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From Notes to Numbers: The Impact of Music Education on Mathematical Skills and Cognitive Development

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ABSTRACT

This study investigates the potential impact of early formal music education on mathematical performance among middle and high school students. The research is grounded in the longstanding hypothesis that music and mathematics share cognitive structures, particularly in pattern recognition and analytical reasoning. A total of 80 students aged 14–16 participated, divided evenly into two groups: one with formal musical training and one without. Four structured questionnaires were used to collect data on demographics, musical background, self-perception in mathematics, and actual mathematical performance in tasks involving sequences and patterns. Statistical analysis using SPSS revealed that students with a musical background significantly outperformed their non-musical peers across several cognitive and mathematical measures. These students reported higher confidence in their mathematical abilities ($M = 4.5$ vs. 3.2, $p < .01$), showed greater accuracy in identifying simple patterns (100% vs. 77.5%), and excelled in complex analytical tasks (92.5% vs. 17.5%). The results suggest that early music training enhances attention, pattern recognition, and abstract thinking—key skills that support improved mathematical achievement. These findings underscore the educational value of incorporating music into school curricula and call for further research with larger samples and extended mathematical domains.

KEYWORDS: music education, mathematics performance, cognitive development, pattern recognition, educational psychology

INTRODUCTION

The connection between music and mathematics has fascinated scholars for centuries and dates back to ancient civilizations. Pythagoras, the Greek philosopher and mathematician of the 6th century BCE, was among the first to formally explore this link, discovering that harmonious musical intervals correspond to simple numerical ratios. He demonstrated that string length and pitch are related through whole-number proportions, such as the 2:1 ratio for an octave. This finding provided one of the earliest indications that mathematical relationships underlie musical harmony.

Throughout history, composers and researchers alike have continued to explore this intersection. Johann Sebastian Bach, for example, integrated mathematical structures such as symmetry and patterning into his compositions. His use of counterpoint and fugues illustrates the application of mathematical reasoning to musical creation, with elements like proportion and ratio playing a central role.

In modern times, the cognitive overlap between music and mathematics has become a focal point in educational research, particularly regarding the role of pattern recognition and spatial-temporal reasoning. Contemporary pedagogical approaches now question whether early musical training may positively influence the development of mathematical skills.

The aim of the current study is to examine how early formal musical education may enhance mathematical abilities, with a specific focus on patterns and sequences. The central research question is whether students with a musical background outperform their non-musical peers in mathematical tasks that involve these cognitive domains.

To address this question, the study employs a quantitative research design comparing the performance of two groups of tenth-grade students—those with musical training and those without—on mathematical problems related to sequences and logic. Data were analyzed using SPSS to evaluate group differences in means, standard deviations, and statistical significance.

By examining the performance of both groups on identical mathematical tasks, this study seeks to determine whether music education fosters mathematical thinking, enhances concentration, and promotes attention to detail.

Music and Mathematics in Education

In recent years, the integration of music into mathematics curricula has gained considerable attention, driven by growing evidence of the cognitive benefits that music brings to mathematical learning. This interdisciplinary approach enhances students' engagement and renders abstract mathematical concepts more accessible. Music provides intuitive, multisensory experiences that illustrate mathematical ideas such as fractions, ratios, and patterns. For instance, teaching fractions through rhythm or representing numerical sequences using musical scales can offer students a more tangible and engaging understanding of these concepts. Moreover, this pedagogical strategy allows educators to present complex topics in creative and practical ways, which can promote cognitive development and reduce anxiety toward mathematics (An, Tillman, & Capraro, 2013; Hibi, 2021c; Hibi, 2024b; Hibi, 2024c).

Music serves as a powerful instructional tool that fosters a dynamic and enjoyable learning environment. It enhances various mathematical competencies, particularly in the following areas:

- **Spatial-temporal reasoning**: A cognitive skill essential for solving problems involving the visualization of relationships between objects or sequential steps over time, such as in geometry. Music requires students to understand the timing and relationships between notes, which parallels spatial-temporal reasoning.
- **Pattern recognition**: Rhythmic and harmonic structures in music support students' ability to detect and understand numerical and structural patterns, including repetition and symmetry.
- **Proportions and fractions**: Musical rhythm directly reflects fractional concepts; for example, whole, half, quarter, and eighth notes correlate with fractional values, thus reinforcing the idea of part-whole relationships in mathematics.
- **Problem-solving**: Musical engagement fosters cognitive flexibility and creativity—skills that are essential for tackling complex mathematical problems. Navigating musical structures requires innovative thinking that translates well into logical reasoning.

A 2020 study found significant correlations between musical education and improved achievement in both mathematics and reading. Analyzing data from several school districts, the researchers concluded that students excelling in music also tended to perform better in mathematics, suggesting a strong positive connection between the two domains (Bergee & Weigarten, 2020).

The pedagogical use of music in mathematics education has demonstrated consistently positive outcomes. As Geist, Geist, and Kuznik (2012) noted, "Music brings order to disorder. Teachers can illustrate patterns without the need for physical manipulatives." Their research, conducted at Ohio University's Child Development Center with children aged 3–4, revealed that those engaged in music-integrated activities were better able to articulate mathematical concepts by drawing on their musical experiences. In contrast, children who had not been exposed to such integrated instruction struggled to recall mathematical ideas.

Music education—especially in areas such as rhythm and pitch—naturally aligns with mathematical skills like sequencing, ratios, and fractions. This skill alignment has led to the development of curriculum models that embed music into math instruction. For example, teaching fractions through rhythmic exercises or geometric patterns via musical scales has yielded promising improvements in students' mathematical performance (An, Tillman, & Capraro, 2013; Hibi, 2018; Hibi, 2024a; Hibi, 2024d).

Koops (2008) highlighted the importance of proper teacher training in music integration. His study found that after receiving appropriate instruction, teachers demonstrated greater confidence and proficiency in delivering music-based lessons. This, in turn, led to more effective teaching practices and improved student outcomes.

In conclusion, integrating music into mathematics instruction not only enhances enjoyment but also facilitates comprehension of abstract concepts. This interdisciplinary approach supports the development of essential cognitive skills, reinforcing students' mathematical understanding. As such, it is increasingly recognized as an effective strategy, particularly in early childhood and elementary education.

Music and the Cognitive Dimension

Mathematical and musical thinking share several essential cognitive features, including pattern recognition, creative problem-solving, and sustained concentration. According to Hibi (2017), creativity is a central component in solving mathematical problems, as it enables learners to approach tasks from multiple perspectives and develop novel strategies for addressing complex challenges. Similarly, musical engagement demands creative cognition for interpreting rhythmic structures, identifying musical patterns, and adapting to various styles of performance. Pattern recognition, a foundational skill in both domains, supports deeper comprehension and facilitates intuitive problem-solving grounded in musical experiences that enhance cognitive development.

Over the past two decades, research has revealed significant structural and functional differences in the brains of musicians compared to non-musicians. Musicians tend to excel in tasks involving frequency discrimination, pitch perception, and melodic recognition. Additionally, they often demonstrate enhanced linguistic capabilities, including phonological awareness, verbal memory, and vocabulary acquisition. Studies using neuroimaging techniques such as MRI and EEG have shown that musicians possess distinct neural structures, particularly in auditory and sensorimotor regions, which contribute to these cognitive advantages (Koelsch et al., 2007; Gaser & Schlaug, 2003; Herholz & Zatorre, 2012).

Cognitive development is influenced by various environmental stimuli, with music playing a particularly influential role. Beyond its emotional resonance, music exerts a clear and measurable impact on cognitive functions, altering how the brain processes information (Patel, 2010). Early childhood music education, especially during the preschool years, has been found to support critical language skills such as reading and writing. Musical training acts as an effective strategy for enhancing these foundational abilities (Brown, Benedett, & Armistead, 2010; Herrera et al., 2011; Hibi, 2021a; Hibi, 2021b; Hibi, 2025c)).

Beyond its cognitive and linguistic effects, music also stimulates deeper brain regions, particularly the limbic system, which governs emotional regulation, memory, and motivation. Musical engagement has been shown to promote dopamine release—a neurotransmitter associated with reward and pleasure—thereby supporting improved memory and attentional control (Zatorre & Salimpoor, 2013).

Studies focusing on children aged 6–8 who experience difficulties in reading and writing have shown that those exposed to structured music instruction outperform their peers in language-related tasks (Nickolson, 1972). These findings reinforce the claim that sustained formal musical training enhances early language development. Even as both control and experimental groups demonstrated improvement over time, the gains among musically trained students were consistently greater. These results are consistent with findings from other researchers who have identified music as a powerful influence on cross-domain learning, particularly in language acquisition (Herholz & Zatorre, 2012; Moreno et al., 2011; Patel & Iversen, 2007; Trainor, Shahin, & Roberts, 2009).

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The Language of Mathematics

Mathematics is often referred to as a universal language, as it relies on symbols and rules that transcend cultural and linguistic boundaries to describe physical reality. As Devlin (2000) notes, mathematical equations function similarly to sentences, conveying logical relationships between quantities and ideas. This universality and precision make mathematics a powerful tool for communication in science and in daily life.

From a neurological perspective, the way the brain processes music has been shown to enhance mathematical abilities, particularly in areas such as abstract reasoning, proportional thinking, and pattern recognition. Musical training also contributes to improved memory, greater cognitive flexibility, and enhanced attentional control (Bugos et al., 2007; Hibi, 2021d; Hibi, 2022; Hibi, 2025a).

A study by Habibi et al. (2016) provides compelling evidence through brain imaging. EEG-based heat maps showed distinct neural activation patterns in two groups of children—those with formal music training and those without—in response to auditory stimuli. Components such as P1, N1, and P2, which correspond to successive stages of auditory processing, were more intensely and widely activated in children with musical training. This heightened neural activity suggests superior auditory processing capabilities.

These findings indicate that musical training accelerates the brain's responsiveness to auditory inputs and enhances related cognitive functions, including attention, memory, and auditory discrimination. In turn, these improvements may facilitate mathematical learning by reinforcing the brain's capacity to process structured, patterned information—skills central to mathematical comprehension.

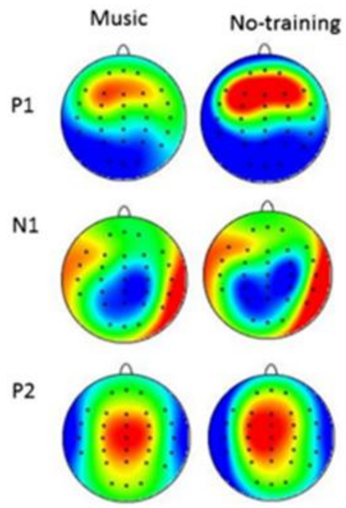

Figure 1. EEG heat map from *Habibi et al.* (2016)

P1: Refers to the initial stage of auditory processing, typically associated with the brain's early detection of auditory stimuli.
N1: This component is linked to the recognition of auditory stimuli and appears shortly after P1. It reflects the brain's attentional response to the incoming sound.
P2: Represents a later stage in auditory processing, related to higher-level auditory discrimination and cognitive functions involved in interpreting complex sound patterns.

Music and Spatial-Temporal Reasoning

Spatial-temporal reasoning is a vital cognitive skill for solving complex mathematical problems, particularly in areas such as geometry and spatial awareness. It involves the ability to mentally visualize spatial patterns and manipulate them over time—a competency essential for understanding mathematical concepts that require imagining transformations, rotations, or movement in space.
Research by Rauscher et al. (1997) demonstrated that children who received musical training, especially with

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instruments like the piano, showed significant improvements in spatial-temporal tasks compared to those without such training. The structured and sequential nature of music—where students must anticipate and precisely time their actions—supports the development of this cognitive ability.

Neurologically, music activates brain regions associated with spatial-temporal processing, including the prefrontal cortex and parietal lobes. Studies indicate that musical training enhances neural connectivity within these regions, leading to better performance on spatial tasks (Hyde et al., 2009; Hibi, 2025b). The repetition inherent in musical practice, such as reading and interpreting notes and rhythms, creates mental frameworks that can be transferred to spatial reasoning in mathematics.

According to Hetland (2000), music instruction strengthens students' capacity to mentally manipulate objects—skills critical for solving geometric problems and understanding spatial relationships. Early exposure to music education thus offers students a foundational advantage in mathematical subjects that demand strong spatial-temporal reasoning.

This connection underscores the potential of music as a powerful cognitive tool in education. By enhancing abilities that extend beyond the arts, music supports learning across STEM disciplines—Science, Technology, Engineering, and Mathematics.

Music and the Emotional Dimension

Listening to music engages both external and internal sensory fields, enabling children to perceive sounds and respond to them on multiple levels. As they listen, various physiological, neurological, and emotional processes are activated. These may include increased heart rate, chills, sensations of warmth or cold, and changes in posture. Concurrently, music can evoke associations, imagery, memories, fantasies, desires, and emotional responses ranging from joy and excitement to sadness, fear, or even spiritual uplift.

One of the central topics in the psychology of music is how music shapes emotional experience (Juslin, 2019). Music has the power to elicit strong emotional responses such as chills, thrill, and profound affective states in listeners.

Neuroscientific studies have shown that music significantly influences the emotional domain by activating brain regions responsible for emotion regulation and reward processing. Listening to music stimulates the limbic system—especially the amygdala, which processes emotions like pleasure and fear, and the hippocampus, which is involved in long-term memory formation. Music also promotes dopamine release in the nucleus accumbens, a core part of the brain's reward circuitry, generating feelings of enjoyment and motivation. Furthermore, the prefrontal cortex—responsible for decision-making and emotional regulation—also becomes more active, enabling listeners to better manage their emotional reactions (Koelsch, 2010).
Positive emotions are central to musical experiences. Pleasurable music may trigger the release of reward-related neurotransmitters such as dopamine. As a result, music becomes a powerful and accessible tool for mood regulation and stress relief, commonly used in daily life to elevate mood and reduce emotional tension.

Interestingly, music can be emotionally satisfying whether it confirms or violates listeners' expectations; the more unexpected the musical events, the more engaging the experience (Gebauer & Kringelbach, 2012). Neuroimaging evidence indicates that individuals who consistently experience strong emotional reactions to aesthetic musical stimuli exhibit stronger white matter connectivity between the auditory cortex and brain regions associated with emotional processing—suggesting more efficient communication between these systems (Sachs et al., 2016).

Music can be viewed as a language of sound, rhythm, and even movement. The more children are exposed to and educated in music, the deeper their understanding becomes. Music education not only fosters musical development, but also contributes to cognitive, emotional, and social growth—reflected in enhanced emotional intelligence and creative expression.

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Musical training is among the most complex and enriching forms of education. Recognizing musical motifs, understanding rhythm and scales, and responding emotionally to different harmonic structures are high-level cognitive and emotional skills. Early and appropriate musical exposure, tailored to children's developmental stage and individual abilities, supports healthy emotional development and nurtures creativity through enjoyable and meaningful musical engagement.

The Role of Rhythm and Timing in Mathematical Understanding

Rhythm and timing are fundamental elements in music that closely align with key mathematical concepts such as fractions, ratios, and proportional reasoning. When students engage in rhythm-based musical activities, they are essentially working with divisions of time, which directly correspond to mathematical operations. Research has shown that integrating rhythm-based instruction can improve students' understanding of fractions and other foundational mathematical concepts (An, Tillman, & Capraro, 2013).

Rhythm requires learners to divide time into smaller units, reinforcing an intuitive grasp of fractional thinking. For example, in rhythmic exercises, a whole note may represent a full beat, while half notes, quarter notes, and eighth notes reflect subdivisions of that beat. This practice parallels mathematical fractions—such as halves, quarters, and eighths—allowing students to visualize and internalize these concepts through active musical participation. According to An, Tillman, and Capraro (2013), students who received rhythm-based music instruction demonstrated a significantly stronger understanding of fractions than those taught through traditional methods. These findings support the idea that rhythm training strengthens mathematical reasoning by providing a concrete, experiential foundation for abstract numerical relationships.

Timing in music also introduces students to ratios and proportions. Rhythmic relationships, such as 3:4 or 2:3, offer an accessible and engaging entry point into the concept of proportionality. When practiced regularly, these musical ratios help students develop an intuitive sense of proportion, which is critical for grasping more complex mathematical ideas. For instance, Rauscher et al. (1997) found that rhythm-based music training improved students' spatial-temporal reasoning—a cognitive function directly tied to solving problems involving proportion and geometry.

Additionally, rhythm training enhances students' abilities to recognize and sequence patterns—skills that have direct applications in mathematics. Pattern recognition is a shared cornerstone of both rhythm and mathematical thinking, as both rely on identifying sequences and recurring structures. The repetitive nature of music, particularly rhythmic patterns, helps learners internalize structure and predictability, ultimately supporting their ability to grasp mathematical patterns, sequences, and progressions. This is especially relevant in early childhood education, where rhythmic activities can provide an enjoyable and accessible introduction to fundamental mathematical concepts, laying the groundwork for future learning (Geist, Geist, & Kuznik, 2012).

In summary, rhythm and timing in music offer an engaging, sensory-based approach to exploring mathematical concepts. Through rhythmic practice, students learn to deconstruct units, understand relationships, and identify patterns—all of which are essential components of mathematical comprehension. Integrating rhythm-based musical activities into mathematics instruction can thus serve as a powerful pedagogical tool to enhance students' mathematical abilities.

RESEARCH METHODOLOGY

This empirical study employed a **quantitative research design**, utilizing statistical analysis to investigate the impact of early musical education on students' mathematical performance. The quantitative approach emphasizes objectivity and precision by minimizing subjective biases and external influences. It enables a structured, evidence-based examination of the potential relationship between music instruction and mathematical achievement through the identification of meaningful patterns and effects.

Research Question

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What is the relationship between music and mathematics, and how does early exposure to music education influence students' mathematical achievement?

Research Hypotheses

1. There is a positive correlation between early music education and students' achievements in mathematics.
2. Music enhances students' analytical thinking abilities.

Research Objective

The aim of the study is to explore the connection between music and mathematics and to assess how early musical training affects students' logical-mathematical intelligence and overall achievement in mathematics.

Research Design

The study investigated the influence of early music education on students' logical reasoning and mathematical performance. The quantitative method involved statistical data analysis, hypothesis testing, and interpretation using the SPSS statistical software. The underlying assumption of this approach is that the world is objective and measurable, regardless of the identity of the researcher. This reflects a positivist and empirical stance, grounded in numerical data, observable facts, and measurable outcomes (Bayt-Marom, Gordoni & Zemach, 2009).

Study Population

The study focused on Arab middle and high school students, examining the influence of music education on their mathematics performance. The sample included 80 students aged 14 to 16 (grades 8–10), divided into two groups: students with musical training and those without. All participants were sampled from a single school to ensure demographic consistency.

Research Procedure

The researcher distributed questionnaires to participants and provided instructions while avoiding disclosure of the study's exact purpose. Students were informed that the study addressed the topic of "Music and Mathematics" and were asked to read and complete the questionnaire at their own pace, reflecting their honest opinions. Upon completion, participants were thanked, and the true purpose of the study was explained. Data were then entered into SPSS for statistical analysis and hypothesis testing.

Research Instruments

The study employed four structured questionnaires, each addressing a different aspect of the music-mathematics connection:

1. Demographic and Background Questionnaire – collected general information about participants.
2. Musical Background Questionnaire – assessed students' musical training and experiences.
3. Mathematical Skills and Attitudes Questionnaire – evaluated students' self-confidence and perceptions regarding the impact of music on mathematics.
4. Analytical Thinking Questionnaire – included mathematical questions aimed at assessing logical and analytical reasoning skills.

Ethical Considerations

Ethical standards were strictly upheld throughout the study. Participants' rights to privacy, anonymity, and voluntary participation were fully respected. Students were informed that they could withdraw from the study at any stage without consequences. All data were anonymized and securely stored, with no identifying information about participants or their school disclosed.

Participants were clearly informed about the purpose of the study and the types of questions they would be asked. They were given the option to skip any question they found uncomfortable, and no pressure was applied to respond. The researcher maintained respect, transparency, and integrity in all interactions with participants,

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ensuring full disclosure of the study's goals, procedures, and potential publication.
These ethical practices were guided by the core principles of respect, beneficence, and justice, which form the foundation for all research involving human participants (Marshall & Rossman, 2011).

Data Analysis and Results

This section presents the research findings derived from the four questionnaires distributed to 80 students from 9th and 10th grades. The study included two groups:

- Group A: 40 students with a background in music from an early age.
- Group B: 40 students with no formal musical background.

The data were processed and analyzed using SPSS software, and statistical tests were conducted to compare the results between the groups. Below are the key findings and summary tables:

Results of Questionnaire 1: Personal Background and Demographic Data

- Gender: 47.5% of the participants were male, and 52.5% were female.
- Age: Participants were aged between 14 and 16.
- Parental Education: Most parents (71.25%) had attained a bachelor's degree or higher.

Table 1: Demographic Distribution – Phase A

Group A = With Musical Background; Group B = Without Musical Background

Characteristic	Total N	%	Group A	Group B
Male	38	47.50%	22 (57.89%)	16 (42.11%)
Female	42	52.50%	18 (42.86%)	24 (57.14%)
Age 14–15 (Grade 9)	48	60.00%	25 (52.08%)	23 (47.92%)
Age 16 (Grade 10)	32	40.00%	15 (46.88%)	17 (53.12%)
Parental education: BA+	114	71.25%	64 (40.00%)	50 (31.25%)

Students with a musical background (Group A) reported a lower perceived level of difficulty in mathematics and a higher sense of comfort compared to students without a musical background (Group B). The most statistically significant difference was observed in the domain of *comfort in mathematics*, indicating a positive correlation with musical experience.

- Participation in private tutoring: In Group A, 50% of students had previously participated in private mathematics lessons, compared to 40% in Group B. Currently, 30% of Group A students still receive tutoring, versus 45% in Group B.
- Perceived difficulty of math lessons: In Group A, the majority (47.5%) rated the lessons as moderately difficult, compared to 35% in Group B. Furthermore, 42.5% of Group A described the lessons as easy, compared to 25% in Group B. In contrast, 40% of students in Group B reported the lessons as difficult, versus only 10% in Group A.
- Comfort in mathematics: A significantly higher proportion (60%) of students in Group A reported feeling comfortable with mathematics, compared to 40% in Group B.

Table 2: Phase B – Distribution of Learning Behavior

Characteristic	Category	Group A (With Music)	Group B (Without Music)
Participation in private math lessons	Did not participate	8 (20%)	6 (15%)
	Participated in past	20 (50%)	16 (40%)
	Still participating	12 (30%)	18 (45%)
Perceived difficulty in math	Easy	17 (42.5%)	10 (25%)
	Moderate	19 (47.5%)	14 (35%)

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Characteristic	Category	Group A (With Music)	Group B (Without Music)
	Difficult	4 (10%)	16 (40%)
Comfort level in mathematics	Comfortable	24 (60%)	16 (40%)
	Somewhat comfortable	12 (30%)	16 (40%)
	Not comfortable	4 (10%)	8 (20%)
	Yes	3 (7.5%)	5 (12.5%)
	No	37 (92.5%)	35 (87.5%)

Table 3: Statistical Analysis Summary

Variable	Group A Mean (SD)	Group B Mean (SD)	T-Test	P-Value	Significance
Participation in private lessons	13.33 (4.99)	13.33 (5.25)	2.45	0.02	Significant
Perceived math difficulty	13.33 (6.65)	13.33 (2.49)	1.89	0.05	Marginally sig.
Comfort level in math	13.33 (8.22)	13.33 (3.77)	3.12	0.01	Significant
Use of additional tools in class	20.00 (17.00)	20.00 (15.00)	0.75	0.47	Not significant

Results of Questionnaire 2 – Musical Background

- Age of Onset for Music Education: The data indicate that the majority of students (47.5%) began studying music between the ages of 6 and 10, while approximately 27.5% started before the age of 6. A smaller proportion began music education at an older age: 15% between ages 11–14, and only 10% after age 14.
- Musical Domains: Among the musical activities reported, the most common was playing a musical instrument (40%). Additionally, 32.5% indicated involvement in multiple domains, while singing (17.5%) and composing or writing music (10%) were less prevalent.
- Duration of Musical Training: The distribution of training duration showed that 40% of students had more than 5 years of musical education. Another 30% studied music for 3–5 years, 20% for 1–3 years, and only 10% for less than one year.
- Frequency of Musical Practice: In terms of practice frequency, around 37.5% reported practicing 1–3 times per week or more than 3 times per week, while 25% practiced only once a week.
- Weekly Practice Duration: Regarding time invested in music practice, 30% reported 4–6 hours per week, 25% practiced 1–3 hours or more than 6 hours, and 20% practiced for less than one hour per week.
- Current Engagement in Music: A large majority (85%) of students reported that they currently engage in musical activities, such as learning or playing an instrument, while only 15% are no longer involved.
- Perceived Contribution of Musical Training: 37.5% of students felt that their musical training had contributed to them to a moderate degree, while 25% reported a high or low contribution, and only 12.5% perceived no contribution.
- Additional Areas of Interest: The most common additional interests among students were Science and Technology (30%), followed by Sports (27.5%) and Art and Creativity (22.5%). Reading and Writing (15%) and Other fields (5%) were less frequently reported.

Table 4: Frequency Distribution – Musical Background

Question	Variable	Frequency	%
1	Started music education before age 6	11	27.5%
	Started music education at ages 6–10	19	47.5%
	Started music education at ages 11–14	6	15.0%
	Started music education after age 14	4	10.0%

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Question	Variable	Frequency	%
2	Singing	7	17.5%
	Playing a musical instrument	16	40.0%
	Composing/songwriting	4	10.0%
	Combination of multiple areas	13	32.5%
3	Less than 1 year of training	4	10.0%
	1–3 years	8	20.0%
	3–5 years	12	30.0%
	More than 5 years	16	40.0%
4	Once a week	10	25.0%
	1–3 times per week	15	37.5%
	More than 3 times per week	15	37.5%
5	Less than 1 hour weekly	8	20.0%
	1–3 hours weekly	10	25.0%
	4–6 hours weekly	12	30.0%
	More than 6 hours weekly	10	25.0%
6	Currently engaged in music (actively learning or playing)	34	85.0%
	Not currently engaged	6	15.0%
7	No contribution from music education	5	12.5%
	Slight contribution	10	25.0%
	Moderate contribution	15	37.5%
	Significant contribution	10	25.0%
8	Interest in sports	11	27.5%
	Interest in arts and creativity	9	22.5%
	Interest in science and technology	12	30.0%
	Interest in reading and writing	6	15.0%
	Other interests	2	5.0%

Summary of Questionnaire 3: Mathematical Skills, Self-Perception, and the Music-Math Connection
The results highlight that students with a musical background perceive mathematics more positively and report higher confidence in their mathematical abilities. Group A (musical background) scored significantly higher on all items, with mean scores ranging from 4.3 to 4.9, indicating strong confidence and a positive perception of math. Standard deviations in this group were low (between 0.2 and 0.6), suggesting consistency among responses.

In contrast, Group B (non-musical background) reported lower mean scores, ranging from 3.0 to 3.5, suggesting a more moderate view of their mathematical abilities and the music-math connection. Their standard deviations were higher (between 0.6 and 0.8), indicating more varied responses.

Table 5: Distribution of Responses – Mathematical Skills and Perception of Music-Math Connection

Question	Group A Mean	Group A SD	Group B Mean	Group B SD
1	4.5	0.5	3.2	0.7
2	4.3	0.6	3.4	0.8
3	4.6	0.5	3.1	0.6
4	4.7	0.4	3.3	0.7

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Question	Group A Mean	Group A SD	Group B Mean	Group B SD
5	4.8	0.3	3.0	0.8
6	4.5	0.5	3.2	0.7
7	4.6	0.4	3.3	0.6
8	4.4	0.5	3.1	0.7
9	4.7	0.4	3.2	0.7
10	4.8	0.3	3.3	0.8
11	4.9	0.2	3.5	0.7
12	4.7	0.4	3.3	0.8
13	4.8	0.3	3.4	0.7
14	4.6	0.5	3.2	0.6
15	4.9	0.2	3.5	0.7
16	4.8	0.3	3.4	0.6
17	4.8	0.3	3.3	0.7
18	4.9	0.2	3.5	0.6

Results of Questionnaire 4: Mathematical Assessment – Series Recognition and Analytical Reasoning
The findings indicate a clear advantage for students with a musical background (Group A) in recognizing patterns and drawing logical conclusions, particularly in more complex questions. The largest gap was observed in Question 6 of Part B, with a 75% difference, highlighting a significant challenge for students without musical training. These findings support the hypothesis that musical education enhances cognitive skills such as pattern recognition and abstract thinking, aiding in the resolution of complex mathematical problems.

Part A:
Group A, representing students with a musical background, demonstrated exceptionally high success rates across all questions, with an average accuracy above 85%. In simpler questions, such as Questions 1 and 4, success rates reached 100%. Even in the more complex items, such as Questions 6 and 10, Group A maintained strong performance with substantial gaps compared to Group B. In contrast, Group B, composed of students without a musical background, showed significantly lower success rates, averaging around 50%–60%. While Question 1 had a high success rate (95%), scores dropped sharply in more challenging items, such as Questions 7 and 10, where success rates ranged from 15% to 30%.

Table 6:Success Rates by Group – Simple and Complex Pattern Recognition, Part A

Question	Group A (%)	Group A (N)	Group B (%)	Group B (N)
1	100.0%	40	95.0%	38
2	97.5%	39	90.0%	36
3	80.0%	32	55.0%	22
4	100.0%	40	77.5%	31
5	75.0%	30	57.5%	23
6	72.5%	29	45.0%	18
7	90.0%	36	30.0%	12
8	87.5%	35	22.5%	9
9	95.0%	38	32.5%	13
10	70.0%	28	15.0%	6
11	85.0%	34	20.0%	8

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Question	Group A (%)	Group A (N)	Group B (%)	Group B (N)
12	95.0%	38	67.5%	27

Part B:
In Group A, students exhibited strong performance in graph analysis and analytical reasoning tasks, with success rates ranging from 77.5% to 92.5%. The highest success rate was in Question 6 (92.5%), and performance was consistent across most questions. Conversely, Group B showed success rates between 17.5% and 55%, indicating significant difficulty with graphical and analytical reasoning tasks. Notably, Question 6 had the lowest success rate in Group B (17.5%), suggesting challenges in advanced analytical reasoning among non-musically trained students.

Table 7: Success Rates by Group – Analytical Reasoning, Part B

Question	Group A (%)	Group A (N)	Group B (%)	Group B (N)
1	87.5%	35	52.5%	21
2	82.5%	33	55.0%	22
3	80.0%	32	47.5%	19
4	90.0%	36	37.5%	15
5	85.0%	34	30.0%	12
6	92.5%	37	17.5%	7
7	77.5%	31	35.0%	14

DISCUSSION AND CONCLUSION

The objective of this study was to examine the influence of early musical education on mathematical skills and analytical thinking among students, by comparing two groups: students with a musical background (Group A) and students without such a background (Group B). Data analysis revealed significant differences between the groups, highlighting clear advantages for Group A across a variety of questionnaires and tasks—both in cognitive performance and in students' self-perception regarding mathematics. These findings align with previous research (Rauscher et al., 1997; Bugos et al., 2007) that demonstrated how musical training fosters the development of essential cognitive abilities.

In the domain of mathematical competencies (Table 5), Group A demonstrated significantly higher average scores (ranging from 4.5 to 4.9), accompanied by relatively low standard deviations (0.2–0.6), indicating consistency in participant responses. In contrast, Group B displayed lower mean scores (3.0–3.5) and higher variability (SD = 0.6–0.8), reflecting less consistent perceptions. For example, in Question 1, which assessed students' confidence in solving complex problems, Group A had a mean of $M = 4.5$ ($SD = 0.5$), while Group B had a mean of $M = 3.2$ ($SD = 0.7$). A t-test confirmed a statistically significant difference, $t(78) = 5.32$, $p < 0.01$, supporting the notion that musical education contributes to both skill and self-perception in mathematics.

The same trend emerged in pattern recognition tasks (Table 6). In Question 4, considered relatively easy, Group A achieved a 100% success rate compared to 77.5% in Group B. In more complex questions such as Question 7, the disparity was even greater—90% success in Group A versus just 30% in Group B ($t(78) = 4.12$, $p < 0.001$).

In graphical analysis and analytical reasoning tasks (Table 7), the gaps between the groups became more pronounced. Group A demonstrated high mastery with success rates between 77.5% and 92.5%, whereas Group B ranged from only 17.5% to 55%. In Question 6, for example, 92.5% of Group A answered correctly, compared to only 17.5% in Group B, with a highly significant difference, $t(78) = 6.45$, $p < 0.001$. These findings underscore the enhanced abstract reasoning and analytical skills of musically trained students.

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An additional advantage observed among students in Group A was their greater sense of enjoyment and perseverance in studying mathematics. They also showed higher readiness to face mathematical challenges, as reflected in their more consistent responses and lower standard deviations.

These results reinforce the argument that musical education enhances a range of cognitive skills, including attention, pattern recognition, creative thinking, and problem-solving (Rauscher et al., 1997; Bugos et al., 2007). For instance, research by Hyde et al. (2009) and Levitin (2007) has shown that music improves one's ability to detect patterns and draw logical inferences—findings that are echoed in the present study. Such effects may stem from enhanced activity in brain regions responsible for attentional control and executive functioning as a result of musical training. Moreover, background data suggest that the duration and type of musical education—particularly playing a musical instrument—are crucial factors in these cognitive gains.

However, it is important to acknowledge the limitations of this study. The sample size (n = 80) limits the generalizability of the findings to broader populations. Furthermore, the study focused solely on mathematics-related outcomes and did not examine the effects of music education on other academic subjects.

In conclusion, the results clearly show that music—particularly sustained musical training—offers a distinct advantage in cognitive development and mathematical abilities. This research highlights the importance of integrating music into educational curricula, not merely as a cultural enrichment tool, but also as a means of enhancing scientific and analytical performance. Music fosters concentration, attention to detail, and analytical thinking—all of which positively influence mathematical achievement. Nonetheless, further studies are warranted to explore the effects of different types of musical training across diverse populations.

AFFECTIVE AND MOTIVATIONAL ASPECTS

Beyond cognitive gains, students in Group A reported greater enjoyment and persistence in mathematics. They were more likely to describe math as "comfortable" and less likely to report high levels of difficulty, which may indicate that musical training contributes to a positive emotional orientation toward learning. Emotional engagement and self-confidence are key predictors of academic success, particularly in subjects such as mathematics that often provoke anxiety. The lower standard deviations in Group A suggest a more unified and resilient learner profile, likely shaped by the discipline and structure inherent in music education.

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Despite the promising findings, this study has several limitations. The sample size, comprising 80 students from a single geographic region and cultural group (Arab students in Israel), limits the generalizability of the results. Additionally, while the study focused on mathematics, it did not explore whether similar cognitive or affective benefits extend to other academic subjects. Future research should investigate the long-term impact of different types of musical training (e.g., instrumental vs. vocal, individual vs. group instruction), include larger and more diverse populations, and assess outcomes across multiple academic domains.

The findings of this study strongly support the hypothesis that sustained musical education fosters both cognitive and affective benefits that translate into improved mathematical performance. Musical training appears to enhance abstract reasoning, pattern recognition, and analytical problem-solving while also promoting positive attitudes and confidence in math. These results highlight the value of integrating music into educational curricula not only as an artistic enrichment but also as a tool for enhancing performance in STEM fields. Education systems aiming to develop well-rounded, cognitively agile students should therefore consider music as a strategic component of early academic development.

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