

**MIDDLE SCHOOL BAND AND CHORAL STUDENTS HAVE HIGHER
COGNITIVE FUNCTIONING AND ACHIEVEMENT IN MATHEMATICS**

by

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(Under the Direction of Rebecca L. Atkins)

ABSTRACT

This study was designed to fill a need to explore the hypothesis that students who participate in middle school bands and or chorus have higher math cognitive functioning than their non-music peers. Using the Measure of Academic Progress (MAP), this study identified specific math domains that middle school music students showed higher functioning than their non-music peers.

Participants were students enrolled at a middle school in Georgia with a total enrollment of 1066. Students continually enrolled in band or chorus from Fall 2020 – Spring 2023 were matched to non-music students for gender, F20 Overall Math score on MAPS, and math course enrollment. The total sample of students ($N = 156$) was non-music students ($n = 78$) and music participants ($n = 78$). Within music participants, students were in band ($n = 46$), chorus ($n = 24$), and some participated in both band and chorus ($n = 8$).

A two-sample *t-test* and repeated measures ANOVA was applied to data sets for each participant group and then compared to each other. The math scores of music participants (band, chorus, and both) were individually compared to non-music participants for the Fall 2020 assessment through the Spring 2023 assessment.

TIME was a significant factor for non-music and music participants. The non-music participant group's baseline F20 OVERALL score was higher than music participants; however, music participants outperformed in terms of mean average in OVERALL math and all domain tests over non-music participants. Band students ($p < .05$) outperformed non-music participants in the domain of Statistics and Probability (StPr). Operations and Algebraic Thinking (OAT) approached statistical significance ($p < .06$) within the band participants. Furthermore, the music participant group did not demonstrate summer regression as did non-music participants

Study findings were consistent with Helmrich (2010), band students outperformed chorus students and students participating in both band and choir. This finding is consistent throughout the study and supports student enrollment in music courses are showing benefits affecting math cognitive functioning from participating in music.

INDEX WORDS: Middle school music, Mathematics, Music and math, Music and math domain, Math cognitive function, Band and chorus academic achievement

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DEDICATION

I am dedicating this dissertation to my wonderful bride, Shirley, who has been by my side throughout this long process. For several years, she has unselfishly delayed continuing her own education so that I could finish my doctorate. Shirley, I love you.

To my amazing children, Madeleine and Reagan, I hope that your journey in music education becomes a lifelong commitment, always finding ways to keep music close to your heart. I love both of you!

Thank you to Rebecca and Skip for not giving up on me. It was a long road, but both of you were with me throughout!

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CHAPTER I: INTRODUCTION

As a middle school principal, I have observed various data sources that indicate that students involved in band and chorus in middle school academically outperform those who are not in band or chorus. This study provides the opportunity to collect quantitative data findings to explore this assumption I can share with my community in continued support for student involvement in music.

The correlation between music education and mathematics education continues to be a necessary topic of research not only for purposes of supporting the importance of music education as an academic content course, but to provide empirical evidence that a music education is an integral part of core academic content.

Participation in music education has been found to be associated with improved academic performance when compared to non-music education participants (e.g., Guhn, 2019). Improved academic outcomes supported through exposure and participation in music have been documented across academic contents in academic performance, reading, cognitive development, and mathematics. The research of Miendlarzweska & Trost (2014) showed skills developed during musical training often transfer to other skills and cognitive functions associated with learning. Evidence from research studies (Akhshabi, 2022; Bahr, 2004; Bahr & Christensen, 2000; Bergee & Weingarten, 2021; Boyd, 2013; Cox & Stephens, 2006; Helmrich, 2010; Vaughn, 2000; and Willis, 2016) have shown the study in music has an influence on math achievement and benefits

students at all ages. This research topic is limited, yet outcomes have been documented between performance in music and mathematics (Bahr, 2000).

With the present focus on improved academic outcomes in general, the body of research is limited when reviewing the correlation between music education and mathematics, more specifically, in specific domain standards. Music participation increases spatial reasoning and full brain processing, both of which are key cognitive areas that increase mathematical ability and aptitude (Cox, 2005; Shaw, 2009). In the Pk-12 setting, content standards guide teachers in identifying and focusing instruction on the essential knowledge and skills students should learn in each grade level for each content area. The domain level is the conceptual elements for middle grades mathematics and consist of Geometry, operation and algebraic thinking, statistics and probability, and real and complex numbers. The research of Akhshabi, 2022; Bahr, 2004; Bahr & Christensen, 2000; Bergee & Weingarten, 2021; Boyd, 2013; Cox & Stephens, 2006; Helmrich, 2010; Vaughn, 2000; and Willis, 2016 have provided results to support the correlation of mathematics and music; however, results were not provided at the lowest component domain to provide a specific conceptual idea that is correlated to a music education. This discussion can provide further understanding of the depth that music affects specific content domains to improve student understanding.

Need for the Study

The correlation between music and mathematics has shown a generalized correlation between the two disciplines. However, Boyd (2013) called for the need to explore how musical participation affects achievement in specific mathematical domains.

Furthermore, Willis (2016) suggested that further understanding of domain specific areas could impact the transfer of other cognitive domains.

McDonel (2015) suggested that additional research is needed to continue exploring the relationship between music learning and mathematics learning in early childhood. Future research might include larger samples of children and be focused on general processes of creating meaning as they relate to music, mathematics, and overall learning. Based on past literature and data generated in this study, music education supports student learning of cognitive functioning and achievement in mathematics. This relationship can be an influence on parents and students when choosing or not choosing to participate in a music ensemble in middle school.

Purpose of the Study

This study examines the impact of music participation on mathematics achievement at the domain level. Furthermore, this study will provide a longitudinal comparison of students who participate in a music ensemble with students that do not participate in a music ensemble and their subsequent mathematics performance at the domain level on a national assessment. A nationally norm referenced test is an effective measure of achievement in this area.

Research Questions

To research the effect music has on mathematic achievement, I developed the following research questions:

RQ1: Is there a difference in mathematical cognitive functioning between students that participated in a middle school music ensemble as compared to non-participating peers?

RQ2: Is there a difference in mathematical cognitive functioning between band participants and non-participating peers?

RQ3: Is there a difference in mathematical cognitive functioning between choral students and non-participating peers?

RQ4: Is there a difference in mathematical cognitive functioning between students that participated in both band and chorus and non-participating peers?

RQ5: Is there a specific mathematical domain where students who participate in band or chorus perform at a higher achievement level?

Overview of Methodology

This research was a study comparing mathematics cognitive functioning of students who participated in a music ensemble with students who did not participate in a musical ensemble. Specifically, the study examined mathematical domains and identifies specific domains supported by music participation. MAP performance scores were used from the study's participants in the fall of 2020 and the spring of 2023. All participants were continuously enrolled for 6th, 7th, and 8th grade years. Additionally, band and chorus participants were continuously enrolled in either ensemble.

A repeated measures ANOVA was applied to data sets for each participant group and then compared to each other. The music ensemble participants (band, chorus, and

both) were compared, individually, to the non-participant group for the fall 2020 assessment and then to the spring 2023 assessment.

Significance of the Study

Georgia students participate in a state mandated assessment which is both a criterion and norm referenced assessment. Due to the criterion component, the state assessment does not correlate with other states as a nationally referenced assessment. The Northwest Education Association (NWEA) provides the Measure of Academic Performance, given nationally and assessed three times per academic year. The results will show the longitudinal performance level of students who participate in music and their subsequent mathematics domain performance as compared to non-music participation and subsequent mathematics domain performance.

Furthermore, this study will provide data that not only examines the impact of music on mathematical domains but will provide the domain that is most impacted by music participation. This study is designed to fill a critical need for better understanding how learning in both music and mathematics lays domain-general and domain-specific cognitive groundwork for mathematical functioning. Providing the education community with data that can be used when aligning music with core mathematical curriculum and music's impact on learning.

Summary

Researchers have identified links between music education and numerous academic, social, and cognitive outcomes (Miendlarzweska & Trost, 2014), including

achievement in mathematics (Helmrich, 2010). There is considerable agreement in the literature that this condition is due to the wealth of assessment data. By conducting this study to determine the impact of music education on students' Measure of Academic Performance mathematics achievement scores, I have generated data to be used to promote the impact music education has on mathematics achievement. Specifically, data generated in this study may be used to support the promotion of music education participation at the middle school level when students are beginning their formal ensemble participation and experience.

Chapter 2: Literature Review

Federal Impact on Music Education

The role of music education as a component of a public education within federal law. Within the last twenty years, education has seen the development of a more accountability-based system with reauthorizations of the Elementary and Secondary Education Act (ESEA). In 2002, President Bush signed into law the No Child Left Behind Act (NCLB) which brought more awareness to failing schools and the need for schools to support all students, specifically students that need additional academic support due to disabilities, language acquisition, or for low-income families. Additionally, NCLB gave specificity to how federal funds were to be utilized on students and programs, including funds for arts' education.

The intent of NCLB was to foster accountability and develop a national platform for high stakes testing across the United States. Within the law, Congress adopted specific core content areas considered important for the child's development. The Arts were included as a core curriculum along with English Language Arts, Mathematics, Science, and Social Studies. President Bush sent a strong message that arts education is an important discipline for students to be engaged in and be able to further develop.

Although NCLB did promote more student performance-based discussions and brought a true awareness to the achievement gap that had been widening with previous reauthorizations, the arts suffered nationally as systems began to focus instructional

practices and funding on the need to support reading and math strategies to close the achievement gap. This was an unintentional outcome of the law. In 2004, the Secretary of Education sent a letter to superintendents emphasizing arts as a core content area to emphasize the importance of an arts education and its inclusion in the federal law reauthorization.

In 2015, President Obama signed the reauthorization of ESEA, Every Student Succeeds Act (ESSA). This reauthorization further included arts education as a part of a “well rounded education” (ESSA, 2015). Chris Woodside, the assistant executive director of the National Association for Music Education, said his organization lobbied to have music specifically listed in the definition, separate from other disciplines. "Having music called out in the definition of what they call well-rounded education provides us with clarity in making sure that, intentionally or unintentionally, you're not going to have music left out." (Zubrzycki, 2015).

Under the reauthorization, States were granted flexibility in funding use and were encouraged to promote creativity and innovation. The idea of adding “Arts” to Science, Technology, Engineering, and Mathematics (STEAM) was included within the law. Also, states were to develop new assessments approved by the federal government to bring about consistency of assessments across states. Over the last four years, the US DOE has offered more policy and implementation waivers to provide flexibility and not a one size fits all approach to the law.

The focus on reading and math has led states and school systems to focus more instructional time, financial resources, graduation requirements on reading and math. In Georgia, State Superintendent of Schools Richard Woods released a statement after

Georgia submitted its ESEA plan as required by the USDOE. “The model of standardized testing that arose during the No Child Left Behind years – end-of-year summative assessments that provide a one-day snapshot too late for teachers to provide remediation – is not working for our kids” (Woods, 2017, p. 1). Superintendent Woods said. Furthermore, he stated, “Georgia has a real opportunity, working with innovative leaders in our local school districts who are at the forefront of these efforts, to change the way testing works in our public schools. We have a chance to build a model of assessment focused on student learning. ESSA provides new opportunities for flexibility from the restrictive federal guidelines that govern testing in K-12 schools, and Georgia will aggressively pursue that flexibility for the benefit of our students” (Woods, 2017, p. 1).

With the arts inclusion as a core element to a well-rounded education, the level of importance was elevated; however, except for the addition of allowing federal funds to support these types of programs, no additional funds were designated to encourage states to create a minimal arts course exposure for all students in each of the state’s communities. If a state wanted to foster such a level of participation and exposure, state revenue and budgeting would have to be utilized.

In Georgia, state graduation requirements include the arts; however, courses that are also allowed can be a combination of other disciplines such as Career, Technical and Agricultural Education (CTAE), and/or Modern Language/Latin. This provision allows music students flexibility in that they can take additional courses within their music interests. Students must complete four additional electives which may or may not include music-based courses to earn the “pathway” certificate.

With changes to the approach to academic core content areas and developing research between music and other core content subjects, the arts define itself as an integrated support for student learning. As Scripp noted in his overview essay, “Research now offers a theoretical basis for, and growing evidence of the significant effects of learning shared between music and other measures of academic achievement” (Scripp, 2002, p.135).

Correlation of Music Participation to Generalized Academic Performance

Kinney’s (2008) research examined school music participation and test scores among urban middle school students on band participation and increased academic performance. Two cohort study groups consisting of sixth grade students ($n = 273$) and eighth grade students ($n = 215$) were compared utilizing a state mandated fourth and sixth grade criterion assessment that measured ability in Reading, Math, Citizenship, and Science. For eighth grade students, the assessment measured Reading, Math, Citizenship, Social Studies, and Science. Results showed “Sixth-grade band students scored significantly higher than choir students and nonparticipants on every subtest of 6th- and 4th-grade achievement tests” (Kinney, 2008, p.154). Additionally, “Eighth-grade band students scored significantly higher than non-participants on 4th-grade Reading and Math and every subtest of the 8th-grade achievement test except Social Studies” (Kinney, 2008, p.154). The limitations to this study included the use of standardized and criterion-based assessments applied to different grade levels. Additionally, the researcher found that the transient nature of urban school settings affected the study and further suggested added studies on transient student participation in music would be beneficial. Research

findings purported a lack of significant differences in achievement between music participants and nonparticipants in choir; however, band students were significantly higher academic achievers prior to enrolling in an instrumental ensemble. Participation in an instrumental ensemble had no adverse effect on test scores achievement. Kinney suggested participation in music may have been meeting a fundamental need of the high-achieving student.

The 2007 research study by Gouzousasis, Guhn, and Kishor focused on the predictive relationship between achievement and participation in music and core academic subjects for twelfth grade students in British Columbia. The researchers studied the extent to which music participation has an impact on academic achievement within three cohorts of students and their respective performance in English, mathematics, and biology. Gouzousasis states the following in support of his current research and future research on music participation {band} and academic achievement,

In sum, previous empirical and theoretical work suggests that arts-based learning has positive effects on students' academic and social development, and that there is an inherent relationship between the arts and various aspects of human development.

“However, there is limited research relating achievement in music courses and achievement in academic courses, and the field is therefore in desperate need of a greater and more diverse number of research studies that either confirm or reject these claims”

(Gouzousasis, 2007, p.3).

Additionally, Gouzousasis' research findings states,

The students who learned to play a musical instrument in elementary and continued playing in high school not only score significantly higher but were about one academic year ahead of their non-music peers with regard to their English, mathematics and science

skills, as measured by their exam grades, regardless of their socioeconomic background, ethnicity, prior learning in mathematics and English, and gender. (Gouzousasis, 2019, p.1).

Research data provided a positive correlation between music participation and academic performance. As noted, cohort group differences were consistent. Students who had participated in Band as an eleventh grader had higher achievement in mathematics, biology, and English. In mathematics, the difference was consistently more than 10 percentage points, with a moderate effect size. In general, eleventh grade band participants were associated with higher achievement in mathematics and biology. “Based on the results, we feel confident in stating that music achievement in Grade 11 is a predictor of academic success in Grade 12” (Gouzousasis, Guhn, and Kishor, 2007, p.87).

Southgate and Roscigno (2009) explored two questions related to the impact of music on childhood and adolescent achievement, searching to connect theories that link music and achievement, such as the sociological aspects of belonging to a group with common interests and goals. The first question related to students that participate in music in and outside of school, and to what extent is such involvement stratified by social class, race/ethnic, and gender status? The second question was do various forms of music involvement influence academic achievement? Researchers utilized the National Educational Longitudinal Study provided by the US Department of Education, which covered English Language Arts and mathematics. This study involved a sample size of over 25,000 adolescent aged students encompassing over one thousand schools. Southgate and Roscigno concluded that “As a mediator of educational outcomes, music involvement holds significance for both math and reading achievement” (Southgate,

2009, p.5). As demonstrated through research, music participation, inside and outside of school, is associated with academic achievement among children and adolescents.

In the 2016 research of dos Santos-Luiz, et al., students ($N = 110$) within a 7th grade grade-span were found to have had a positive correlation between music participation and achievement. This study was conducted twice over a three-year period with results of the longitudinal analysis revealing better academic performance by music students after controlling for prior academic achievement ($\eta^2_p = .07$).

Whitson, et al. (2019) evaluated after-school music programs that served low-income, urban children, and adolescents. The research examined academic and nonacademic outcomes through a mixed-method design. Research findings from an independent *t*-test revealed that lower-income students were rated higher on responsibility/discipline than higher-income students. Furthermore, students who attended the program more than three times per week were rated even higher.

The focus of Thornton's study (2013) compared statewide test scores in Pennsylvania for students participating in voluntary music classes or ensembles and students not involved in music classes or ensembles. Scores from 7,000 students in the 5th, 8th, and 11th grades were disaggregated from school systems within the state. Thornton found significantly higher scores were shown by students involved in voluntary music classes or ensembles as compared to students not involved in voluntary music classes or ensembles. Although the study has a survey size of $N = 7,000$, the study only represented 11 school systems. This population represents fewer than 6% of the districts originally selected for participation, which means the results may not be generalizable or applicable to other school districts; however, the data demonstrated a significant positive

impact on assessment scores by music participants. Thorton's point to music educators was that "the most appropriate and positive use of this data is to show that the time students invest in music participation does not seem to negatively affect PSSA (Pennsylvania System of School Assessment) scores.

The research study of Bergee and Weingarten (2021) focused on the relationship between music participation and reading and math achievement as measured by a music achievement test and the Missouri Assessment Program. Their research of students in 4th through 8th grades found a strong correlational relationship between music achievement and reading and math achievement.

The correlation that music has with academic performance has been researched with findings demonstrating that music involvement has a positive impact on academic performance (Kinney, 2008; Gouzousasis et al, 2007; Southgate and Roscigno, 2009; Whitson, 2019; Thorton, 2013; and Bergee and Weingarten, 2021). In the research, the studies of Kinney (2008), Gouzousasis et al (2007), Thorton (2013), and Bergee and Weingarten (2021) utilized state supported assessments. These assessments were given to specific grade levels such as 4th and 6th grades (Kinney, 2008), 12th grade (Gouzousasis, 2007), 5th, 8th, and 11th grades (Thorton, 2013), and 4th and 8th grades (Bergee and Weingarten, 2021). Although the data findings supported that student performance was higher with music participants than non-participants, the assessments were a mixture of standardized and criterion referenced which do not purport the same expected academic outcome. Kinney (2008) noted that his study in an urban setting was hindered by a transient population. For the Gouzousasis (2007) study, in British Columbia, provincial examinations may be taken up to three times. Since students selected the best score for

university applications, the researchers selected the best examination percent score for each participant as indicator of academic achievement in the subject.

Southgate and Roscigno (2009) provided support for music participation and higher academic performance through a sociological study. Researchers assessed patterns of music involvement and effects on math and reading performance for both elementary and high school students. A limitation to this study was a self-reported aspect from parents/guardians of concert attendance and as the researcher indicated “This indicator likely captures not only household cultural capital in some generic sense, but also the more general appreciation of music by parents and the likely introduction, appreciation, and use of music in the household” (Southgate and Roscigno, 2009, p.12).

The potential impact that low socioeconomic status and the potential impact on music and higher academic performance was the focus of Whitson’s (2019) research. Whitson suggested that the positive benefits for participation in these programs {afterschool music and arts programs} include academic outcomes as well as nonacademic outcomes that are related to overall well-being, interpersonal skills, and academic achievement.

The formal study of the relationships between music participation and academic performance is a valuable and valid measure. As reported, the impact findings are provided through multiple measures.

Achievement as Reflected in Reported Content Grading

Content grading is reflected within a student’s transcript of academic performance, outlining a student’s determined grade point average, numerical grade, or

alpha numeric grade. The process of determining a student's grade for a class is not a consistent process if each teacher is allowed to provide non-standardized assessments that may reflect bias and or subjectivity. Although each state has a defined grade level curriculum, consistency in grade level content grading is compromised as teachers select formative and summative assessments for determining a student's performance.

“Our findings suggest that learning a musical instrument during childhood and adolescence are associated with school grades which are one sixth of a standard deviation above those of musically inactive students” (Hille & Schupp, 2014, p.57). dos Santos-Luiz et al. (2016) reported, “In addition to the greater academic achievement of music students, we also noted that these students' academic performance remained constant over time (from the seventh to the ninth grade), while non-music students demonstrated a significant worsening during the same period of time” (p.524). Hadlock (2018), further explored the relationship between musical training and academic achievement to identify the overall effectiveness of musical training on academic performance for three different age groups: elementary, secondary, and college level students. Results for secondary students, inclusive of middle and high school level, found that musical training correlated with an increase in academic performance, especially for comprehension and memory.

Cox and Stephens' correlational methodology research on the effect of music participation on mathematical achievement and overall academic achievement focused on high school students, comparing students with limited music credits to students with no experience. “The findings provided no statistically significant difference in the mean math grade point averages (GPA) or their mean cumulative GPAs (Grade Point Averages)” (Cox, 2006, p.762). Students were split into two groups based on the number

of music credits earned. Students with two or more music credits per grade level were placed into Group A. This group included ninth grade, tenth grade students with four or more music credits, eleventh grade students with six or more music credits, and twelfth grade students with eight or more music credits. The remaining students were placed into Group B. “Group A students performed better than group B students. However, the differences were not statistically significant” (Cox, 2006, p.762). Additionally, research findings through scatter plots indicated a slight upward trend in Grade Point Averages (GPAs) as the number of music credits increased. Lower GPAs were nonexistent as earned music credits increased. As noted by Cox and Stephens (2006), the final indicator of college readiness showed that students engaged in music participation were more prepared for college. Scores on the College Entrance Board Exam (1995, as cited in Cox & Stephens) showed that students, who had some form of music performance on their transcript, scored 39 points higher on the mathematics section of the Scholastic Aptitude Test (SAT) in comparison to those students who did not participate in music. Similarly, students who had music performance and appreciation courses listed on their transcript scored 46 points higher on the mathematics portion of SAT in comparison to those who did not have music performance or participation.

Grading policies are implemented inconsistently throughout content areas, education levels, regions, etc. Grades can have a scoring weight depending on the emphasis that a teacher and or school system require for specific grades which can comprise of summative, formative, interval, and diagnostic forms of assessment. Summative assessments are designed to measure if a student has mastered all their grade-level content. Formative assessments assist educators in understanding if a child is

learning a concept being taught to them. Interim assessments are given at various intervals throughout the year and are designed to assist educators obtain a detailed snapshot of how students are growing during a given school year. A diagnostic assessment is given to students before instruction to identify where they may have skill gaps.

Using academic grading (Hille and Schupp, 2014; dos Santos-Luiz, 2016; Hadlock, 2018; Cox and Stephens, 2006); Brookhart, 2019) to determine music's impact on academic performance is inconsistent and problematic. "Early researchers attributed the inconsistency in teachers' grades to one or more of the following: the quality of students' work, the criteria for evaluating the work, teacher severity or leniency, differences in tasks, the grading scale, and teacher error" (Brookhart, 2019, p.1). Although Cox reported an upward trend in GPAs as music credits increased, applying grade points without consistency of practice and standardization can demonstrate results that cannot be applied consistently.

Executive Functioning

In considering music participation and academic achievement, research has shown that aspects of music have a positive effect on executive functioning. The constructs of music lend students access to both sides of the brain, creating a stronger accessibility for visual memory, working memory, attentive focus, and cognitive development.

The 2011 study by researchers Goerge and Coch addressed the hypothesis that previous music training is related to improved working memory among college aged students. The research compared non-professional musicians with multiple years of

experience to non-music participants with no to little music participation. An ANOVA with group (musician, non-musician) and subtest (Abstract Visual Memory, Memory for Location, Digits Forward, Letters Forward, Digits Backward, Letters Backward) was used to compare scaled subtest scores between groups. A main effect of group ($F(1, 30) = 8.62, p < .01$) indicated that musicians scored higher than non-musicians across subtests (subtest \times group, $p = .858$). The data found that music training is related to improvements in working memory, there were moderate positive correlations between years of music training across groups and average visual memory task scaled scores ($r = .398, p < .05$), Digits Forward scores ($r = .365, p < .05$), Digits Backward scores ($r = .393, p < .05$), and the average of executive memory task scaled scores ($r = .371, p < .05$).

The scope of Goerge and Coch (2011) was limited, having only 32 participants. Additionally, as the researchers noted, criticism may exist due to their interpretation of the results focused primarily on working memory and the ability of the music-participants having greater ability to focus attention than non-participants. Also, researchers noted that intelligent quotient (IQ) may play a role in the data results and the need for further study of an intelligence quotient and working memory of musicians.

Their findings supported long-term music training in non-professional musicians is associated with improvements in working memory, in both the auditory and visual domains, and the potential for improvements in attention. Musician participants outperformed non-musicians in visual, phonological, and executive memory subtests. Additionally, musicians demonstrated faster auditory and visual working memory

representations and efficiency in working memory resources to process auditory deviant stimuli.

Findings from the quasi-experimental study on the impact of music on working memory by Roden et al. (2014) suggested that participation in musical training is a benefit in the areas of cognitive functioning that relate to auditory information processing. The study, ($N = 50$), uses two groups of children, ages 7 and 8 years old, with one group receiving music education for 45 minutes weekly in instrumental music and the other group receiving extended natural science training.

An experimental research study conducted by Holochwost, Propper, Wolf, et al. (2017) focused on the impact music education had on improved academic performance and executive function. The study findings provide a significant correlation between music education participation and academic performance. Results indicated that students in the music education program scored higher on standardized tests, earned better grades in English language arts, and math, and exhibited superior performance on select tasks. The study further reports findings that students in multiple years of music participation showed superior performance in executive functioning tasks and short-term memory. For the effect that this study has on the future studies of the correlation between music education and academic performance “Considered in the context of this literature, the present results suggest that music education may foster the cognitive capacities that underlie academic achievement, or, at the very least, improve the ability to take tests that measure that achievement” (Holochwost, 2017, p.159).

Miendlarweska and Trost (2014) reviewed literature on musical training and its effect on brain structure and function in adult musicians. Further, their study examined

transfer effects on various cognitive functions as compared to other long-term practice activities in childhood. The researchers emphasized the important and overlooked role of other factors that could contribute to the observed cognitive development, considering structural and functional brain differences between musicians and non-musicians.

Miendlarweska stated “the mechanism of rhythmic entrainment and social synchrony as factors contributing to the plasticity-promoting role of musical training that is unique to music education” (Miendlarweska, 2014, p.1).

Academic achievement is a factor that enhances essential skills as demonstrated by studies on executive function (Goerge and Coch, 2011; Roden, 2014; Holochwost et al, 2017; Miendlarweska and Trost, 2014); where the data indicated that music participation led to improvements in executive function; specifically in attention switching and inhibitory control.

Achievement as Reflected in Reading Competencies

Music participation has a positive effect on reading competencies. The available research examined various aspects of reading and how the two are correlated to support academic achievement.

Babo (2004) investigated and clarified the relationship between instrumental music participation and academic achievement through multiple regression analysis. Analyses suggested that instrumental music participation related significantly to explaining the variance in language arts scores when controls were entered for intelligence quotient (IQ), social emotional studies (SES), and gender. Intelligence quotient is determined to be the strongest contributor to all standardized scores. Further

analyses suggested that instrumental music participation contributes significantly to the variance for both math and language arts scores when controlling for gender and social emotional studies. SES was found to have a significant impact on all test scores, whereas gender (male) only contributed significantly to one set of standardized math scores. “Results from this study appear to suggest that instrumental music participation does have a positive relationship to a student's academic performance with the strongest association occurring in reading and/or language arts” (Babo, 2004, p.23).

The researcher, Butzlaff (2000) examined whether instruction in music may help children require reading skills. The meta-analysis research examined correlational and experimental designs. Within the body of research, Butzlaff found twenty-four studies that are correlational designs and six experimental designs. The studies for the correlational model were from the 1980's to late 1990's. For the meta-analysis model, the six studies represent the period from late 1970's to early 1990's. The meta-analysis of the correlational studies showed that students studying music do in fact have significantly higher scores on standardized reading assessments. The experimental design of the six studies, in contrast to the correlational studies, produced results that are neither large, robust, nor reliable.

Cogo-Moreira et al (2013) examined the impact of music participation and academic achievement in Portugal. Cogo-Moreira studied the effectiveness of music education to improve reading skills and academic achievement among children with reading difficulties. The study spanned students from the ages of eight to ten with a sample size of ($N = 235$). The experimental research included five schools, randomly selected, to incorporate music classes ($n = 114$), and five schools selected as control

groups ($n = 121$). Two different methods of analysis were used to evaluate the effectiveness of the intervention with one as an Intention-To-Treat (ITT), and the other Complier Average Causal Effect (CACE) estimation method, which accounts for compliance. The results of the ITT did not demonstrate a significant impact with one effect existing for the rate of correct real words read per minute; however, the CACE results show more promising effects were observed in terms of the rate of correct words read per minute ($\beta=13.98, p < .001$) and phonological awareness ($\beta=19.72, p < .001$).

The two studies (Babo, 2004 and Cogo-Moreira et al, 2013) and meta-analysis (Butzlaff, 2000) provided data results that support music's impact on reading and reading competencies. Babo's (2004) study of the relationship between instrumental music participation and academic achievement suggested that instrumental music participation has a positive relationship to a student's academic performance, with the strongest association occurring in reading and/or language arts. The multiple regression analysis was designed to account for gender, socioeconomic status, and intelligence quotient. The results from Cogo-Moreira et al (2013) linked music with supporting reading skill sets through word accuracy, in-text accuracy, and phonological awareness. The findings as noted by Cogo-Moreira were statistically significant; meaning that children who received the music intervention read 13.98 more correct words per minute than children who did not receive the music intervention. One factor to consider when comparing this study to contemporary studies between music and reading achievement in the United States is the study was conducted in Portugal.

Based upon the findings of Butzlaff (2000), music and written text involve formal written notation which must be read from left to right supporting student reading

motor skills. Additionally, reading requires a sensitivity to phonological distinctions, and skill in music listening requires a sensitivity to tonal distinctions.

Achievement as Reflected in Mathematical Competencies

As a precursor to discussing what research has provided on the correlation between music and mathematics, there must be an acceptable understanding of what academic achievement is at the middle grades level, specifically as it relates to content standards. Achievement is defined as the current level of a student's understanding. The federal government within the Elementary and Secondary Education Act (ESEA) provides a broad definition that achievement is the percentage of students at a school that their learning currently meets or exceeds grade level standards. For Georgia, the definition mirrors the federal understanding of achievement. Within each level, there are specific standards or goals that a student must successfully demonstrate to be considered grade level achievement. Standards are evaluated based on student performance and curricular programs, emphasizing gathering information to base subsequent instruction. The standards also acknowledge the value of gathering information about student growth and achievement for research. Achievement was assessed through consistent and comprehensive assessments. However, these assessments may be collected in a variety of ways (e.g., test, standardized tests, projects, assignments, essays, observations, self-assessment, peer assessment etc.) thus, creating the challenge of defining what is truly academic achievement. For this study and the remainder of this study, academic achievement is the measurement of academic content covered within a specified grade level.

Research has demonstrated the existence of a strong correlation between music and mathematics. As noted in the research, a limited number of studies have focused on different elements of mathematics and the positive correlation with music participation.

Miksza (2010) found in a longitudinal study on participation in high school music ensembles and extra-musical outcomes not only supports the impact that music participation has in academic core subjects, but further investigated the impact that music participation has on community ethics. Miksza reported that “music participation was a significant ($p < .001$), positive predictor of math achievement scores indicating that those in music had higher math achievement scores than those not in music” (Miksza, 2010, p.17). Furthermore, the data were collected from 12,160 high school sophomores representing 603 high schools across the United States, providing a large sampling size. In addition to the impact that music participation had on mathematics, the study provided significant evidence that “students in high school music ensembles are significantly more likely to (a) have higher standardized math achievement scores, (b) be more concerned about community ethics (i.e., building friendships, helping others, correcting social inequalities), and (c) be more committed to school (i.e., less late arrivals, less cuts/skip” (Miksza, 2010, p.22). Research studies of extra-musical outcomes have not been extensively investigated with data sets that represent broader populations of students. The results of this study contribute to the generalizability of such relationships.

McDonel (2015) investigated the connection young children make between music learning and mathematics learning and if there is a relationship between young children’s emergent rhythm development and emergent numeracy development. McDonel utilized a mixed-methods design and quantitative data were embedded within a primarily

qualitative analysis. Preschool children in an intact class were observed for 11 weeks at predetermined points during spring 2012. Data results provided a correlation of music aptitude, rhythm achievement, and numeracy achievement scores with supportive evidence regarding the relationship of early rhythm and early mathematics development.

In a 2022 study by Akhshabi et al., two schools in Tehran participated in an investigation of music and melodic teaching's impact on the math learning progress of third-grade elementary school students. The research adopted a quasi-experimental design with the experimental group learning concepts using music and melodic teaching while the control group learned concepts using the lecture-based teaching method. The data instruments that Akhshabi, et al., used are a demographic information questionnaire, mathematical motivation questionnaire, a progress test, and an achievement test. Results of covariance analysis showed that teaching math using music and melodic methods has a significant positive impact on elementary school students' math learning (70.8%) and more motivated learning (86%).

Participants received assessments for intelligence quotient (IQ), socio-economic background and musical background to determine any differences in variables. The Cattell's Culture Free Intelligence Test by Weis (2006) was administered to measure intelligence utilizing four subtests: series, classifications, matrices, and typologies. Additionally, seven subtests from a standardized and computerized working memory battery were designed to assess phonological loop, visuospatial sketchpad, and central executive function. After the pre-assessments, participants were exposed to the interventions in the fall of 2009 and continued through the spring of 2011. Data results showed that the group receiving music training scored significantly higher than the

natural science training in assessments addressing phonological loop components. The music group showed significant increases in the One-Syllable Word Span Test scores over all time points, while the natural science group showed no such improvement. Additionally, the music group demonstrated a continuous improvement in the Nonword Recall Test. Natural science children only showed improvement in the first phase of the study, but no further increases in their performances thereafter. Taken together, findings suggested that the music group benefited from instrumental music training. Specifically, the data from the music group showed an increase of 17% in rehearsing and 15% in storing phonological information. Finally, the data suggested a positive effect of music training on the central executive (Counting Span Test and Complex Span Test) in the underlying working memory. This finding corroborated Moreno's et al (2011) study on the effect of executive function for instrumental music training, which is associated with changes in brain plasticity.

Vaughn's (2000) three meta-analyses incorporated correlational studies, experimental training studies, and background music studies. The research focused on the hypothesis that, "if music is based on mathematical principles, and if an understanding of music requires some understanding of these principles, then it is possible that music education can lead to an improved understanding" (Vaughn, 2000, p.149). The general methodology of the meta-analysis was a compilation, after an initial electronic database search, studies that included advocacy, program descriptions, award/reward, and memory aids, were eliminated as they did not meet the primary focus of effects of music instruction. The final selected studies examined eight correlational studies examining whether students who chose to study music have high math outcomes, five experimental

studies testing the hypothesis of music instruction causes mathematical improvement, and twelve experimental studies tested the hypothesis that academic performance on math assessment is facilitated by background music.

The meta-analysis of the correlational studies comprised national standardized math assessment performance data of 3rd through 12th grade students from the period 1950 - 1999. The total sample size of the twenty correlational studies was $N = 5,788,132$. The selected studies examined mathematical performance and music training for 1 - 6 years.

Utilizing the Stouffer's Z test yielded a high significant ($Z = 192.59, p < .0001$), indicating that the findings can be generalized to new subjects selected for the study. The T -test yielded ($Zr = 7.527, p < .0001$), indicated results can be generalized to new research studies. The overall positive effect size ($r = .15$) was significant with a 95% confidence interval. As the research further examined only College Board results, the effect size was quite significant with ($\chi^2 = 6378, Df = 9, p < .00001$). Vaughn noted that the effect sizes increase steadily with each year of music participation. For discussion, Vaughn reported that the meta-analysis demonstrates an overall modest positive association between voluntary study of music and mathematical achievement. Furthermore, Vaughn stated that, "The meta-analysis demonstrates a modest positive association between the voluntary study of music, on the one hand, and the mathematical achievement, on the other hand" (Vaughn, 2000, p.154). Although this claim is consistent with the positive effect size, further research studies in experimental training is necessary.

The experimental training studies that Vaughn (2000) researched encompassed six experimental designs. Participants were given instruction in vocal or instrumental music for at least four months to two years then assessed math skills. As with the correlational studies, the period ranged from 1959 - 1997. The total sample size is $N = 357$. The participants' ages range from preschool to elementary age. The design consists of two truly experimental studies where individual students were randomly chosen for the music or control group. The other four studies were quasi-experimental in that students were assigned in groups at the class level or were a part of a convenience sample group. The music and control groups of the four studies had the potential of sampling students with similar grade point averages, social class, musical experience, etc. due to the class assigned. A standardized math achievement assessment was utilized for three of the studies. The additional three were math assessments developed by the researcher.

Results of the studies provided a weighted mean effect size of $r = .16$, indicating larger studies have higher effect sizes. The Stouffer ($Z = 2.62, p = .004$) indicated that the positive effect size was not likely due to chance. The T-test showed a 95% confidence interval ranging from .03-.23, indicating that similar tests will not result in a mean effect size of zero or below.

Vaughn noted that within the studies, the study that produced the highest effect size had the experimental and control groups receive the same instruction in math and the experimental group received music instruction. Vaughn's study suggests that music instruction combined with mathematical instruction focused on spatial-temporal thinking can lead to improved math performance.

Based on previous research that demonstrated musicians use similar brain functions to process music and complete algebra problems, Helmrich (2010) hypothesized that students who participated in a music program, instrumental or choral, would perform better on tests of mathematical ability. Helmrich provided noteworthy evidence supporting the connection of band participation and mathematics, specifically in the domain of Algebra. Within the data from six secondary schools in Maryland, the researcher found a significant mean difference in algebra achievement occurring between the instrumental {band} and neither-instruction {non-music participants} groups ($SD = 13.34, p < .001$). Furthermore, the results found a greater level of significance within the African American population participation in ($SD = 18.87, p < .001$). This study involved a sample size of 6,026 students.

To investigate inter-domain transfer between mathematical skills and musicianship, Bahr and Christensens' (2000) research of 85 students in Australia investigated the nature of problem-solving skills between two dissimilar content domains. All students were enrolled in a math extension course regardless of students' mathematical thinking. Students were given a musicianship rating scale assessing knowledge of, pitch and tonality notation, keys and scales, intervals and harmony, time and rhythm, and terminology. Additionally, students were given a mathematics assessment designed to assess mathematical understanding of concepts taught in the first semester of their 10th year of formal education. The math assessment covered concepts in number handling; algebraic expressions involving substitution and elimination; three-dimensional shape visualization, abstraction and rotation or reflection; graphing; and completion of patterns. Data results demonstrated a significant linear trend on assessment

items with deep structural overlap ($F(1,61) = 3.91, p = 0.026$). In contrast, the relationship between musicianship and non-overlapping items on the math assessment was not significant ($F(1,16) = 2.28, p = 0.068$). According to Bahr, “The study supports existing literature which suggests that transfer occurs as a result of deep-structural similarity of domains” (Bahr, 2000, p.195). Results further indicated that transfer could occur without explicit instruction designed to support transfer of knowledge. For educators, the research supported the idea that musical training promotes mathematical performance relative to their peers.

Curt Willis’ 2016 dissertation *Impact of Music on Mathematics Achievement* studied the correlation between music participation and multiple year mathematics achievement of middle grades students enrolled in a private school. Willis utilized the total math scores from the Iowa Assessment to determine the impact of music education on students’ math achievement, while controlling for factors such as students’ sex and socioeconomic status.

Results of a *t-test* demonstrated there were no differences in baseline scores between the group of students who received music education and the group of students who did not receive music education. Results of a regression model for 2013 - 2014 showed that music education was a significant predictor of math growth scores ($p = .015$). Results of a regression model for 2014 - 2015 indicated that only socioeconomic status was a significant predictor of math growth scores ($p = .039$). Regarding limitations to this research study, Willis noted that, “Although this study was limited by the use of a convenience sample and the potential impact of both students’ prior experience and

mediating factors on the relationship between music education and student achievement in math, this study is valuable” (Willis, 2016, p.75).

Joshua Boyd explores *The Relationship between Music Participation and Mathematics Achievement in Middle School Students* (Liberty University, 2013). Boyd found that, “there was a positive correlation between students’ participation in music and their achievement in mathematics” (Boyd, 2013, p.3). Boyd utilized the Georgia Criterion Competency Test’s Mathematics assessment as well as a student music participation survey. Within the data analysis results, Boyd found that, “...Group 3, which had 3 years or more, showed a greater increase in mathematics CRCT (GaDOE, 2011) scores than the groups with 2 or less years of music participation” (Boyd, 2013, p.96). His findings supported a strong correlation between years of music participation and mathematics achievement over a period.

Music participation and instruction, at all levels of education, correlates positively to mathematical understanding. Research provided substantial evidence supporting the claim (Miksza, 2010; McDonel, 2015; Akhshabi et al, 2022; Vaughn, 2000; Helmrich, 2010; Bahr, 2000; Willis, 2016; and Boyd, 2013) through a variety of studies.

The studies of McDonel (2015) and Akhshabi (2022) set groundwork for music instruction support of mathematical understanding at the elementary level. Early adolescent integration of music focused on rhythm, melodic dictation, and musical aptitude enriched student understanding of numeracy. Additionally, Akhshabi’s findings further reported that utilizing music as an intervention to learning mathematical concepts promotes motivated learning among adolescents.

Secondary mathematics instruction (Miksza, 2010; Helmrich, 2010; Bahr and Christensen, 2000; and Vaughn, 2000) provided meaningful results that support musical training, and the impact music has on mathematics. In the Miksza (2010) study, students in high school music ensembles were significantly more likely to have higher standardized math achievement scores, more concerned about community ethics, and more committed to school. This study provided evidence of academic benefits of music participation and the social humanistic characteristics and traits acquired. Bahr and Christensen's results indicated that in the domains of mathematics and music, students who had training in musicianship performed better than students with no musical training in mathematical areas of structural overlap. However, they did not perform better in areas without overlap. A positive correlation between the voluntary study of music and mathematical achievement was the findings of the meta-analyses of Vaughn (2000). The findings also included that music training was effective at improving mathematics performance.

Willis (2016) and Boyd (2013) focused on respective state assessment results to demonstrate the impact that music participation has on mathematics at the middle school level. In the study by Willis, results indicated there was an association between music education and student achievement in math, particularly student achievement on the Iowa Assessments math test. Willis noted that his study was the only, at the time of publication, resource for the Iowa Assessment used for music comparison. The Boyd (2013) findings demonstrated that, for students who participated in music for 3 years, there were stronger correlations with higher mathematics scores on the Georgia CRCT Assessment than for students who participated in music 2 years or less. This was an

indication that the strength of the correlation between years of music participation and mathematics achievement strengthened over time.

Summary

The body of research has substantiated the relationship between music and academic achievement. Literature has identified consistent links between music and other academic domains. These links were found among young children (McDonel, 2015), middle school students (dos-Santos-Luiz et al., 2016), and high school students (Cox & Stephens, 2016). Bamberger and diSessa (2013) argued that if music is approached as a response to coherent musical structures, it can serve as a context for the eliciting and perceiving of mathematical ideas. In reading, experiences with music have been shown to help students from low socioeconomic backgrounds retain an age-normal level of reading performance better than with a matched group of students who did not receive these experiences. "Perhaps music discrimination at a more micro level -- pitches, intervals, meters -- shares a cognitive basis with certain patterns of discrimination in speech. Similarly, the more macro skills of modal and tonal center discrimination share some psychological or neurological space with aspects of math cognition." (Bergee, 2021, p.416). This summary statement by Bergee (2021) is an example of the available research findings of the link between music and academic achievement. Although his research demonstrates a strong connection, more research that explores the actual connection is needed.

Goerge and Coch (2011) executive functioning research data suggested that music training is related to improvements in working memory, there were moderate positive

correlations between years of music training across groups and average of visual memory task scaled scores. Additionally, Roden, et al. (2014) suggested that participation in musical training is a benefit in the areas of cognitive functioning that relate to auditory information processing. Through meta-analyses of experimental studies, Vaughn (2000) revealed that active music instruction, in which students listen, sing, make music, and move responsively and rhythmically to music, often through games, appears to enhance pre-K and elementary-aged children's spatial temporal performance and mathematics skills.

The Need for Further Research

Boyd and Willis' research on the correlation between math and music participation utilized multi-year state assessment data to demonstrate the positive impact music has on mathematics. Music participants' performances on the identified state assessments were analyzed at a generalized level. Although both studies' data supported their hypothesis, a study that further defines the correlation at the domain concept level in mathematics is needed. As Boyd states in chapter five of his dissertation, "In a future study, one could compare how music participation affects individual domains of mathematics achievement or how it affects certain mathematical domains over others" (Boyd, 2013, p.119).

Willis' suggests for further research, "Although school efforts to improve student outcomes can be successful when they are focused on improving teaching methods (Hiebert & Morris, 2012), teacher productivity (Adelman & Taylor, 2011), and building school/community partnerships (Sheldon, Epstein, & Galindo, 2010), based on the

literature and the data generated in this study, the potential for music education to be used as a means of improving student achievement should not be overlooked” (Willis, 2016, p.75). Additionally, Willis noted the importance that music education can have on closing the achievement in mathematics. More research must be conducted that provides data as to the association that music has on specific concepts and standards in mathematics to demonstrate more specifically what aspects are positively correlated.

The review of literature studying the effects of music education and academic outcomes spans research from the federal government, generalized academic performance enhancement, content grading data, cognitive functioning, and reading and mathematics competencies. Studies have been carried out multiple times to confirm these effects. The implications of these findings are widespread. Music education uniquely supports students' development and academic success in a more holistic way than other programs. The holistic support is due to the unique correlation that music has with academic content areas.

Despite the multiple variances in the literature regarding the way music education can positively impact learning and the potential impact on mathematics, especially at the cognitive domain level, the evidence showed a connection between the two. Based on this understanding, further research would benefit all stakeholders.

Chapter 3: Methodology

Introduction

This study explored the hypothesis that students who participated in middle school band and or chorus had higher math cognitive functioning than their non-music peers. This study was designed to fill a need for better understanding how learning in both music and mathematics lays domain-general and domain-specific cognitive groundwork for mathematical functioning. Using the Norwest Evaluation Association's (NWEA) Measure of Academic Progress (MAP), this study identified specific domains within mathematics that middle school music students demonstrated higher functioning than their non-music peers. As noted in chapter 2, the domain level is the conceptual elements for middle grade mathematics consisting of Geometry, operations and algebraic thinking, statistics and probability, and real and complex numbers.

Each domain contained specific conceptual elements that were assessed to inform the overall domain. Geometry comprised of Geometric measurement and relationships and congruence, similarity, right triangles, and Trigonometry. Operations and algebraic thinking included expressions and equations, use functions to model relationships. Statistics and probability included interpreting categorical and quantitative data and using sampling and probability to make decisions. Real and complex numbers include ratios and proportional relationships, perform operations, and extend and use properties. All mathematic domains aligned with national, and state expected curriculum.

Research Methodology and Design

This research was a study comparing mathematics performance of students who participated in a music ensemble with students who did not participate in a musical ensemble. Specifically, the study examined mathematical domains and identifies specific domains supported by music participation. Assessment data from the Northwest Evaluation Association's (NWEA) Measure of Academic Progress (MAP) performance scores were used from six assessments beginning in the fall of 2020 through the spring of 2023. Student data was selected for participants who were continuously enrolled for 6th, 7th, and 8th grade years at the school. Additionally, band and chorus participants were continuously enrolled in either ensemble.

Research Questions

To research the effect music has on mathematics, five essential research questions were used:

- RQ1: Is there a difference in mathematical cognitive functioning between students that participated in a middle school music ensemble as compared to non-participating peers?
- RQ2: Is there a difference in mathematical cognitive functioning between band participants and non-participating peers?
- RQ3: Is there a difference in mathematical cognitive functioning between choral students and non-participating peers?

RQ4: Is there a difference in mathematical cognitive functioning between students that participated in both band and chorus and non-participating peers?

RQ5: Is there a specific mathematical domain where students who participate in band or chorus perform at a higher cognitive functioning level?

Ethical Consideration

This study was designed to collect only student performance data and course enrollment. Student demographic data was not collected or utilized in the results. The University of Georgia IRB did not require student or guardian permission to collect data (see Appendix A).

Data Sources

NWEA uses anonymous assessment data from over 11 million students to create national norms, placing students and schools within a representative national sample. By drawing from an incredibly wide pool of anonymized test records (pulled from millions of test events from over 24,500 public schools in 5,800 districts, spread across all 50 states). For each individual school, MAP provides a context for comparing grade level achievement and growth in a single school relative to other schools across the nation. MAP Growth is the only interim assessment that provides school-level norms, comparing specific grade levels at each school to students in the same grade across the nation. In the most recent technical guide, NWEA provided the sampling information for grades 6 – 8, reliability coefficient, and standard error. An error greater than 0.8 is considered sound

reliability. The reliability coefficient was 6th grade at 0.970, 7th grade at 0.974 and 8th grade at 0.976.

MAP Growth test results are provided in the form of a Rasch Unit (RIT) score reflecting students' academic knowledge, skills, and abilities. A RIT score has the same meaning regardless of grade level or age of the student. NWEA provided each student with an achievement percentile, RIT score, and level bands consisting of High achievement (99 - 81%), High Average achievement (80 - 61%), Average achievement (60 - 41%), Low Average achievement (40 - 21%), and Low achievement (20 - 1%).

To address reliability and validity, NWEA has conducted a series of studies for MAP Growth tests, and the results indicate that the constructs underlying the tests remained consistent at different grades or time. "These findings support using MAP Growth results to measure student achievement and learning. Other evidence based on internal structure (i.e., construct validity) includes results from test-taking engagement and differential item functioning (DIF) studies" (NWEA, 2019, pg. 95).

Instrumentation and Data Analysis

Mathematics Measure of Academic Performance data was collected over a three-year period with two reported assessments from students who participated in band and choral music ensembles compared to students who did not participate in a music ensemble. MAP was given three times per year; fall, winter, and spring, however, only two assessment data points were utilized for this study, fall of 2000 and spring of 2023. The winter assessment was not selected as it is used as a checkpoint on student progress. The fall 2000 assessment was used as a baseline data point. The significance of the fall

assessment is that it was given to all 6th graders within the first month of school and before any significant musical ensemble education began. The spring 2023 assessment is a culminating assessment of student progress through middle school. Students have completed three full years of instruction in mathematics and for band and choral students, the third year of participation. Students who dropped participation each year were not included in the study data. Data collection spanned two cycles beginning in fall of 2020 and concluding in spring of 2023. Each assessment cycle consisted of three administrations of the mathematics section of MAP.

MAP assessments are not timed, and students may take as much time as they need to complete them (this eliminates some of the pressure and anxiety students may feel about taking tests). Most students take less than an hour to complete a MAP assessment.

Student data was collected and analyzed by a six-digit number pre-assigned to each student by the school system, allowing an identifying number for the student information system and MAP. Data was organized by performance and non-performance, mathematics norm referenced percentile, then by the specified domain.

Throughout the study, students that were music participants received daily music instruction for 50 minutes during their connection class period. This instruction was provided through a band or choral ensemble class. Students who were in both band and chorus, received 100 minutes of instruction daily from both ensembles.

Data Collection Procedures

All students at the school participated in the MAP assessment August 11 – 13, 2020 for the baseline data through the March 22 – 24, 2023. Students completed the

mathematics assessment online through the NWEA portal. After the assessment window closed, NWEA provided a comprehensive comma separated data file. The initial comprehensive file had several columns removed to maintain confidentiality. Any name or demographic data was removed, and student results were linked to the pre-assigned six digit school system student number.

A list of all students' enrollment for band, chorus, band and chorus, and non-participation students was organized by the pre-assigned number and disaggregated onto separate data sheets. Student results were further sorted by the mathematical domains of Geometry, operation and algebraic thinking, statistics and probability, and real and complex numbers.

Participants

Participants were students enrolled at a middle school in Georgia with a total school enrollment of 1066, representing 355 students in 6th grade, 359 students in 7th grade, and 352 students in 8th grade. The school racial demographics consisted of students identifying as 80% white, 7% Hispanic, 8% Asian, 3% Multi-Racial, and 2% Black. The percentage of students from economically disadvantaged families was 9%. Based on 2021 census data, the subject school's community is considered affluent, with the median household income being \$106,165 compared to the national median income of \$62,982 or the average median income of surrounding counties of \$45,192.75. The level education for the county consisted of 96% of adults having at least a high school diploma as compared to the national statistic of 88.9 %. Additionally, 51.6% of the community's adults possessed an undergraduate degree or better compared to the national

of 33.7%. Students have access to five post-secondary institutions within a 25-mile radius. I did not develop a process to control for race or income as the stratification addressed gender, math enrollment coursework, and baseline academic performance.

For this study, 8th grade students who were continuously enrolled for the three-year period at the school were included. Of the total 352 students in 8th grade, 293 met the criteria. 62 students were removed from the study since they did not meet the study enrollment parameters because they were late enrollees.

From the sample of 293 students; 64 students participated in band, 27 participated in chorus, 9 students participated in band and chorus. I then matched the music participants with a non-participant. When matching participants through the data, students' OVERALL math RIT score from fall 2020 was used as the baseline. Students were matched by gender first and then were matched by RIT score within one point between the music participants and non-participants. Any outliers were removed and in the case of math scores, any student that could not be matched by a corresponding score due to gender was removed.

The fall 2020 student math course enrollment (accelerated, advanced, and grade level) data was reviewed to ensure that the percentage of matched students were not disproportionate within and compared to the participant and non-participant groups. Music participant students ($n = 78$) had 24 students or 31% of the group enrolled in Accelerated Mathematics (first level course), 39 students or 50% of the group enrolled in Advanced Mathematics (second level course), and 15 students or 19% enrolled in Grade Level Mathematics (third level course). The non-participants ($n = 78$) had 25 students or 32% of the group enrolled in Accelerated Mathematics (first level course), 36 students or

46% enrolled in Advanced Mathematics (second level course), and 17 students or 22% enrolled in Grade Level Mathematics (third level course). Although students were taught by a different math teacher each year, each grade level math teacher collaborated weekly on content standards, county level math pacing, gave common summative assessments, and met monthly as a vertical content team across all three grade levels.

The finalized participant data set contained students ($N = 156$) enrolled in six groups: (a) Non-Participate in Band ($n = 78$), (b) Participate in Band ($n = 78$), (c) Non-Participate in Chorus ($n = 24$), (d) Participate in Chorus ($n = 24$), (e) Non-Participate in Both ($n = 8$), and (f) Participate in Both ($n = 8$). Of the 156 students, 82 were female and 78 were male. The math score was measured over six terms: Fall 2020, Spring 2021, Fall 2021, Spring 2022, Fall 2022, and Spring 2023.

Chapter 4: Results

Methodology

This research was a study comparing mathematics performance of students who participated in a music ensemble with students who did not participate in a musical ensemble. Specifically, the study examined mathematical domains and identifies specific domains supported by music participation. MAP performance scores were used from the study's participants from the fall of 2020 through the spring of 2023 assessments. All participants were continuously enrolled for 6th, 7th, and 8th grade years. Additionally, Band and Chorus participants were continuously enrolled in one or both ensembles. Students were pre-assigned to a six-digit number. There was no randomization as the stratification process limited the number of students who would qualify as either a music participant or a non-participant. Students were pair matched according to gender and baseline assessment score (Fall 2020) on the OVERALL score of MAP test.

Problem Description

In this study, the focus was on comparing student math scores between non-music participants and music participants in Band, Chorus, or Both on overall math performance. The goal of the analysis was to determine how participating in music ensembles may positively affect mathematical cognitive functioning and performance. In addition to the overall math data, the subdomains examined were Operations and

Algebraic Thinking (OAT), Real and Complex Numbers (RaCN), Geometry (GEO), and Statistics and Probability (StPr).

Data results from six assessment points comprised across the range of all participants ($N = 156$). Each assessment score encompassed a fall and spring data set for academic years 2020 – 2021, 2021 – 2022, and 2022 – 2023. The Fall 2020 data was utilized as the baseline data set for matching purposes. Each math assessment score was calculated by NWEA and assigned to each student based-upon his/her knowledge of math cognitive thinking.

Results

First, I ran the OVERALL mean scores for the non-music participants ($n = 78$) and the music participants ($n = 78$) from the fall 2020 math assessment. The baseline mean score for non-music participants ($M = 225.96$, $SD = 10.07$) and the baseline mean score for music participants ($M = 225.44$, $SD = 10.27$). The baseline non-music participants' mean score showed a slightly higher average than participants (see Table 4.1). There was no significant difference in the baseline scores of participants.

Table 4.1*Descriptive Statistics for Overall Math Mean and SD*

Term	Non-Music Participant		Music Participant	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
2020 - Fall	225.96	10.07	225.44	10.27
2021 - Spring	236.71	10.89	237.73	11.17
2021 - Fall	236.28	11.10	239.03	11.14
2022 - Spring	246.17	12.40	247.97	11.59
2022 - Fall	245.45	14.07	247.90	12.60
2023 - Spring	251.79	15.45	254.08	15.32

I compared the OVERALL mean scores for both groups from the spring 2023 math assessment. The final OVERALL data for non-music participants ($M = 251.76$, $SD = 15.45$) and the final assessment data for the music participants ($M = 254.08$, $SD = 15.32$). The data demonstrated that music participants outperformed non-music participants by a mean average of 2.29 points. It is important to note that the music participants overcame an initial mean average deficit of .52 as compared to non-music participants.

Secondly, a paired samples t-test was used to compare the difference in scores between the Fall 2020 and Spring 2023 test score on the OVERALL test comparing the non-music participant and music participant scores. An independent sample *t-test* for Equality of Means *t-test* ($p = .03$) met the significance level, (see Table 4.2), reporting that there was a significant difference between the non-music participants ($M = 25.83$, $SD = 8.69$) and music participants, ($M = 28.39$, $SD = 8.17$); [$t(154) = -1.897$, $p = .03$] (see Table 4.2).

Table 4.2*Descriptive Statistics for Overall Math M and SD 2020 and 2023*

Term	Non-Music Participant		Music Participant	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
2020 - Fall	225.96	10.07	225.44	10.27
2023 - Spring	251.79	15.45	254.08	15.32
Total Growth	25.83		28.64	

Next, a three-way repeated measures ANOVA was performed to determine if there was a significant interaction between participation and non-participation, within groups (band, chorus, and both), and TIME on the OVERALL math score and the four subdomains of OAT, RaCN, GEO, and StPr. In all data sets, there were no unacceptable outliers detected and the tests found that normality assumption and homogeneity of variance assumption were met. In this study, music participants and non-music participant (between-subjects factor), within groups (within-subjects factor), and time (within-subjects factor) were the three independent variables. The dependent variable was the math assessment scores.

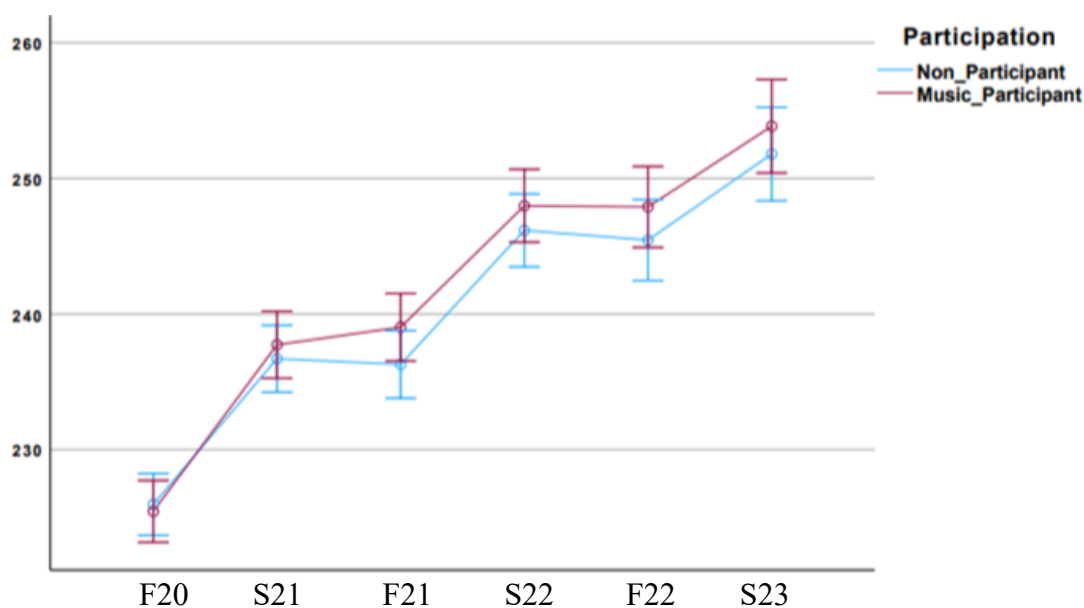
In the repeated measures ANOVA, I found no significant difference in the OVERALL scores between the non-music and music participants across test scores, [Pillai's Trace = $F(1, 150) = .31, p = .057, \eta^2_p = .937$].

The repeated measures ANOVA revealed a significant effect of OVERALL math performance based on TIME for music participants, [$F(5, 150) = 245.12, p < .001$] and non-participants, [$F(5, 150) = 203.33, p < .001$]. TIME was statistically significant on mean scores between the Fall 2020 assessment ($M = 225.71, SD = 10.14$) and the Spring 2023 ($M = 252.82, SD = 15.37$); [$F(3, 568) = 468, p < .001$]. Pairwise comparisons (with

Bonferroni correction) revealed a significant difference between the means for the math performance over TIME with participants and nonparticipants, $p < .001$. This was consistent in four of the six assessments. The fall administrations in 2021 and 2022 reflected a regression in the score from the previous spring, $p < 1.0$. The regression was expected due to summer break and consistent with local and national NWEA data (see Figure 4.1).

Figure 4.1

Estimated Means Non-Music and Music Participants on OVERALL

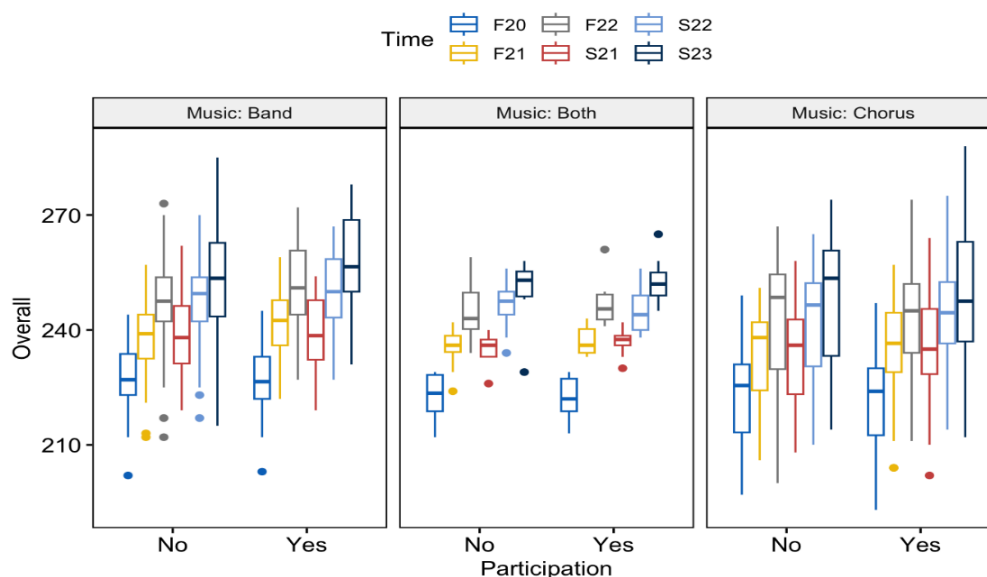


The repeated measures ANOVA revealed a significant effect of OVERALL math performance based on MUSIC (band, chorus, both) between tests, [$F(2, 150) = 3.92, p < .02$]. The OVERALL boxplot shows different music ensembles: Band, Chorus, and Both, with the distribution of the test scores over time in non-music participants and music participants, respectively. Distinct colors indicate a TIME factor of data. The data

showed a trend in OVERALL mean scores increasing over time, except Fall 2022. From the repeated measure ANOVA test, the MUSIC factor (Band, Chorus, and Both) and the TIME factors were significant. Since the MUSIC groups were divided by matching the scores between music participants and non-music participants from the boxplots showing below, the Band participants in every semester had higher overall scores than the other two groups. Besides, the TIME factor was significant, from the previous plot, the students' overall score had an upward trend (see Figure 4.2).

Figure 4.2

Boxplot Means Non-Music and Music Participants on OVERALL



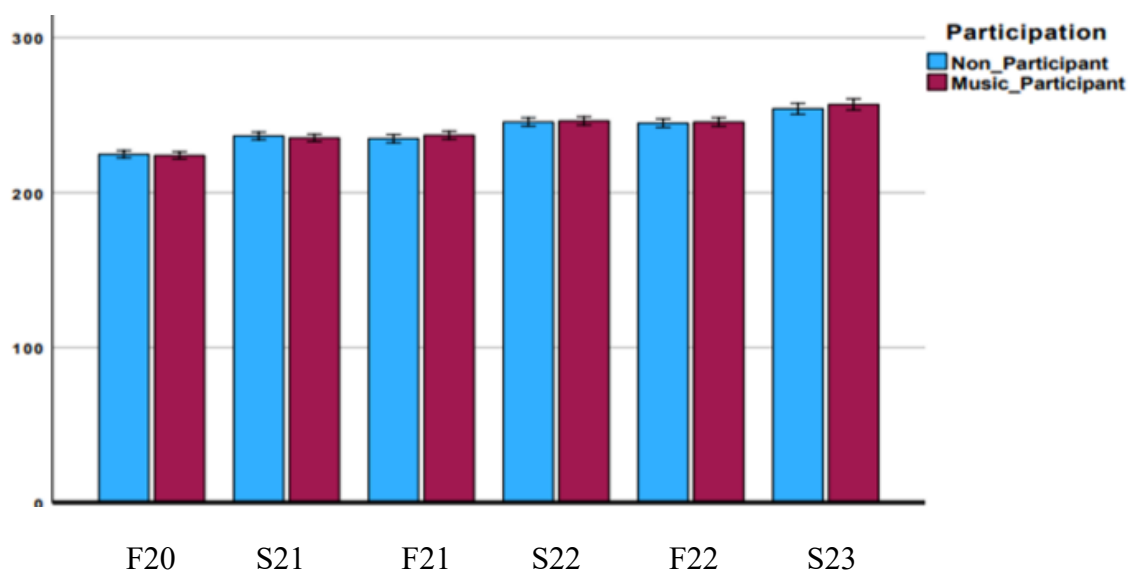
Operations and Algebraic Thinking Analysis

In the repeated measures ANOVA, I found no significant difference in the OAT scores between the non-music and music participants across test scores, [Pillai's Trace = $F(1, 150) = .81, p = .06, \eta^2_p = .904$].

The repeated measures ANOVA revealed a significant effect in the math domain of Operations and Algebraic Thinking (OAT) performance based on TIME for music participants, [$F(4.55, 682) = 242.98, p < .000$] and for non-participants, [$F(5, 150) = 203.33, p < .001$]. Pairwise comparisons (with Bonferroni correction) revealed a significant difference between the means for the math performance over TIME with participants and nonparticipants, $p < .001$. This was consistent in four of the six assessments. The fall administrations in 2021 and 2022 reflected a regression from the previous spring, $p < 1.0$ (see Figure 4.3 and 4.4 for the means).

Figure 4.3

Estimated Means Non-Music and Music Participants on OAT



For OAT, not only did the non-music participants regress in the F21 and F22 assessments, but the music participants regressed in F22, (see Table 4.3).

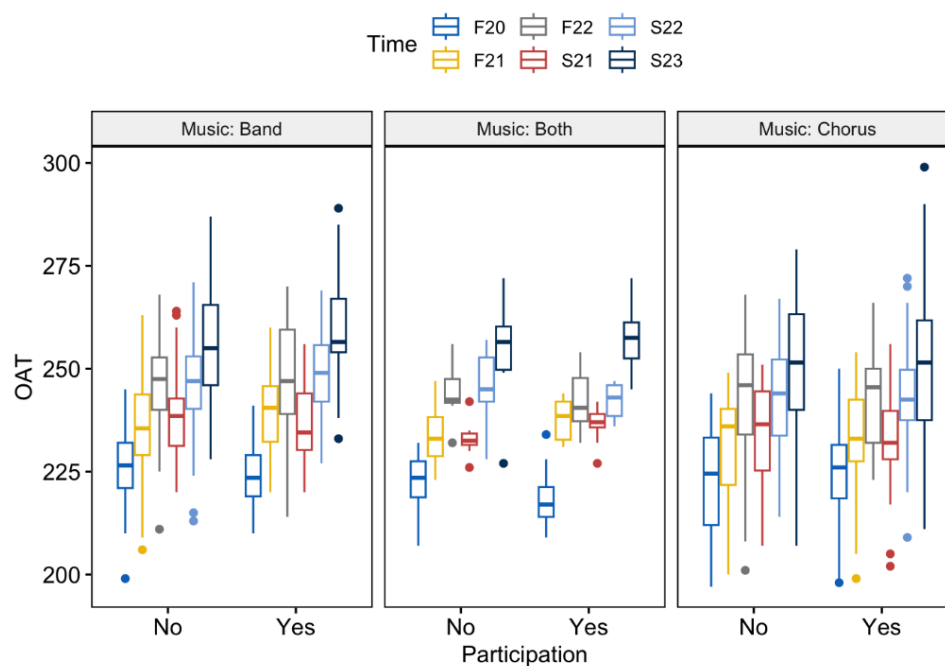
Table 4.3*Descriptive Statistics for OAT Mean and SD*

Term	Non-Music Participant		Music Participant	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
2020 - Fall	224.76	10.97	224.00	9.44
2021 - Spring	236.58	10.84	235.33	10.37
2021 - Fall	234.86	11.86	237.03	11.47
2022 - Spring	245.54	12.36	246.28	11.6
2022 - Fall	244.79	12.17	245.53	12.45
2023 - Spring	254.09	15.51	256.90	15.83

The repeated measures ANOVA did not show a significant effect of OAT performance based on MUSIC (band, chorus, both) between tests, [$F(2, 150) = 3.02, p < .052$]. The analysis of Operations and Algebraic Thinking subdomain boxplot is divided: Band, Both, and Chorus. Distinct colors indicate a TIME factor of data. The data showed a trend in overall mean scores increasing over time, except Fall 2022. Utilizing the table below, only the TIME factor is a significant factor. The box plot demonstrates that students increased performance over time (see Figure 4.4).

Figure 4.4

Boxplot Means Non-Music and Music Participants on OAT



Real and Complex Numbers Analysis

In the repeated measures ANOVA, there was no significant difference in the RaCN scores between the non-music and music participants across test scores, [Pillai's Trace = $F(1, 150) = .06, p = .81, \eta^2_p = .843$].

The repeated measures ANOVA revealed a significant effect on the math domain of Real and Complex Numbers performance based on TIME for music participants, [$F(4.64, 695.65) = 155.52, p < .001$] and non-participants, [$F(5, 150) = 74.57, p < .001$]. Pairwise comparisons (with Bonferroni correction) revealed a significant difference between the means for the math performance over TIME with participants and

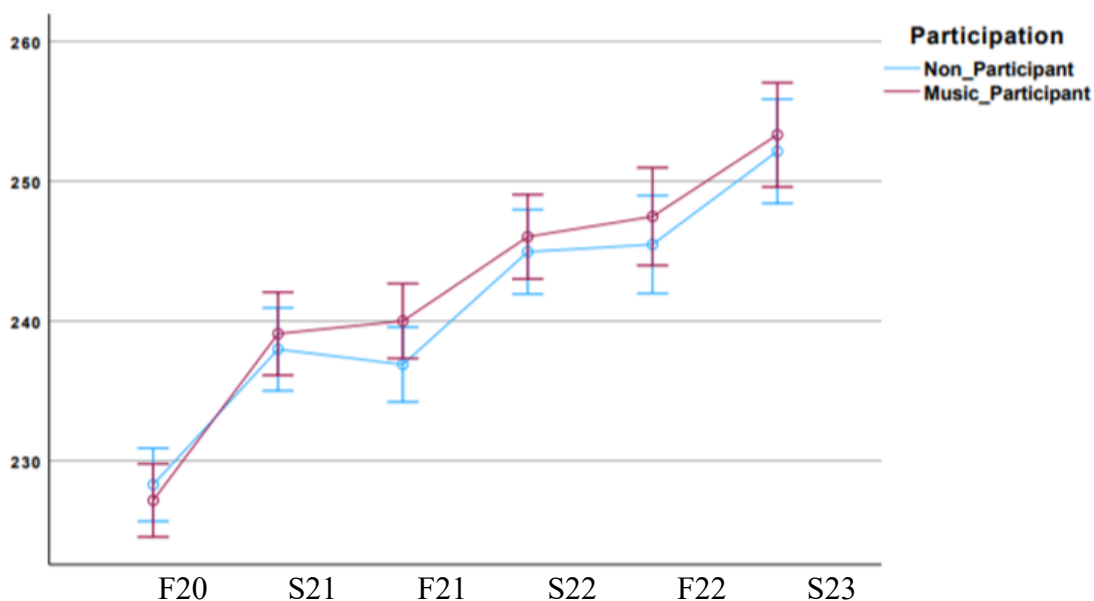
nonparticipants, $p < .001$. This was consistent in five of the six assessments (see Table 4.4).

Table 4.4

Descriptive Statistics for RaCN Mean and SD

Term	Non-Music Participant		Music Participant	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
2020 - Fall	228.29	10.79	227.17	12.49
2021 - Spring	237.97	12.49	239.09	13.98
2021 - Fall	236.88	12.25	240.00	11.68
2022 - Spring	244.95	13.79	246.03	13.15
2022 - Fall	245.47	15.71	247.47	15.6
2023 - Spring	252.14	16.04	253.32	17.24

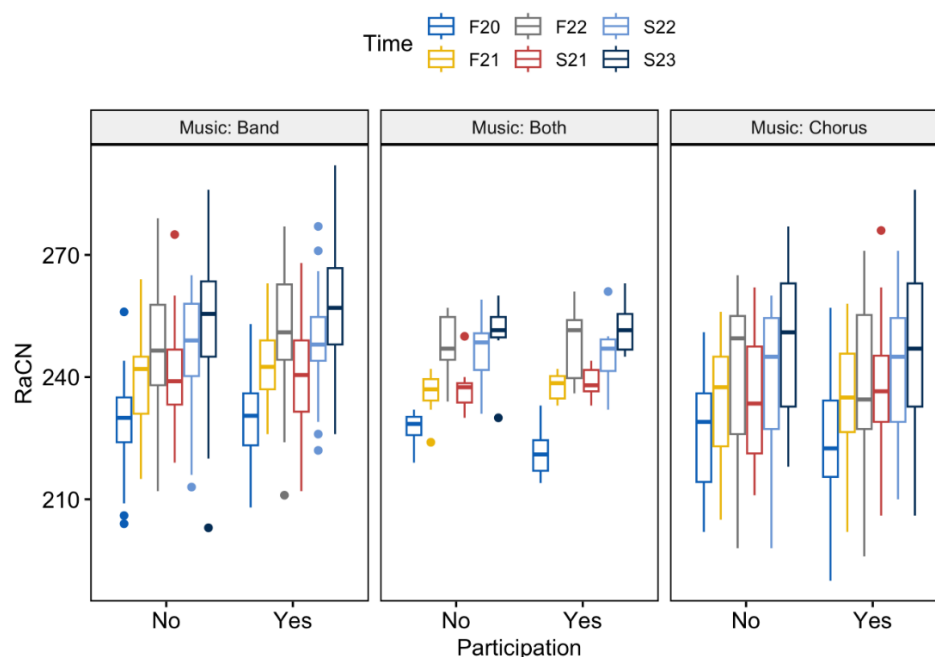
The fall administrations in 2021 reflected a regression from the previous spring, $p = 1.0$. The regression was expected due to summer break and consistent with local and national NWEA data (see Figure 4.5).

Figure 4.5*Estimated Means Non-Music and Music Participants on RaCN*

The repeated measures ANOVA revealed a significant difference between the means of RaCN performance based on MUSIC (band, chorus, both) between tests, [$F(2, 150) = 4.38, p < .01$]. The analysis of Real and Complex Numbers subdomain boxplot was divided into: Band, Both, and Chorus. Distinct colors indicate a TIME factor of data. The data demonstrated a trend in overall mean scores increasing over time. Since music participants in this study were divided by matching the scores between non-music participants and music participants, the Band groups had slightly higher mean scores than the other two groups (see the boxplots in Figure 4.6). The TIME factor was significant, and students' mean RaCN scores had an upward trend.

Figure 4.6

Boxplot Comparison Groups on RaCN



Geometry Analysis

In the repeated measures ANOVA, there was no significant difference in the GEO scores between the non-music and music participants across test scores, [Pillai's Trace = $F(1, 150) = .43, p = .52, \eta^2_p = .840$].

The repeated Measures ANOVA revealed a significant effect on the math domain of Geometry performance based on TIME for music participants, [$F(4.55, 682.49) = 132.77, p < .001$]. and non-participants, [$F(5, 150) = 80.93, p < .001$]. Pairwise comparisons (with Bonferroni correction) revealed a significant difference between the means for the math performance over TIME with non-music participants and music participants, $p < .001$. This was consistent in five of the six assessments for non-music

participants (see Table 4.5). The Spring 2023 was the only assessment in GEO that non-music participants outperformed music participants.

Table 4.5

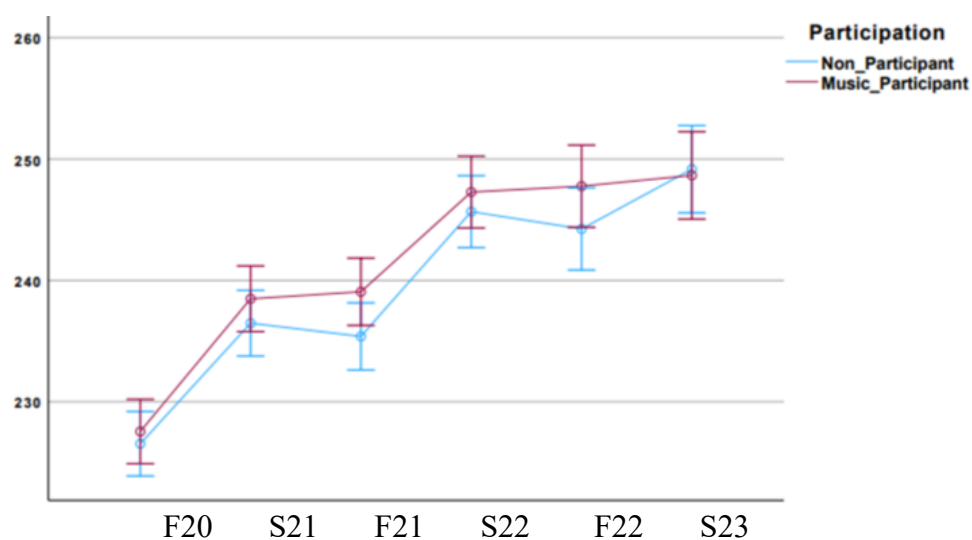
Descriptive Statistics for GEO Mean and SD

Term	Non-Music Participant		Music Participant	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
2020 - Fall	226.54	11.11	227.55	12.58
2021 - Spring	236.47	11.75	238.49	12.45
2021 - Fall	235.38	12.66	239.06	12.07
2022 - Spring	245.67	14.01	247.28	12.41
2022 - Fall	244.24	16.16	247.77	14.01
2023 - Spring	249.17	16.49	248.65	15.66

The fall administrations in 2021 reflected a regression from the previous spring, $p = 1.0$ (see Figure 4.7).

Figure 4.7

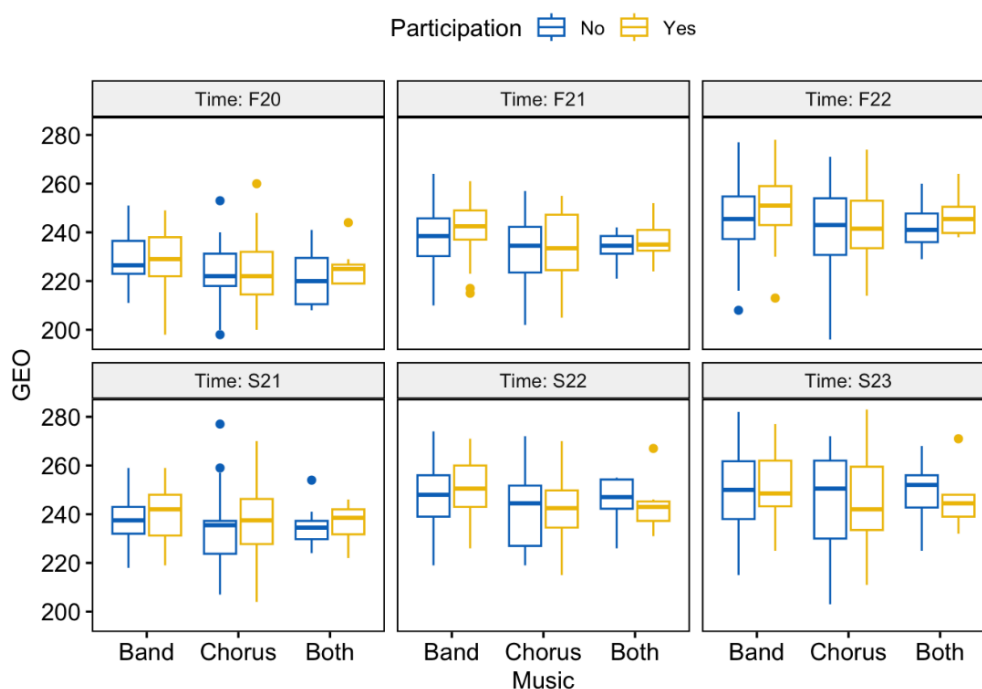
Estimated Means Non-Music and Music Participants on GEO



The repeated measures ANOVA revealed a significant difference between the means of GEO performance based on MUSIC (band, chorus, both) between tests, [$F(2, 150) = 4.56, p < .01$]. Since the MUSIC groups are divided by matching the scores between non-music participants and music participants from the boxplots showing below, the Band groups in every semester have higher mean scores than the other two groups. The TIME factor is significant and the students' GEO score has an upward trend except for non-participants in Fall 2021 and Fall 2022. MUSIC participants demonstrated a steady improvement through every assessment, (see Figure 4.8).

Figure 4.8

Boxplot Means Non-Music and Music Participants on GEO



The analysis of Geometry subdomain boxplot is divided into: Band, Both, and Chorus. Assorted colors indicate a Time factor of data. The data demonstrated a trend in overall mean scores increasing over time.

The table above shows music participants outperformed non-music participants in five of the six assessments addressing GEO. Important to note, the music participants scored higher in this domain in the Fall 2020.

Statistics and Probability Analysis

In the repeated measures ANOVA, there was no significant difference in the StPr scores between the non-music and music participants across test scores, [Pillai's Trace = $F(1, 150) = .93, p = .34, \eta^2_p = .910$]. See Table 4.6 for the means and standard deviation for Statistics and Probability across all text scores.

Table 4.6

Descriptive Statistics for StPr Mean and SD

Term	Non-Music Participant		Music Participant	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
2020 - Fall	224.26	12.67	222.88	12.63
2021 - Spring	235.77	13.36	238.01	13.39
2021 - Fall	237.94	12.69	240.29	14.08
2022 - Spring	248.51	14.25	251.78	13.98
2022 - Fall	247.49	17.68	250.79	14.35
2023 - Spring	251.56	18.15	256.55	17.23

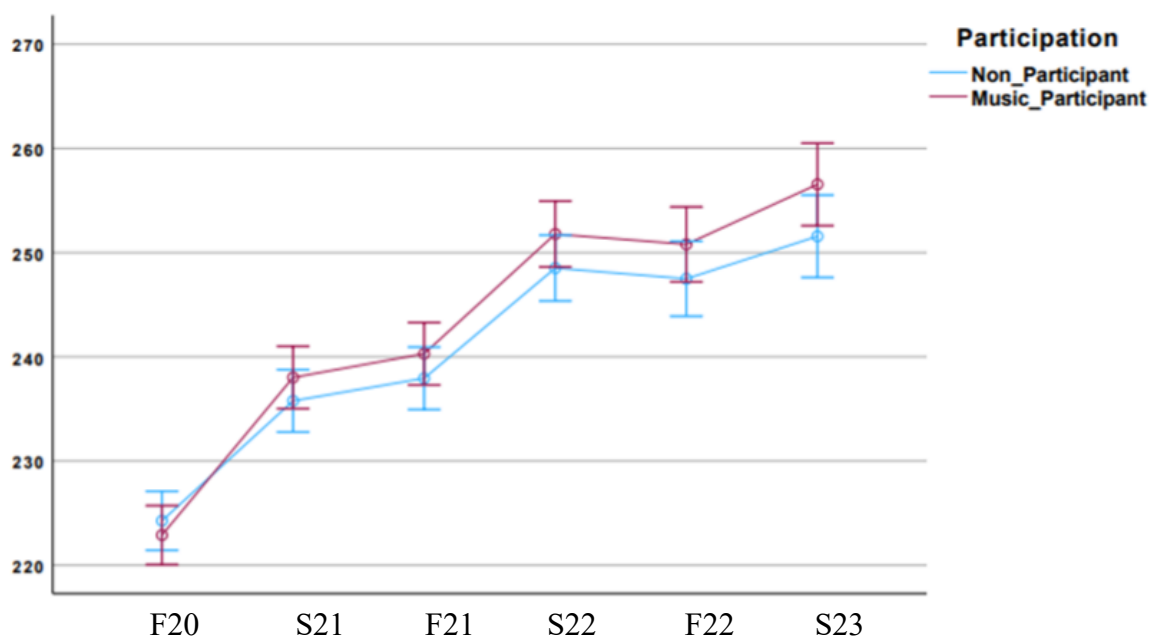
The repeated measures ANOVA revealed a significant effect on the math domain of Statistics and Probability performance based on TIME for music participants, [$F(4.58,$

687.58) = 227.05, $p < .001$] and non- participants, [$F(5, 150) = 125.48, p < .001$].

Pairwise comparisons (with Bonferroni correction) revealed a significant difference between the means for the math performance over TIME with participants and nonparticipants, $p < .001$, (see Table 4.6). This was consistent in five of the six assessments. The fall administration in 2020 reflected the only assessment that non-music participants outperformed music participants, (see Figure 4.9).

Figure 4.9

Estimated Means Non-Music and Music Participants on StPr

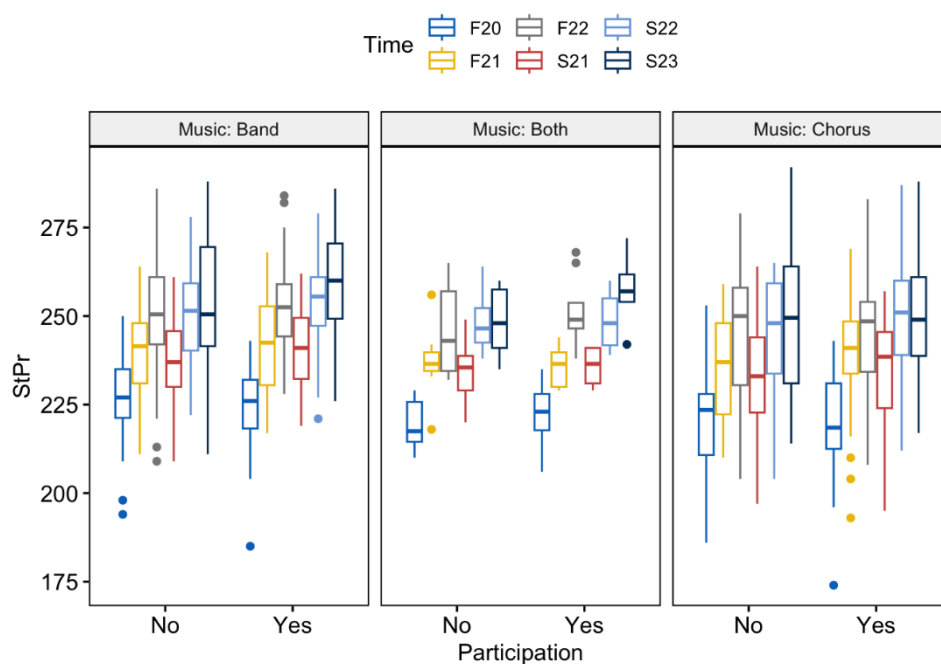


The repeated measures ANOVA revealed a significant difference between the means of StPr performance based on MUSIC (band, chorus, both) between tests, [$F(2, 150) = 3.30, p < .04$]. Since the MUSIC groups were divided by matching the scores between non-music participants and participants in MUSIC, from the boxplots showing below, the MUSIC groups in five of the six assessments have higher mean scores.

The analysis of Statistics and Probability domain boxplot is divided: Band, Both, and Chorus. Assorted colors indicate a Time factor of data. The data demonstrated a trend in overall mean scores increasing over time. Band students outperformed chorus and students in both band and chorus. The table above shows no significant factors and demonstrates that participation in a music ensemble or non-participation has no significant difference in StPr scores, (see Figure 4.10). However, the mean score average between the two groups showed a significant difference over TIME.

Figure 4.10

Boxplot Means Non-Music and Music Participants on StPr



Summary

There were significant results found for all tests (OVERALL, OAT, GEO, RaCn, StPR) for TIME across all groups. Additionally, a significant difference was found

between non-participants and music participants between the first test of Fall 2020 and the final test in Spring 2023. Furthermore, a significant difference was found between groups for the Statistics and Probability domain, while the Operations and Algebraic domain approached significance at the .052 level. No significant differences were found for the Geometry or Real and Complex numbers domain. Furthermore, in pairwise comparisons, significant differences were revealed between tests from the Spring to Fall test administrations, except Spring 2023 in GEO, when non-music participants had a higher mean average than music participants.

When comparing, the Band, Choral, and Both groups to non-participants, music students consistently outperformed non-music participants in all assessments. The data for Both, fall between the Band and Chorus students in five of the six assessments. For the collective data of music participants, Chorus underperformance lowers the music participants mean average.

Chapter 5: Discussion

Introduction

While there is little doubt that increased student involvement in music stimulates brain activity at high levels and fosters greater learning (Johansson, 2006, p. 62), questions remain about whether musical stimulation improves mathematical performance. This study explores the hypothesis that students who participate in middle school band and or chorus have higher math cognitive functioning than their non-music peers. This study is designed to fill a critical need for better understanding how learning in both music and mathematics lays domain-general and domain-specific cognitive groundwork for mathematical cognitive functioning. Using the Norwest Evaluation Association's (NWEA) Measure of Academic Progress (MAP), this study identifies specific domains within mathematics that middle school music students demonstrate higher cognitive functioning than their non-music peers. The domain level is the conceptual elements for middle grade mathematics consisting of Geometry, operations and algebraic thinking, statistics and probability, and real and complex numbers.

As Gaab and Zuk suggests, "To date, a few studies have suggested a link between musical training and executive-functioning skills. But longitudinal studies are also needed to establish whether this is a causal link or whether these skills develop side by side" (Gaab & Zuk, 2017, p.74).

Research Findings

According to Luiz's research, musical elements are related to certain arithmetical operations (division, multiplication, addition, and logarithmic function), trigonometry and geometry, (Luiz, 2007, p.136). To examine the impact that the data has on supporting my hypothesis, I will examine each of the five questions by pairing my research with previous research studies focused on math performance and music students.

RQ1 - Is there a difference in mathematical cognitive functioning between students that participated in a middle school music ensemble as compared to non-participating peers?

Helmrich (2010) explored the effect of musical training on analytic processes, such as those used in algebra, looking at the scores of musicians and non-musicians included among those of over 6000 students taking the Maryland Algebra/Data Analysis High School Assessment. The findings remained consistent across each area of study, music participants outscored non-music participants, with instrumental musicians outscoring their choral counterparts.

As with Helmrich's findings, there was a significant difference comparing the OVERALL math performance of non-music participants ($n = 78$) and music participants ($n = 78$). Although both groups showed significant mean growth from the first administration of the MAP assessment to the last, the music participants had an additional growth of 2.81 points.

The music participants baseline data was -.52 points behind the non-music participants. Over the next five MAP administrations of the OVERALL math, music

participants outperformed the mean average of the non-music participants. Although each administration assessment total range of differences between non-music and music participants are from the lowest of 1.02 points (Spring 2021) to the highest of 2.75 (Fall 2021) points, the music participants did not perform below the non-music participants after the initial 2020 baseline assessment.

For the overall mean average growth from the six assessments, non-music participants growth is 25.83 and music participants growth is 28.64. The NWEA provides a guideline of the 2020 national average growth statistics, (see Table 5.1). According to the overall national growth for the 2020 NWEA Math Achievement Norms, the composite 6th grade, which all participants were enrolled in 2020, had a national growth of 8.13 points. The non-music participants at this school showed a growth of 11.51 points while the music participants showed a growth of 15.13 points, twice the national average.

Table 5.1

NWEA Math Achievement Norms

2020 Mathematics Student Achievement Norms						
Grade	Fall		Winter		Spring	
	Mean	SD	Mean	SD	Mean	SD
K	139.56	12.45	150.13	11.94	157.11	12.03
1	160.05	12.43	170.18	12.59	176.40	13.18
2	175.04	12.98	184.07	13.01	189.42	13.44
3	188.48	13.45	196.23	13.64	201.08	14.11
4	199.55	14.40	206.05	14.90	210.51	15.56
5	209.13	15.19	214.70	15.88	218.75	16.70
6	214.75	16.12	219.56	16.74	222.88	17.47
7	220.21	17.41	224.04	17.96	226.73	18.60
8	224.92	18.94	228.12	19.33	230.30	19.95
9	226.43	19.83	228.67	20.06	230.03	20.63
10	229.07	20.23	231.21	20.61	232.42	21.25
11	231.72	20.61	233.49	20.91	234.25	21.65
12	233.02	21.60	233.31	23.07	234.19	24.63

It is important to note that in the fall administrations of the assessment, national and local results typically find results are affected by summer regression, meaning that students are not engaged in math instruction over the summer months and lose some cognitive math functions. In this study, I found music participants did not demonstrate any summer regression. The non-music students show an aggregate summer regression in the Fall 2021 ($M = 236.28$ or $-.43$ points) as well as in the Fall 2022 ($M = 245.45$ or $-.72$ points). Furthermore, students that participated in band had higher mean score averages after the Fall 2020 assessment than students who were in chorus, both, and non-music participants. I attribute this difference in scores to band students' daily exposure to activities that further develop not only their cognitive skills but develops attributes such as listening, coordination, and thinking skills. It is this transfer of skills into math that uniquely develops their math cognitive functioning.

RQ2 - Is there a difference in mathematical cognitive functioning between band participants and non-participating peers?

Students who participate in band have a higher mean score over chorus, both, and non-music participants. This is consistent in OVERALL math as well as each domain. The OAT domain was close to significance between Band participants and non-music participants by less than 1.0 point, although this does not meet the statistical significance p value, a value of .06 is important.

In the StPr domain, Band student performance is statistically significant when compared to non-music participants. The StPr domain, also, has the largest mean difference when comparing non-music students (Fall 2020 $M = 227.19$, Spring 2023 $M =$

253.71) to Band students (Fall 2020 $M = 225.04$, Spring 2023 $M = 259.54$). This variance represents non-music students baseline understanding of StPr by 2.0 points; however, in Spring 2023 Band students outperformed non-music students by almost 6.0 points. Band students not only had a lower baseline understanding, but their growth is significantly greater having overcome the beginning deficit plus the above performance.

RQ3 - Is there a difference in mathematical cognitive functioning between choral students and non-participating peers?

Data from the repeated measures ANOVA did not reveal any statistically significant results comparing non-music participants and chorus participants. TIME remained significant in the OVERALL math data and each domain for non-music and chorus participants. Chorus participants did not surpass non-music participants in growth on any assessment, but as mentioned, showed growth over the six assessments.

RQ4 - Is there a difference in mathematical cognitive functioning between students that participated in both band and chorus and non-participating peers?

Except for TIME, there is no statistically significant difference found in the assessment data for non-music participants compared to students in BOTH band and chorus. The Fall 2020 OVERALL baseline mean average for non-music participants ($M = 226.32$) was slightly higher than the mean average for BOTH Band and Chorus participants ($M = 225.81$). The Spring 2023 OVERALL mean average was 1.96 points higher for BOTH Band and Chorus participants ($M = 253.94$) compared to non-music participants ($M = 251.98$).

RQ5 - *Is there a specific mathematical domain where students who participate in band or chorus perform at a higher cognitive functioning level?*

As stated in my rationale for this study, Boyd states in chapter five of his dissertation, “In a future study, one could compare how music participation affects individual domains of mathematics achievement or how it affects certain mathematical domains over others” (Boyd, 2013, p.119).

Operations and algebraic thinking (OAT) include expression and equations, use functions to model relationships. OAT data found a significant difference in participant and non-participant students' performance over time, ($p < .001$). This is an expected outcome as students should improve in math cognitive functioning over a period. OAT was the only domain where non-music students outperformed music students in the first year or two assessments. When comparing other domains, OAT later developed into a strength for music participants. Also, OAT was the baseline second lowest domain performance of the music participants yet became the second highest growth area for music participants over the three years.

For the first three administrations of MAP (Fall 2020, Spring 2021, and Fall 2021), the non-music participants outperformed music participants in the OAT domain. However, in the Spring 2022, music participants had a higher mean score for the final three administrations (Spring 2022, Fall 2022, and Spring 2023). The final mean average for non-music participants ($M = 254.09$) and music participants ($M = 256.90$), demonstrating a higher mean average for music participants of 2.81 points. In terms of mean averages, the music participants showed a mean growth of almost 33 points

compared to non-music participants average mean growth of 29 points. Operations and algebraic thinking were close to statistical significance ($p < .06$) within the Band participants, but not when combined with chorus and both students. From a teaching perspective, this is significant to learning. The baseline data showed that the MUSIC students were slightly behind non-music participants, but after one year, the MUSIC group continued to outperform non-music students.

Real and complex numbers (RaCN) include ratios and proportional relationships, perform operations, and extend and use properties. RaCN data found no significant difference in participant and non-participant students. However, students in different comparison groups are significant, indicating that the three matching groups are statistically different in their respective RaCN performance scores. Also, TIME is a significant factor and students' performance in the RaCN domain. Mean scores for music participants demonstrate no summer regression as compared to non-music participants which shows a regression in the Fall 2021 assessment. The final mean average for non-music participants ($M = 252.14$) and music participants ($M = 253.32$), demonstrating a higher mean average for music participants of approximately 2.0 points. In terms of mean averages, the music participants show a mean growth of 26 points compared to non-music participants' average mean growth of almost 24 points.

The fall of 2021 assessment, non-music participants regressed over the summer trailing their spring 2021 score by more than 1.0 point, however, music participants grew over the summer by almost 1.0 point. As a principal, having data where students did not regress over a period of no instruction is a crucial factor when planning for student growth and academic success. It is possible that the music participants continued

practicing throughout the summer and were engaged in a summer music camp. During the summer months, they continued to be engaged in music instruction.

Geometry (GEO) consists of Geometric measurement and relationships and congruence, similarity, right triangles, and Trigonometry. GEO performance within different comparison groups is significant, indicating that the three matching groups are statistically different in their respective GEO scores. Also, TIME is a significant factor, indicating that students' performance in the GEO performance scores. Student participants in a Band ensemble have significantly higher scores in GEO than non-participants in Band, ($p = .03$). Notably, in the Fall 2021, students who participated in a Band ensemble had significantly higher scores in GEO than non-participants. Mean averages for music participants demonstrate no summer regression as compared to non-music participants which showed a regression in the Fall 2021 assessment. The final mean average for non-music participants ($M = 252.14$) and music participants ($M = 253.32$), demonstrating a higher mean average for music participants of more than 2.0 points. In terms of mean averages, the music participants showed growth of more than 26 points compared to non-music participants average mean growth of 23 points.

The GEO data is interesting as music participants outperformed through five of the six assessments with the Spring 2023 being the assessment when non-music participants outperformed music participants. I expected this domain to demonstrate the greatest success and growth with music participants since music is interwoven with shapes and patterns. The results were not what I had expected and in fact this domain was the least growth area for both groups. This may be attributed to the limited instruction that students receive in GEO content within math while in middle school.

Statistics and probability (StPr) included interpreting categorical and quantitative data and using sampling and probability to make decisions. StPr also shows a significant difference in TIME for both groups. Students in different comparison groups are significant, indicating that the three matching groups chosen are statistically different in their StPr scores. Among the four domains, StPr demonstrates the most significant difference between non-music and music participants ($p = .03$).

For the Fall 2022, music participants showed regression from the previous spring. Music participants' Fall 2020 score ($M = 222.88$) was lower than non-music participants' Fall 2020 score ($M = 224.26$). The final mean average for non-music participants ($M = 251.56$) and music participants ($M = 256.55$), demonstrates a higher mean average for music participants of almost 5.0 points. In terms of mean averages, the music participants showed a mean growth of 33 points compared to non-music participants' average mean growth of 27 points. For music participants, StPr was the strongest performance and growth demonstrated over the three-year period yet was the lowest domain performance in the Fall 2020.

While analyzing the data, Band students ($p < .05$) outperformed non-music participants in Statistics and Probability (StPr). With combining Band participants along with students that were in Both, there is a statistical significance ($p < .03$) in StPr. This indicates that students in Both benefited from participating in band in this domain, however, did not benefit from their chorus instruction within StPr.

Limitations

The sample selected does not reflect the entire student population, although stratification of sampling was used to match the sample as closely as possible. This study represents one middle school population with one school culture. The middle school has a low percentage of students that meet the criteria for low income and low minority students. The school and community demographics do not reflect the student population of adjoining school systems. The third limitation is the general size of the study. These results should not be generalized to other populations.

Based on 2021 census data, the subject school's community is considered affluent, with the median household income being \$106,165 compared to the national median income of \$62,982 or the average median income of surrounding counties of \$45,192.75. The level education for the county consisted of 96% of adults having at least a high school diploma as compared to the national statistic of 88.9 %. Additionally, 51.6% of the community's adults possessed an undergraduate degree or better compared to the national of 33.7%. Students have access to five post-secondary institutions within a 25-mile radius.

The majority of students have a background in general music before beginning middle school. However, the quality and quantity of musical experience or exposure differs at each elementary school. Some students may have experienced weekly elementary music instruction, intermittent quarterly music instruction, choral ensemble exposure, grade level musical(s), instruments, etc.

As the music students sampled were determined only through their current participation in school band and chorus during their sixth year, students who participate

in private musical study, such as piano lessons, or are part of outside musical groups are not identified in the music group, which may have an impact on the results of this study.

Finally, students who participate in private math tutoring are not accounted for within the study. This academic support may be a factor that influences student math performance.

Summary of Results

In 2008, Kinney found that band students outperformed their non-musical counterparts in both sixth and eighth grade math proficiency tests, and instrumental musicians scored the highest of the music students, with choral students showing no significant differences in scores. Although my selected assessment instrument is different than the instrument that Kinney used in his study, my results concur with previous findings.

As reported in this study, TIME was a significant factor for non-music and music participants. Students' growth was significant, and as reported, the music participant group had higher growth in OVERALL math cognitive function and the four math domains. The music participant group did not demonstrate summer regression and outperformed non-participants in mean average over the six assessments.

Within my study and consistent with Helmrich (2010), Band students outperformed Chorus students and Both. When studying this group against itself, the data, again, shows that TIME was significant for each, however, Chorus underperformed against Band and Both. I expected Both participants to outperform Band and Chorus since they receive twice the amount of music instruction on a daily basis. Additionally,

these students receive instruction that is unique to both genres. The data only shows that Both participants outperform Chorus and is behind Band participants.

Overall, it is particularly important to note that the non-music participant group's baseline data (Fall 2020) was higher than music participants; however, music participants outperform in OVERALL math and three of the four domain means over non-music participants. This is consistent throughout the study and supports that students enrolled in music courses are showing benefits affecting their math cognitive functioning from participating in music.

Recommendations for Future Research

Results of this study provide several possibilities for educators, including encouraging students in both areas of study to recognize the connections between the two, if not particularly the influence of one over the other. Additionally, teachers in both fields may begin more collaborative efforts to support the learning in both content areas. Future studies may include looking at the specific interaction between the two content standards and how music supports student cognitive functioning in mathematics.

As future studies explore the connection between music and mathematics, further research is needed as to why the connection, specifically what elements of math domains connect directly with music. In my study, I found a strong connection between statistics and probability. The next step is to explore why there is a connection. It will benefit the education community to explore defined partnerships between music and math teachers. Coteaching similar elements of music and mathematics with interchangeable terms, and using both numeric and musical notation examples, may reinforce basic underlying skills

associated with both elements. Gardner (2013) notes, “Individuals who are mathematically talented often show an interest in music. This linkage occurs because mathematicians are interested in patterns, and music offers itself as a goldmine of harmonic, metric, and compositional patterns” (Gardner, 2013, p. 12).

Mathematical cognitive understanding and musical approaches may result in a stronger methodology for teaching mathematics. It is important that musical elements maintain their independence as they are truly the foundation of musical understanding. This follows Gardner’s (2000) recommendations of using multiple modes of teaching concepts: “One can find at least seven powerful entry points to diverse concepts. These opening gambits help to introduce important and challenging topics” (Gardner, 2000, p. 188).

Further study is needed to address all levels of students and their involvement in music and mathematics, including those students who participate in non-school related music activities and those with a wide variety of math experiences. One area to address may include perceived access to music programs; for example, if students perceive barriers such as financial constraints, not allowing access to specific music ensembles.

Finally, a study should be developed to explore music participants and summer learning regression. This type of study would be a benefit in the next steps to compare math cognitive function between music and non-music participants.

The result of my study contributes to existing studies that connect music and math, adding further evidence that music students outperform non-music students in academic areas, especially in math. The stratification of groups was a strength of this study as I wanted to ensure that the non-music and music participants were evenly

matched from the baseline data. This stratification made the data findings even more significant. Over the three-year period and six assessments, the music student group continued to outperform non-music students and even show no regression of content knowledge.

Although further research is warranted to examine the effects of music and math, this study serves as an appropriate starting place for researching the connection to music and band, especially when looking at Operations and Algebraic Thinking and Statistics and Probability.

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Appendix A

Wednesday, November 22, 2023 at 14:20:13 Eastern Standard Time

Subject: Study Not Human Subjects Research
Date: Tuesday, July 20, 2021 at 4:13:31 PM Eastern Daylight Time
From: IRB@uga.edu
To: Rebecca L Atkins, MICHAEL SCOTT EDDY, Clint F Taylor

Notification of Not Human Research Determination

To: Rebecca Atkins
Link: [PROJECT00004143](#)
P.I.: Clint Taylor
Title: Exploration of Mathematical Computation and Reasoning for Middle School Band and Non-Band Students
Description: The Human Subjects Office has reviewed this submission and assigned a determination of Not Human Research. For additional details, click on the link above to access the project workspace. The determination letter can be found in the History under "Letter Sent".