programs, beyond those uncovered from the research questions.

Further analysis revealed that the educational level of the students’ parents tended to be related to socio-economic status (SES). In this particular sample, the five students identified as low SES were all Hispanic, and all indicated a parental level of education where one or more parents had a high school degree or less. The only exception to the pattern of education level correlating to low SES was for one white NSMPPM student whose parents had only high school diplomas but were not low SES. Of the five low SES students, two were in the SMP group, both with passing math scores. The remaining three fell into NSMP groups, two in the commended math group,
and the final student in the passing math group. The remaining 19 students did not indicate low SES status.

One of the interview questions asked students was whether they had additional thoughts to share about their experiences in music or mathematics. Though many students replied that they did not, one SMPCM student addressed the social importance of their musical participation.

I think that... being a part of something musically, whether its dance or music all the time, or actively in a group that performs music or whatever, I just think that it gives you another sense of self... and gives you another family...cause I found it really important though high school and pretty sure though college, that having that group of people that you connect with on a whole other level is really, really important.

Upon further reading of transcripts, this concept of friends and meeting people appeared in one other instance. One of the SMPPM students referred to the desire for her future children to be involved in music, based on her experiences. When asking for clarification, she replied that music helped her by providing the opportunity to meet people who were able to help her, “I mean you get to know a lot of people through band, especially...and they can help you with different things, like math.” Social connections are an important part of the adolescent period, and many of these connections are made during school.

Summary

This chapter provided data from student interviews and standardized testing, as well as insight about multiple intelligences from the MIDAS instrument. Data were presented for each question that rely on the responses of each of the four groups. Students had a variety of perceptions regarding all four of the research questions, many of which triangulate with either test data, student performance in math classes, or
MIDAS results. Certain patterns and trends emerged in the four separate groups, as well as both music/non-music and high/low math cross comparisons.

Not surprisingly, students involved in school music programs had a higher perception of themselves as musicians than their NSMP counterparts; however math perceptions varied far more widely among the groups. While one might expect a higher math self-perception among the commended math groups, all four groups had a wide variety responses. Both SMP groups did show a higher self-perception in mathematics, although the NSMPCM showed a more moderate perception, even though their MIDAS and TAKS scores suggest the higher level of math achievement. Students in the NSMPPPM group showed the widest variety in perception.

Early experiences in music and math do seem to shape some student perceptions of the fields, as well as to support involvement in school music programs and advanced math classes in high school. Students in the SMP groups revealed positive early experiences in music. While all groups reported math activities in their early family lives, student perceptions of their ability and their enrollment in advanced classes varied greatly.

Students in school music programs showed a far greater interest in remaining involved in music in their post high school experiences, although students from all groups expressed a desire to remain active listeners to music. Mathematically, students from all four groups expressed a desire to follow math-related careers. Four students expressed an interest in following musically related careers, one from SMPCM, two from SMPPPM, and one from NSMPPPM.

Finally, 14 students from all groups indicate a belief that music and mathematics
were connected. Five other students expressed a belief that a connection might exist. Only five students, two from the SMPPM and three from NSMPPM groups, expressed a belief that music and math had no connection. The most common theme that developed from the students that felt a connection either existed or could possibly exist involved a belief that higher math skills supported a greater understanding of musical rhythm elements. This is contrary to the findings of many correlational studies that suggest that musical participation supports high math performance.
APPENDIX E

EXPANDED DISCUSSION
The purpose of this study was to determine students’ perceptions of both music and mathematics over the course of their high school experiences as well as their lives, outside of the school setting, and to determine their perceptions of the relationship between music and mathematics learning. Specifically, the research questions were:

- How do students perceive themselves as musicians and mathematicians?
- What experiences do students have in the fields of music and mathematics?
- Where do students perceive themselves continuing in the fields of music and mathematics?
- How do students perceive the fields of music and mathematics relating to each other?

Data from student interviews, TAKS scores, and multiple intelligences assessments provided a look into the lives and experiences of high school students. Students were classified into four categories: School Music Participation Commended Math (SMPCM), School Music Participation Passing Math (SMPPM), Non-School Music Participation Commended Math (NSMPCM), and Non-School Music Participation Passing Math (NSMPPM) based on enrollment in school music programs and standardized testing measures. Each of the four questions provided a greater insight into the experiences of students as well as shed light on unexpected findings.

Discussion of Findings

*How do students perceive themselves as musicians and mathematicians?*

Musically, the students in the school music participation groups had a stronger perception of themselves as musicians than the non-school music participation group, both in the interviews and Multiple Intelligence Developmental Assessment Scales (MIDAS) data. This is not surprising, due to the high musical involvement of the school music participation groups. This is not to imply that the Non-School Music Participation
(NSMP) groups did not value music; quite to the contrary, many of these students considered music listening to be a major part of their lives. Students from all groups also spoke of musical activities beyond the scope of school music programs, such as playing guitar, mixing music electronically, or just very active listening. Often, these musical skills were not taught as an aspect of school music, but high levels of interest in these fields imply that a possible avenue to furthering the musical education of all students may need to explore non-traditional routes.

One other interesting aspect mentioned by several students was a conception that being a musician implied playing an instrument. Three members of the NSMP groups and one vocal member of the SMPCM group communicated this idea. Although this is of interest, it is common among musicians to refer to orchestra and band members as musicians and vocal performers as singers. This perception and language seems to have pervaded the language and references of the students interviewed. This common acceptance at this educational level suggests that students are hearing these references elsewhere and mimicking the linguistic distinction. These findings aligned with the earlier studies that showed a distinction between academic achievements at higher levels among instrumental musicians when compared to choral musicians. It is possible that these distinctions lead to lowered sense of accomplishment, resulting in a lowered accomplishment.

Many of the students in both the SMP and NSMP passing math groups considered themselves high in mathematics, with several referring to math as their favorite or best subject; however, not all enrolled in Advanced Placement Math classes, as did the majority of their counterparts in the Commended math groups. This suggests
that for student with passing TAKS scores, limited consideration was given to TAKS scores or math enrollments when forming perceptions of their own math ability. Again, this is seen in looking at student career choices that focus highly on mathematics, from all groups. Students with only passing TAKS scores and low to moderate MIDAS scores in Mathematical-Logical Intelligence reported an interest in pursuing careers related to mathematics, such as engineering. It was apparent that students ignored assessment data when self-determining their areas of strengths and weakness. It is possible that students who perceived themselves capable of achieving degrees that require high levels of mathematics may know something the tests and surveys are not showing.

Many of the Commended Math students defined themselves as mathematicians, not by their mathematical ability, but rather by the level of Advanced Placement (AP) math classes they have taken or in which they are currently enrolled. For Commended Math enrollments in AP, there were five from each CP groups. Both students choosing not to participate in AP math identified themselves as Hispanic. For those students with passing TAKS scores that did choose to participate in AP math classes, all students identified themselves as white, with two from the SMP group and one from the NSMP group. These enrollment numbers were in line with campus AP enrollment trends, but they do suggest possible inequities in AP math enrollments between ethnic groups. It was difficult to ascertain from the responses why the Hispanic students elected no AP classes, but from a counseling perspective, it is a clear signal to investigate further why this disparity occurs.

Only one student, from the NSMP group, self-referred as having low ability. This student readily acknowledged struggle in math. A second student from NSMP stated a
dislike for the subject as the reason for not taking a math class this year, since state graduation requirements had already been met; this student had moderate ability in mathematics.

What experiences do students have in the fields of music and mathematics?

The greatest distinction between the groups with regard to this question was family support and expectation of including mathematics and music in family life. Initial student perceptions revealed different levels of importance of music and math in family activities; however, more probing questions revealed that most early memories of both fields were related to family activities and experiences. Not surprisingly, students in SMP groups reported more musical experiences and a perception of greater musical importance by their families than students not participating in school music groups. However, based on student interviews, students from all groups reported family involvement in mathematics, though the involvement in supporting mathematics learning ranged from expectations to do homework to pointing out mathematics in real world contexts within the family interactions. In addition, not all students who received commended level on the mathematics test chose to participate in higher-level math courses. This may be due to several factors; however, it is worth noting that even though several passing math students reported they had a high interest in mathematics and family support, their ability as measured in MIDAS and TAKS, was consistent with their the decisions to not participate in advanced math classes. However, as previously stated, enrollment in advanced math courses or TAKS scores did not necessarily affect student perceptions of their math abilities.
Where do they perceive themselves continuing in the fields of music and mathematics?

The students in all groups showed a variety of interest in possible futures as related to mathematics and music. All but one stated a plan that includes a college degree and several indicated an interest in graduate school. Sixteen of the students, from across all groups, indicated a career that related directly to mathematics, and four indicated a field related to music. Other students saw no music or math in their futures, citing other interests or the demands of their particular career paths.

Musically, the SMP groups expressed a higher level of continuing active music pursuits than the NSMP groups. Nine of the twelve school music participants planned to continue music in some form, while three indicated that their musical involvement would end with the conclusion of high school. The three that indicated their musical experience would soon end all stated that they enjoyed their time in music but did not see a place for music in their futures, although they would want their own children to experience music. While the goal of high school music programs is not to encourage all students to major in musical fields, school music participation has the potential to instill a lifetime love and interest in music. In the sense, that music influenced the student’s lives in a way that they wanted their children to have the same experience, appears to have been accomplished this goal with all of the NSMP groups. Four of the NSMP group members felt that music would have no part of their futures, while the remaining eight felt that music would continue in their lives in the form of enjoyment or stress relief.

Mathematically, all students saw the value of math classes and acknowledged that they would have some aspects of math in their futures, either in the form of college classes or directly on the job, in the case of the student entering the construction trade.
Sixteen of the students expressed specific desire to enter a field related to math, including engineering, accounting, business and medicine. For students who expressed a feeling of dislike for mathematics or struggled, there was a common theme of taking the minimum requirement of mathematics in college. They seemed to view math as an obstacle to overcome. Four students felt their math had little place in their futures, citing primarily that their major relied little on mathematics.

One additional element that emerged was a lack of understanding in the students of what their level of mathematics would be in their future majors. Several students indicated that they believed math would play a small role in their future career choices, when they were in fact selecting fields that rely heavily on science or statistical analysis. One student entering the field of physical therapy even stated that he or she did not see math as much as science driving future studies. It appeared that this student failed to see any connection between mathematics procedures in a math class and those in a science class.

*How do they perceive the fields of music and mathematics relating to each other?*

The students from all four groups had a variety of opinions on the possibility of music and mathematics relating to one another. Almost three-fifths of the sample felt that there was some sort of connection, and another fifth felt unsure about the concept. These students cited three possible causes for a connection: a) brain connections between music and math, b) connections between the cognitive aspects of math that support musical meter, rhythm, and structure, or c) anecdotal evidence of musicians who were successful in mathematics. The remaining students who saw no connection generally stated a belief that music and math are too different to be related.
While the possibility of neuro-connections between the fields was not tested within the sample, and anecdotal evidence could not be supported or denied, the idea that cognitive connections existing between musical elements and mathematics did emerge. The cognitive aspect 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 the students that a stronger understanding of math supported this aspect of music.

Students from all groups expressed a belief that math supported rhythmic elements. Eight different students make this assumption of connecting math to music. A word search in NVivo also found that the word “counting” or some related variation appeared 23 times, and rhythms appears 13 times in responses to the interview question relating to the perception of such connection between music and mathematics. The following statements from the interview transcripts each reflect this:

- If you’re better at math, you can decipher rhythm,
- You have to know math to actually count out the measures and stuff
- You need math for numbering measures, counting time and all that kind of stuff
- Math is part of music I should say, not the other way around… but… um… especially with counting… even feeling it… beat… you know… counting can get complication in music
- 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
- I mean math has some part in music
- 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
- There are a lot of numbers in it [music]…. Maybe beats per minute
While most correlational studies have suggested that musical participation supports mathematics achievement, this finding suggests that the students in the sample perceived an opposite connection, where mathematics concept understanding supports musical understanding. 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.

The vast majority of the students indicated a preference for algebra, as noted in the interviews and the MIDAS. These students suggest that ability to solve equations by substituting numbers was easier than dealing with “shapes” and “three-dimensional figures.” The students who preferred geometry cited the opposite reasoning that dealing with shapes was far easier than substituting symbols, and dealing with equations was far more difficult. There was no obvious pattern in algebraic or geometric preference with a belief in a connection between music and math.

Gardner (2013) 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” (FAQ, What about the often noted connection between mathematical and musical intelligences?, ¶ 1). Students were asked about their ability to perceive patterns in both mathematics and musical selections. Mathematically, five of the six students in the SMPPM, NSMPCM, and NSMPPM groups reported they easily could spot patterns. In the SMPCM group, only four reported the ability to easily recognize patterns in numeric sequences. This is of considerable interest, as the previous literature would suggest that those in school music would have the superior
mathematic skills, especially those musicians in the commended math group. The student interviews revealed that perceptions of students in this study were contrary to the findings of existing correlational studies.

Musically, all of the SMP groups reported that they easily recognized musical patterns. In the NSMP groups, the students who could identify patterns spoke about structural and formal elements, such as repetition of the chorus. Though an ability to identify patterns in no way represented a definitive connection between music and math, where one influences the other, this is one shared element between the two fields.

If the students did show a natural tendency to gravitate toward algebra, it is possible that they viewed aspects of rhythm similar to linear equations. This could possibly explain the statements of students that they felt there were many elements of mathematics inside of music, specifically in rhythm. Algebra deals with three elements: variables, functions, and patterns. When viewed from this perspective, the connection seems to be students’ perception as both math and music embody these similar elements. In spite of this, the data did not bear out that students perceived that one was directly related and/or influenced the learning of the other.

Summary

Popular culture has created a system of beliefs that foster an idea that musical instruction directly fosters mathematical ability. Researchers have tried to explore this idea over the past decades using numerous approaches to find only correlational data that cannot provide any empirical evidence of actual causation. Rather than continue this tradition, this study sought to go directly to the students who were and were not
actively involved in school music programs from various levels of mathematics success to review their perspectives and experiences in the two fields.

Student experiences and perceptions were captured in the form of student interviews, test results, and the Multiple Intelligence lens, using the MIDAS instrument. Students had a wide variety of perspectives of themselves as both musicians and mathematicians. Those students with early experiences in music and mathematics had a higher perception of the importance of those fields, regardless of racial, gender, or SES differences in all groups. When comparing student perceptions to standardized test data, it was apparent that test data played little role in shaping student perceptions of themselves in the field of mathematics. However, the MIDAS data seemed to reflect a much more accurate match to student perceptions, especially when reviewing sub-scores of related skills under the intelligences.

MI theory suggests each individual has the potential to develop each of the multiple intelligences, with greater or lesser degrees in each. The theory goes on to point out that some people are inherently endowed with greater intelligence in one or more areas of intelligence, but not necessarily that one influences the acquisition of the other. Schools could then work to the strengths of each student. In identifying the MI profile of each student and providing it to them for their review, the researcher had an opportunity for open dialogue about the hopes, dreams, and aspirations of each of the students involved. All students reported being unsurprised by the findings of the MIDAS and felt that it reflected an accurate description of their perceptions of themselves in not only musical and mathematical fields, but in all the MI areas. In many ways, this unexpected finding may have been one of the most important contributions to the needs
of the students. The findings in this study supported Gardner’s original theoretical position that each person is endowed, and although the intelligences occupy the same brain space, the influence of one over the other was again, not confirmed.

Regarding standardized testing studies, the initial findings of this study reflected patterns matching the current literature, where students in music groups significantly outperformed the non-music participation peers. However, these data came only at the rawest level of analysis, using final scaled scores. When individual objectives of the TAKS were measured, the analysis revealed that in many cases the NSMP groups outperformed their SMP peers on specific mathematical tasks. This was further triangulated with student interviews and MIDAS scores to suggest that initial test score findings failed to capture accurate comparisons among the groups. Large-scale studies seeking to find correlations between music and math may be served by addressing specific skills in mathematics beyond just final scores. Further, the added elements of the student interviews provided an important missing piece in understanding the motivation and perception of students being studied.

The most important discovery from reviewing student perceptions came when reviewing student responses to the belief of a connection between music and mathematics. Fourteen of the sample agreed that a connection did exist, while five remained undecided on the topic. From these nineteen student responses that suggested a connection could exist, I postulate a common belief among these students that mathematical ability actually fostered musical behavior, especially in behavior related to counting, rhythm, and meter. This runs counter to findings presented in the literature review; however, none of the cited studies addressed actual student
perceptions of the relationship between music and mathematics. This suggests that further study is warranted to determine if this finding is an isolated event or perhaps more common that originally believed.

Recommendations for Schools

Based on the findings, several recommendations are warranted for teachers of music and math, as well as for school leaders, such as administrators and counselors. Students reported several perceptions that indicated a lack of full understanding. These related to the perception that instrumental music was somehow superior to vocal music, the role of AP mathematics, and the role mathematics plays in their future careers. Finally, more effort should be given to inform school music participants of opportunities to continue music participation in their post-secondary lives.

Students expressed a belief that school music participation implied involvement in instrumental music over vocal music. While this stereotypical statement is not uncommon, it may warrant vocal music educators’ better advocating for the level of training required for vocal performance. Further, it suggests a need to discern the root causes of this perception. Whether is a cultural belief of families, or that some teachers foster this difference between vocal and instrumental music, it should be addressed to validate the musical level of all genres of school music participation. It is incumbent on all music faculty to guide students to know that all forms of music performance require the same level of rigor to develop to a level of excellence. Recently in Texas, mariachi bands are making their way into school music curriculum: this adds another area for potential disparity in the performance demands. It would behoove school leaders,
particularly music performance leaders, to guide students to embrace these new school performance opportunities.

That some students identified their math ability solely on their AP enrollments should be disturbing for educators. If today’s students fail to see the value of the critical thinking skills learned in mathematics, and instead are focused on the GPA benefit of classes or the desire to be in the top 10%, then educators, administrators, and counselors have failed to provide relevant connections between mathematics and real world problems. It might be valuable for schools and universities who award AP credits for course replacements to reconsider the effect this practice has on students' mathematics competence. The pressure for career and college readiness standards seeks to raise the bar above AP into reasoned mathematics that prepares students for college mathematics, rather than with a single AP test score.

From a counseling perspective, beyond helping students find a college and gain acceptance into it, we must work with them to ensure they understand the implications of their degree plans and course requirements. The students seemed to show a lack of understanding of what classes they would be required to complete in their intended majors. This was most evident when reviewing the student perceptions of what level of mathematics would be required of them in their future college majors, particularly among the MP group that showed interest in engineering and medicine.

An additional area to address from a music teacher and counseling perspective would be to inform students of the opportunities to continue music participation at a collegiate level. Many post-secondary institutions offer some form of musical ensemble that is open to non-music majors. Some of these ensembles have scholarship
opportunities attached to them as well. The three SMP students choosing not to continue music involvement in their post-secondary plans all cited the belief that their intended major would be their primary focus while in college. Music teachers and counselors could point out that there are potential opportunities if these students changed their minds later. Further, the one NSMP student who planned to work with music in the broadcasting career may face challenges if trying to enroll in certain music classes. A lack of music foundation may lead to placement in developmental music classes that would require a tuition fee and not count toward any portion of a music degree.

Future Research

While the results of this study provided many answers to questions about how this particular group of students experienced and perceived music and math, many additional questions linger. Future research can easily build off these findings and address related topics. One possibility would be the examination of MIDAS, TAKS scores, and interview data using a neuro-scientific approach. These data provide a profile of the four groups, but with the added element of brain mapping during both musical and mathematic activities would add a layer of understanding not addressed in the current study.

Additionally, the 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. However, 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. This theme was not fully developed in this study, but further research would be valuable.

Other literature suggests that musical intelligence may also play a role in language development. The study could easily be adapted to include the English Language Arts portion of the Exit TAKS and combine the Linguistic Intelligence results of the MIDAS. All students in the sample completed all portions of the MIDAS, and scores for each of the intelligences and sub-scores were available, although they were not relevant to the current study.

Rhythm/meter/time instruction to beginning musicians could be another line of research. Since these are the elements that the students most readily identified as the source of a connection between music and mathematics, it would be a valued study to explore if these musical elements are taught as a function of special relationships or as a linear element. This may influence student perceptions of any connection.

A final direction to consider is the involvement in any school activity on academic performance. Perhaps the level of involvement and motivation plays a role in student academic performance, as it relates to performance on standardized measures. Previous motivational studies in music often fail to address students directly. As testing is often used in correlational studies, it is critical to include the opportunity to allow students to express in their own words their experiences. Drawing conclusions solely from test data may misrepresent the phenomenon. The experiences and perceptions of the teachers and students provide an important piece of data to explaining any aspect
of schools. Additional studies may investigate student involvement or measure levels of motivation in students; however, they should continue to utilize student perceptions as a data source.

This study sought to address the perceptions and experiences of students in music and mathematics using a combination of data from TAKS scores, Multiple Intelligences assessments, and student interviews. The combination of the three data sources together provided a much clearer picture of the daily lives of students as they interacted with both music and mathematics than can be obtained from test scores alone. Standardized test scores provide a look at student performance on a single day.

This research provided the opportunity for students to speak in their own words about their perceptions and experiences in music and mathematics. TAKS data and MIDAS information were useful in triangulating with interview findings that revealed the perceptions of the students who were living the high school experience, providing a new lens from which to view the questions of connections between music and mathematics. Contrary to most existing literature, the students who perceived a connection between the two fields saw mathematics driving a deeper understanding of the musical element of rhythm. Not surprisingly, students with rich backgrounds in music and mathematics had a higher perception of the importance of those fields.

Further, it became readily apparent, that test data often played a minimal role in shaping student perceptions of themselves in the field of mathematics. Finally, it became apparent that by listening to the experiences of high school students, there are many areas in which schools can grow, to meet the needs of their students. Schools
often fail to engage actual students when considering policy changes. The experiences of students should be a key element in these decisions.

As researchers, we can never experience or perceive the lives of students exactly as they live them; however, we can give voice to their perceptions and experiences by allowing them tell their stories. This study allowed students from four distinct groups to express their perceptions and experiences of music and mathematics as they related to their lives and their futures. Musically, students from all groups valued music. While those heavily involved in musical performances valued these experiences, those not involved in performance interacted with music though listening, attaching great value to their enjoyment. Mathematically, all students understood the value of math even if they do not all enjoy the subject.

As far as their perceived connection between the two fields, the students had mixed feelings. The students who did not believe a connection existed stated they felt the two fields were too different to be related. Those who did believe in a connection, or were unsure of one, cited the mathematic level of other musicians, the possibility of shared brain activation, or cognitive connection between the two fields. The perceived cognitive connection focused on rhythmic understanding, and it implied that higher mathematic ability supported the ability of musicians to decipher rhythmic patterns. This belief runs contrary to many existing correlational studies that suggest music involvement influences math skills development. Further study of a larger sample is needed to determine how common this perception is among high school students. The findings in this study demonstrated again that the question of the influence of one discipline over the other remains unanswered.
Personal Reflection

As a former music teacher, I had preconceived notions of the idea that music supported mathematical performance. I began my undergraduate study as the Mozart Effect began to draw national media attention. At this same time, Gardner’s Frames of Mind was celebrating its 10th anniversary, drawing renewed interest in the study of multiple intelligences. These two pieces resonated with me early in my educational career although I had a limited understanding of either.

It was difficult for me to understand the position of music education faculty who cautioned against the idea of musical study supporting mathematic ability. School administrators embraced this idea, and it appeared a perfect solution to protect music programs from budget cuts. Correlational studies were beginning to appear that suggested music students outperformed their peers on standardized math tests, which seemed to suggest a further justification for school music programs.

Even as I transitioned from the music classroom to a counseling position, I noticed trends that seemed to support the idea of music supporting higher academic performance. Currently, in my role, I play a large part in graduation ceremonies. I began to track the number of top 10% students graduating with music experience and found a much higher percentage of musicians in that group than participants in the other organizations in the school. I also took note of national tests, such as the SAT and ACT, and noted that more of the campus high scorers were enrolled in school music groups. Additionally, this mirrored my own personal experience, as a band student who graduated as valedictorian and rated in the top 5% of the national ACT scores. These ideas and experiences led to this study, as well as a desire to leave an impact on the
field of music education; even though I no longer teach in a music classroom, I still consider myself a music educator and strong advocate for the profession.

Exploring the data and listening to the perceptions of the students as they told their stories has provided an opportunity for me to see this topic in a new light. Further, it made me reconsider my own experiences in a way that would not have been possible without having such a catalyst. I began to question how I approach rhythmically complex passages as a musician, and found that I also approach them in linear fashion. This carried over into my own teaching. I specifically taught dotted-rhythms as an algebraic expression, where \( x. = \frac{1}{2} x + x \).

This study provided the realization that when studying student performance, we as an educating community fail to address the perceptions of the students we are trying to study. We often search for factors to explain the performance of certain students over others without speaking to these students directly. Confidentiality and parental permissions may make this a cumbersome process, but the results of speaking to the students would far outweigh the process of obtaining permissions needed.

A final unexpected finding of this study was in the experience of interacting with students. As a counselor for the school, I previously knew some of the students in the sample but not all. After the series of interviews, and asking the students to be the experts about their own experiences, I had a new level of interaction with the students. Several of the students, even those not assigned to my portion of the alphabet, continue to seek me out to share updates about their college admission process, to ask questions, or simply to say hello. The opportunity to talk directly with students about their interests is a powerful tool for building positive relationships with students,
especially when the students are allowed to be the experts about themselves. The opportunity to administer and interpret the MIDAS with these students showed how much they wanted to have these types of conversations. I believe that this type of interaction offers a perfect opportunity to provide college and career guidance that is truly meaningful to the students; one where they are the guiding the discussion about their aspirations, and the counselor is there to support them with information and tools to help those aspiration become realities.
On-Line Survey (Administer to all participants prior to Interviews)

MIDAS

- Multiple Intelligence Inventory

Survey Monkey/ Biographical Survey

- Biographical information (Family structure, educational level of parents/guardians, siblings, birth order)
- Educational information (have you always attended MISD, if not where else have you gone to school)
- Do you currently perform as a musician in any capacity?
- What music classes are you currently enrolled?
- If so, when did you start?
- Were you involved in MISD sponsored music programs in the past?
- If not, why?
- If so, for how long? Why did you continue/discontinue?

- What math classes have you taken? What are you taking now?
- In what math related, extracurricular have you been involved? Competitions? Clubs?
- In what ways do you currently use math outside of the school day?

- Testing Information (Have you taken the SAT or ACT? If not, are you planning to?)
  - TAKS results will be included
  - AP Scores will also be included if available

First Interview: Early History
1. Is education important? Why?
2. Was music/math an important part of your family activities?
3. What are your earliest memories of music/math as a child?
4. What level are you involved in music/math?

Second Interview: Current Experiences

1. Do you have any musical or math experiences or recognitions you would like to share?
2. Do you have any experiences in music or math that were negative?
3. How important is music? Math?
4. To what extent do you consider yourself a musician/mathematician?
5. 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?

Multiple Intelligence Specific Questions

Spatial
- What role do proportions play in solving mathematical problems?
- How easily do you identify other patterns in mathematic/numeric sequences?
- Can you easily estimate distances?
- How do you feel that you perform on problems that require you to substitute codes or symbols?

Logical-Mathematical
- What strategies do you apply to mathematics? Problem solving approaches?
- How well do you do when confronted with mathematical logic problems? (Word Problems)
- How well do you feel you perform in geometry or algebra? Why?

Musical
What experiences do you have in sight reading music?
What strategies do you utilize when approaching a new piece of music?
Do patterns easily appear to you in music?
What role do proportions play in music?
What experiences do you have in reading music notation?
Can you transpose music to another key?
Do you play/have you played a keyboard instrument?

Report student MIDAS results.

What is your reaction to these scores?
Are any of these areas a surprise? Why?
Do any of your perceptions of yourself as a musician or mathematician change after hearing these results?

Third Interview: Future Plans

1. What are you plans after graduation?

2. What role does music/math play in your plans?

3. If you have children of your own, how important is it/will it be for them to study music/math?

4. Do you have any additional thoughts about the notion that music and math might be connected?

5. What other information would you like to share regarding your experiences in music/math?

6. Has the information you learned about yourself through the MIDAS results changed the way you view yourself as a musician? Mathematician?
APPENDIX G

OUTLIERS
Through the identification of the 24 participants of the study, one additional student was interviewed as a NSMPPM student. It was later determined that this student had three years of high school music participation, but was not involved during her senior year. The purpose of the stratification selection was to create four distinct groups of similar experiences. This student did not meet the criteria, and was later excluded from the data set and replaced with another student meeting the NSMPPM criteria; however, her experiences and perceptions also provide a valuable understanding to the research questions.

The MIDAS showed the student had a high Musical Intelligence, but low in both Spatial and Logical-Mathematical. Though her TAKS scale score of 2363 outperformed both Low Math groups, she was below the means scores of both High Math groups. Her sub-scores in Properties and Attributes of Functions, Linear Equations and Inequalities, and Two- and Three- Dimensional Representations outperformed the means of all four groups.

It was through the course of the interviews that many of her perceptions between music and math become most clear. The student elected to not participate in music classes her senior year because she noted that she, “really had to focus on school and work this year...and I’m not going to pursue a career in music...even though I enjoy it, and even though I’m really sad I can’t do choir this year...I didn’t have time.” She did note that she would like to return to choral music either in college or in her adult life through community or church choirs, and that studying music would be very important to her future children. The student plans to major in education, and become an English or history teacher. She also recognized the importance of mathematics to her future,
specifically in regards to colligate coursework. Mathematic study will also have high importance to her children.

When asked about any connections between music and mathematics, she noted, “I think they are definitely connected... I don’t really see a question about it... just because...there is so much...I mean I think...math is involved in music...I don’t know if music is involved in math...but... math and music is definite....yes.” She further expanded on this idea by noting,

I agree with certain types of music, like I agree with band or orchestra instruments...I totally agree...I mean like I have tons of friends in band and they all... like music theory...is huge on math...it’s all... it’s a basic need for music, but like ...with choir...it could have been...it would have been easier with math, I think ... just because the scales...I think it would have made a little more sense, and I think it would have been easier to get a grasp on, but I don’t think it was essential to what I was doing.

The student was also able describe her approaches to new music in very technical musical terms, such as establishing the key and starting pitch, but also from the perspective of the Low Music groups. She expressed in that just listening to music, the lyrics carry the most meaning to her.

Like the majority of music students, she showed a distinctive preference to algebra. She reported that,

Geometry was the hardest math class ever...yeah, it was really difficult for me, and I think that’s just because the shapes really freaked me out, like I’m good with equations, algebra was all equations, and you know plugging this into this
and I can...I can understand that, and I can make sense of that... I focus on the numbers, and if I have geometry, there’s too much going on, and it just doesn’t make sense to me, and I just barely made it by in that class.

This response was similar to many of the High Music groups, in their view of algebra versus geometry.

Overall, this student provided a view into a student with a great deal of music training who was not identified as high in school music under the initial search criteria. The experience of these students or of students that study music outside of the school setting are often overlooked in many of the correlations studies that look at the standardized scores of musicians. This is another example of why student interviews are so critical in explaining social phenomenon in schools.
APPENDIX H

INFORMED CONSENT FORMS
Before agreeing to your child's participation in this research study, it is important that you read and understand the following explanation of the purpose, benefits and risks of the study and how it will be conducted.

Title of Study: Student Experiences and Perceptions in Music and Mathematics

Student Investigator: Jeff Cranmore, University of North Texas (UNT), Department of Education. Supervising Investigator: Dr. Jeanne Tunks

Purpose of the Study: You are being asked to allow your child to participate in a research study which involves student perceptions and experiences in music and mathematics. During interviews, the focus will be on your experiences and perceptions of both music and mathematics and their relation to each other. These interviews, along with your student records will be used to create a model of the experiences and perceptions of students in music and mathematics.

Study Procedures: Your child will be interviewed before and after their regularly scheduled classes. These interviews will last no longer than 90 minutes. They will be interviewed three times over the fall 2013 semester. Interviews will be arranged at a time and place convenient to them so as not to interfere with instructional time. Student interviews will be conducted at the time most convenient to the student, either before or after school, and will occur in an open area of the school, such as the library, cafeteria or counseling office.

Foreseeable Risks: Because your child is relating their own experiences and perceptions, there are no foreseeable risks are involved in this study.

Benefits to the Subjects or Others: This study is not expected to be of any direct benefit to your child, but we hope to learn more about the experiences and perceptions of students in regards to music and mathematics. This information may contribute to the field of multiple intelligences and teacher preparation.
Compensation for Participants: Participants will not receive compensation.

Procedures for Maintaining Confidentiality of Research Records: The confidentiality of your child’s individual information will be maintained in any publications or presentations regarding this study. A pseudonym will be used to represent both your child and the school district. All transcripts of observations and interviews will be maintained on the student investigator’s personal computer, which is fingerprint locked. Any paper forms will be secured in a locked filing cabinet in the student investigator’s personal office. All records will be kept for three years and then destroyed as per federal guidelines.

Questions about the Study: If you have any questions about the study, you may contact Jeff Cranmore at XXX-XXX-XXXX or Dr. Jeanne Tunks at XXX-XXX-XXXX

Review for the Protection of Participants: This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at (XXX) XXX-XXXX with any questions regarding the rights of research subjects.

Research Participants’ Rights:

Your signature below indicates that you have read or have had read to you all of the above and that you confirm all of the following:

- Jeff Cranmore has explained the study to you and answered all of your questions. You have been told the possible benefits and the potential risks and/or discomforts of the study.
- You understand that you do not have to allow your child to take part in this study, and your refusal to allow your child to participate or your decision to withdraw will involve no penalty or loss of rights or benefits. The study personnel may choose to stop your child’s participation at any time.
- You understand why the study is being conducted and how it will be performed.
- You understand your rights as the parent/guardian of a research participant and you voluntarily consent to your child’s participation in this study.
- You have been told you will receive a copy of this form.
Printed Name of Participant

Signature of Participant                               Date

For the Student Investigator or Designee:

I certify that I have reviewed the contents of this form with the subject signing above. I have explained the possible benefits and the potential risks and/or discomforts of the study. It is my opinion that the participant understood the explanation.

Signature of Student Investigator                               Date
APPENDIX I

STUDENT ASSENT
Student Assent Form

You are being asked to be part of a research project being done by the University of North Texas Department of Education.

You are being asked to participate in a research study that involves student perceptions and experiences in music and mathematics. During interviews, the focus will be on your experiences and perceptions of both music and mathematics and their relation to each other. These interviews, along with your student records will be used to create a model of the experiences and perceptions of students in music and mathematics.

You will be interviewed before and after your regularly scheduled classes. These interviews will last no longer than 90 minutes. You will be interviewed three times over the fall 2013 semester. Interviews will be arranged at a time and place convenient to you so as not to interfere with instructional time. Student interviews will be conducted at the time most convenient for you either before or after school, and will occur in an open area of the school, such as the library, cafeteria or counseling office.

If you decide to be part of this study, please remember you can stop participating any time you want to.

If you would like to be part of this study, please sign your name below.

__________________________________  ______________________
Printed Name of Student                    Date

__________________________________  ______________________
Signature of Student                     Date

__________________________________  ______________________
Signature of Student Investigator        Date
APPENDIX J

TAKS SCORES OF SAMPLE COMPARED TO ALL STUDENTS AND ALL MUSIC STUDENTS
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<th>Non-Commended Mean</th>
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APPENDIX K

DISTRICT APPROVAL FORM
McKINNEY INDEPENDENT SCHOOL DISTRICT
APPLICATION FOR EXTERNAL RESEARCH STUDY

APPLICATION

INSTRUCTIONS

The application should be typed or clearly printed in block type. Applications must have a brief summary of the study including: the research question(s), a description of the participants, a brief description of research methodology with copies of any and all instruments to be used (e.g., surveys, interview questions, questionnaires, checklists, observation sheets, psychometric assessment, etc.) attached, and a timeline. Completed applications (original copy) will be reviewed within seven days of submission and a decision rendered within 14 to 21 days of the request, if all documentation is provided. Incomplete requests will be returned, without review, to the researcher for completion. Research ethics will be notified by letter of approval or denial if it is determined that the research project does not meet district standards or protocols.

Under some circumstances, protocols may be approved contingent upon the provision of additional information ("approval pending" status). Under these circumstances, the additional information must be provided before approval will be given and data are collected.

All completed research applications for review must be forwarded to:
Office of Accountability
Attn: Geff Sanderson
McKinney Independent School District
#1 Dumas Street
McKinney, TX 75069

I. General Information (FOR STUDENTS ONLY)
(If you are not a student please continue to Section III)
Researcher's Name: Jeff Cranmore
Researcher's Address: 5000 Youpon
McKinney, TX 75071
Researcher's Email: jcranmore@mckinneyisd.net

II. School Information (FOR STUDENTS ONLY)
(If you are not a student please continue to section III)
School/Campus: University of North Texas
Department/Program: [ ] Arts/Technology [ ] Business
[ ] Education [ ] Math [ ] Science [ ] Other

Current Date: 4/9/2013
Proposed Start Date of Research: June 1, 2013
Proposed Completion Date of Research: November 1, 2013
Faculty Supervisor's Name: Jeanne Tanks
Faculty Supervisor's Email: Jeanne.Tanks@unt.edu
Title of Research Project: Student Perceptions of Musical and Mathematical Experiences

Would the information used in this research project be beneficial to the student?
[ ] Yes [ ] No

III. Required Attachments

1. Research Plan
   [ ] Students
   [ ] Parents
   [ ] Staff
   [ ] Teachers/Administrators
2. Please attach research questions.
3. Attach brief description of research methodology.

FOR INTERNAL OFFICE USE (ONLY)

Checklist:
[ ] Application [ ] Research Questions [ ] Participant Description [ ] Description of research methodology

Approved

Office of Accountability
Rev. 6/18/2011

Signature of Faculty Supervisor
Date: 4/2/13
COMPREHENSIVE REFERENCE LIST


