The Effect of Musical Intelligence on Students' Academic Achievement in Science

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Abstract

Gardner's Multiple-Intelligences theory can serve as a powerful instrument for an assessment of learners' abilities and aptitudes. The present cross-sectional descriptive-correlational study aimed to assess Gardner's Multiple Intelligences profile, specifically Musical Intelligence and Mathematical Intelligence, of science students at The City College of New York in the academic fall semester of 2021. The relationship between Musical and Mathematical Intelligence and academic performance was examined. Data was collected by administering Gardner's Musical and Mathematical Intelligences Assessment Scales to 160 subjects selected by non-probability convenience sampling. Academic performance of students was evaluated by grade point average (GPA). The results show 6/13 components of Musical Intelligence had a positive correlation to GPA compared to 7/13 components being negatively correlated. Alternatively, 2/11 components of Mathematical Intelligence were positively correlated while 9/11 components were negatively correlated. Overall there are more positive correlations in Musical Intelligence when compared to Mathematical Intelligence. Students with a higher GPA believed it would help to learn a scientific concept using a musical tune. There was a negative correlation between knowing how to play a musical instrument and GPA, while there was a positive correlation with believing that learning a musical instrument can help when learning science and GPA. This study can be used as applied knowledge to improve the quality of education counseling provided for future science students.

Introduction

Gardner's theory of Multiple Intelligences proposes that people do not have one type of general intelligence, but rather as people experience the world differently, they gain different types of intelligences. These intelligences were presented as Linguistic, Logical/Mathematical, Spatial, Bodily-Kinesthetic, Musical, Interpersonal, and Intrapersonal. A major concern of Gardner when proposing this theory was the fact that many schools exclusively teach using linguistic symbolization and logical-mathematical symbolization (Gardner & Hatch, 1989). When students are offered a variety of learning experiences through the teaching strategy based on Multiple Intelligences, they become more actively engaged, connected, and invested in their individual learning process and natural curiosity. Because of this, student's participate more frequently and retain more knowledge because they understand the material in a more complex way (Abdi et al., 2013).

There are still no definitive results on the effect of Musical Intelligence in learning science. There are many studies that prove Musical Intelligence does have an effect on education, but many studies disprove this idea. Musical Intelligence refers to many aspects of music.

Only when a student plays an instrument does the right and left hemispheres work together equally. The right hemisphere of the brain creates the holistic relationship of tones into chords, or harmony. The left hemisphere generates melodies and direction. Another key aspect of Musical Intelligence is transposition, which is the moving from one key to another. Another key aspect of music is when the student learns to hear the music in their mind for a few seconds before actually starting to play. This creates imagination development. This is directly correlated with what a music maker has to do because they must hear the music in their mind first before being able to add on to the song or add another part on top of it. The longer the line that is repeated and kept in the mind before it is played, the greater the opportunity for improvising (Reinhard, 2015).

A study by Weber et al. (1993) suggests that music can be a tool for metacognition, or thought about one's thinking. This has shown to increase our understanding for learning, especially in mathematics and language (Weber et al., 1993). According to a study by Graziano et al. (1999), second graders who had keyboard training did better on tests in mathematics than a control group who did not have keyboard training (Graziano et al., 1999). As both hemispheres are involved in the process of musical thinking, a brain study was done on professional string players showing that there was new circuitry in the right brain (Elbert et al., 1995). While playing an instrument (especially keyboard instruments) appear to have the most improvement in cognitive performance, vocal training, musical learning in general, and rhythmic training can also have an effect (Luiz et al., 2009).

There is a brief improvement in spatial tasks when Mozart tapes were listened to compared to silence or a relaxation tape (Rauscher et al., 1993). Yalamanci (2013) studied the effect of Musical Intelligence on science education by teaching a PowerPoint presentation with Enzymes Music to the third grade students in Kafkas University. The results showed that there was a significant increase in score from the pre-test and post-test in the experimental group. Additionally, there was a significant difference in retention rate of the material three weeks after the activities were taught (Yalamanci, 2013). A study by Ribeiro and Santos (2017) suggested that non-instrumental musical training (NIMT) had an effect on mathematical skills. 223 8-year-old children from Brazil were split into two clusters: cluster 1 had expected achievement in math, while cluster 2 had low achievement in math. NIMT was conducted and both groups showed significant differences from pre-NIMT to post-NIMT on scores in counting backwards, dictation of number, mental calculations, reading numbers, contextual estimation, and problem solving (Ribeiro & Santos, 2017). There is a potential advantage for using science-content songs for teaching. Song lyrics that present factual information can help students retain and understand the material (Campbell, 1990). Music training can be a dominant way for some students to learn. Therefore, it would make sense for teachers to incorporate this method of teaching (Boyer, 1983).

Musical Intelligence has also been disproven as a method of teaching in education. For example, a study by Ruthsatz et al. (2008) revealed that there is no significance between general intelligence and musical achievement by a significant correlation between accumulated

practice time and musical achievement. The only significance was seen in professional musicians who had higher mean levels of general intelligence, musical achievement, and accumulated practice time (Ruthsatz, 2008). Another study by Ahvan and Pour (2016) done on secondary students revealed that while Logical, Visual, Verbal, Bodily, Interpersonal, Intrapersonal Intelligence had a significant positive correlation with academic achievement, Musical Intelligence was a negative predictor of academic achievement (Ahvan & Pour, 2016). Afaneh and Khazendar conducted another study on students from 1st to 10th grade that showed no differences in academic achievement for males and females in Musical, Intrapersonal, or Interpersonal Intelligence (Afaneh & Khazendar, 2004).

The topic of Musical Intelligence in science education proves to be a complex and abstract idea. While studies say that the "critical periods" of optimal brain development for musical learning most likely occur before the end of age 10 when musical pruning occurs (Langstaff, 1996), there is still other research to be done on whether attaining Musical Intelligence training through school can improve students ability to learn. Our research focuses on Musical Intelligence and the GPA of science students, alternatively investigating Logical/Mathematical Intelligence and the GPA of science students. We are also interested in understanding the connection between having previous experience learning how to play a musical instrument and GPA in science students. This will give us a broader understanding of the influence of music and Musical Intelligence on education in science.

Methods

This project was designed to test Musical Intelligence and Logical/Mathematical intelligence in science students. The project took place as an online survey at the City College of New York (CCNY) during the fall semester of 2021. The City College of New York is an urban minority serving public college with a commuter student body. Inclusion criteria were that participants: (1) be enrolled as a student at CCNY (2) declared as a science major (3) be able to speak and read English (4) provide informed consent. A total number of 200 participants were invited, but 160 participants were included in analyses. We created a survey made up of both Likert-type and open-ended questions in order to gather data about student conceptions and practices. Statements that proved Musical Intelligence and Logical/Mathematical Intelligence were referenced from Walter Mckenzie, n.d. and Thomas Armstrong (p. 35, 37). The survey was administered to, and collected from 166 participants with approval from the CCNY Internal Review Board (IRB).

The Likert-type questions were on a five-point scale using numerical values as follow: Strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5). The average numerical values of students responses for each question were calculated and displayed in scatter plots. The graphs were created with GPA on the x-axis and the Likert scale on the y-axis. The questions that were asked in the survey were split into different graphs based on positive or negative correlation, and musical intelligence or mathematical intelligence. The split was made in order to clearly view which questions have correlations with GPA, and

which questions were asked for musical versus mathematical intelligence.

For the three open-ended questions, we used a rubric to convert the respondents' answers into numerical values ranging from 1 and 2 and 1-5. The Likert-type questions values were averaged and displayed in scatter plots. Similar to the questions on the survey that were based on the Likert-scale, GPA was on the x-axis, and the average answer of respondents was on the y-axis.

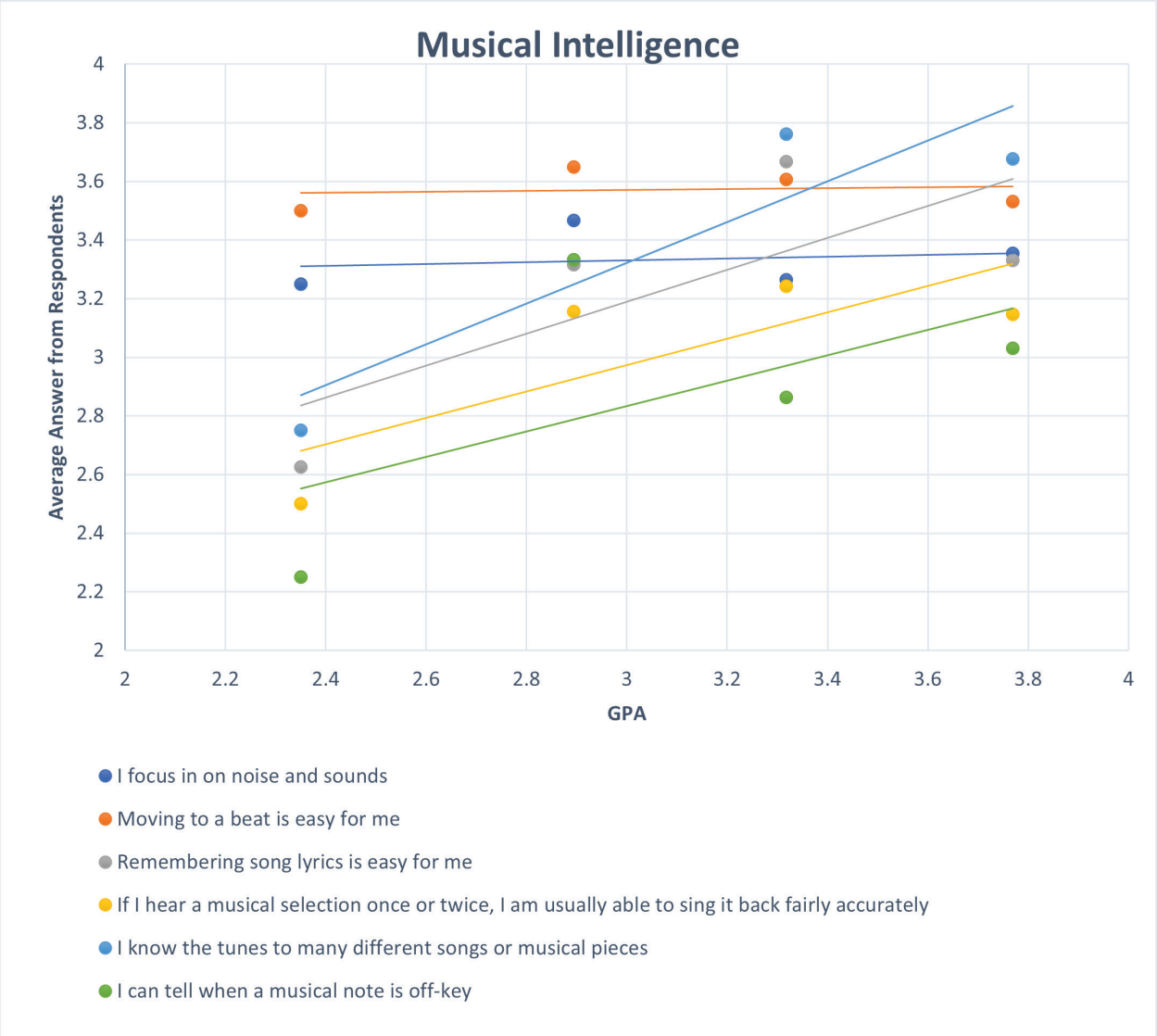

Figure 1: Average responses of students GPA to Likert-type questions in our survey about musical intelligence. All the correlations in this graph are positive. The score of the answers were as follows: Strongly disagree=1, Disagree=2, Neutral=3, Agree=4, Strongly agree=5.

Guiding Research Questions

- How did science students respond to questions that rated their Musical Intelligence and Mathematical Intelligence?
- Is there a correlation between Musical Intelligence and GPA in science students?
- What role does Logical/Mathematical Intelligence play in the GPA of science students and how does this compare with Musical Intelligence?
- Do students rely on musical tunes or previous musical experiences to learn science?

Results and Discussion

The graph in figure 1 shows the various statements that, if answered a 5 on the Likert Scale shows a high level of Musical Intelligence. According to the trendline of the various statements, these are all positively correlated. Our data shows that as student's GPA increases, students tend to have an increased ability to focus in on noise and sounds, it is easier for students to move to a beat, it is easier to remember song lyrics, it is easier to hear a musical selection once or twice and sing it back fairly accurately, students know more tunes to many different songs or musical pieces, and it is easier to tell when a musical note is off-key.

These statements can all be related to teaching a musical tune in education. From these questions, it can be inferred that the student focuses on the music and is able to interpret the music they listen to. Being able to remember song lyrics, singing a song back fairly accurately, knowing the tunes to many different songs or musical pieces, and being able to tell when a music note is off-key all require analysis and focus of the music. This shows that students with a higher GPA have a "good ear" for music. When learning a musical tune to help learn scientific concepts, this idea can come into play.

Students who have a higher GPA are able to better understand and break up music into its components. This will help students when they add scientific concepts to music they listen to because they can remember the lyrics easily. According to past research done by Ferreri et al., music enables people to chunk words together and this can positively influence both episodic encoding and retrieval of verbal information (Ferreri et al., 2015). Chunking allows a group of words or phrases to be learned together rather than one at a time. Because of this, music can provide a less demanding way to retrieve information. Learning a scientific concept using a musical tune can therefore help students, and from our data it has shown that there is a possibility that students already use this method to learn science because of the correlation with GPA.

Overall in this graph, there are six out of 13 questions that were asked in the survey that show a positive correlation with Musical intelligence and GPA in science students.

The graph in figure 2 shows the various statements that, if answered a 5 on the Likert Scale shows a high level of Musical Intelligence. According to the trendline of the various statements, these are all negatively correlated. Our data shows that as student's GPA increases, students tend to have a harder time picking up on patterns, are less likely to make tapping sounds or sing melodies while working, studying, or learning something new, less

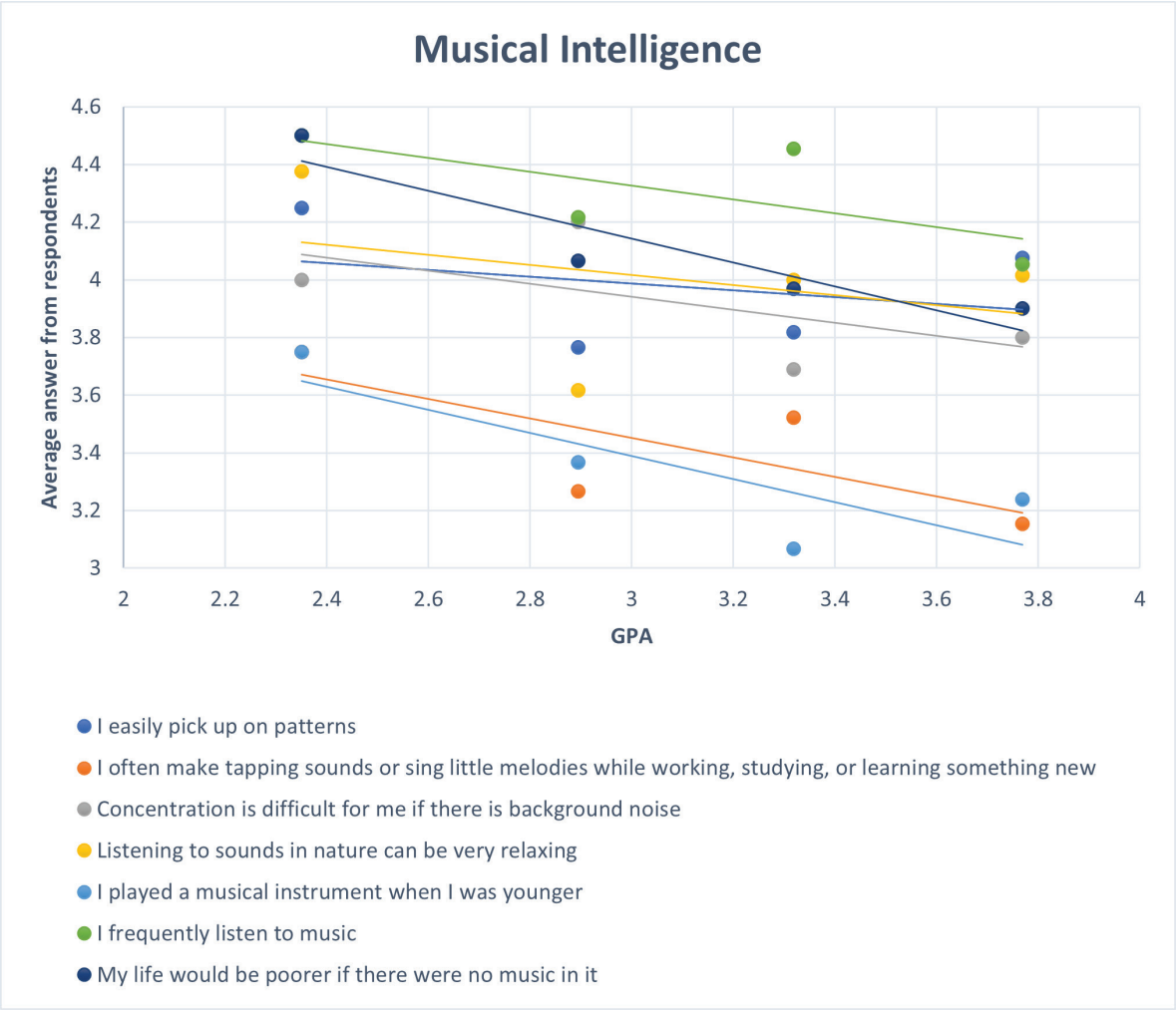

Figure 2: Average responses of students GPA to Likert-type questions in our survey about musical intelligence. All the correlations in this graph are negative. The score of the answers were as follows: Strongly disagree=1, Disagree=2, Neutral=3, Agree=4, Strongly agree=5.

likely to be disrupted by background noise when trying to concentrate, less likely to find relaxation in listening to sounds of nature, less likely to play an instrument when they were younger, less likely to listen to music frequently, and less likely to have a poorer life without music in it.

People with musical intelligence are able to hear and recognize patterns easily. This is attributed to being sensitive to rhythm and sound. Based on these results, students may not look for patterns in new information in order to increase learning. According to previous research, musicians show auditory perception and production abilities, such as enhanced capacity to detect deviations in complex regularities and tone patterns (Tervaniemi, 2001). This distinction in musical patterns may not transfer to patterns in science education. This may be a reason why the correlation is negative.

The next two questions with a negative correlation, which are making tapping noises or sing little melodies while working, studying or learning something new, and concentrating

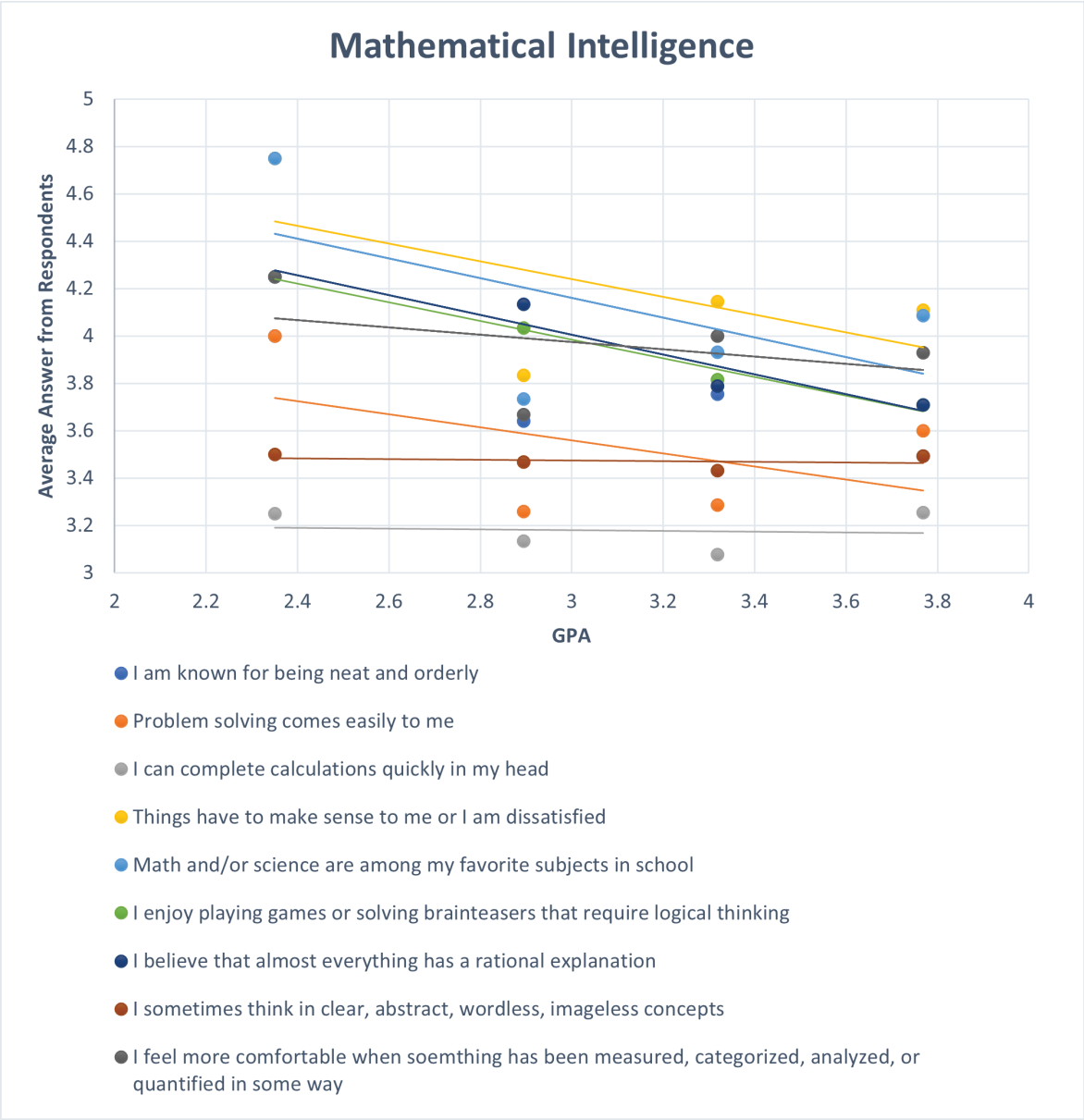

Figure 3: Average responses of students GPA to Likert-type questions in our survey about Logical/Mathematical intelligence. All the correlations in this graph are negative. The score of the answers were as follows: Strongly disagree=1, Disagree=2, Neutral=3, Agree=4, Strongly agree=5.

is difficult if there is background noise are both related to listening to music while working/studying. In this case, listening to music is not the main activity that the student is prioritizing. Overall in this graph, there are seven questions out of 13 that were asked in the survey that show a negative correlation with Musical intelligence and GPA in science students.

The graph in figure 3 shows the various statements that, if answered a 5 on the Likert Scale shows Logical/Mathematical Intelligence. According to the trendline of the various statements, these are all negatively correlated. Our data shows that as student's GPA increases,

students tend to be less neat and orderly, they are less likely to have problem solving come easy, they are less likely to complete calculations quickly in their head, they are less likely to feel that they are dissatisfied if things do not make sense to them, they are less likely to have math and/or science as their favorite subjects in school, they are less likely to enjoy playing games or solving brainteasers that require logical thinking, they are less likely to believe that almost everything has a rational explanation, they are less likely to think in clear, abstract, wordless, imageless concepts, and they are less likely to feel comfortable when something has been measured, categorized, analyzed, or quantified in some way.

The reason for measuring Mathematical Intelligence was to have a comparison with Musical Intelligence using another of Gardner's Multiple Intelligences from his theory. Mathematical Intelligence is the closest related Intelligence one would suppose a science student would have. Mathematical Intelligence involves the mental capacity to understand numbers, scientific processes, logic, and reasoning. However, overall in this graph, there are nine out of 11 questions that were asked in the survey that show a negative correlation with Mathematical intelligence and GPA in science students. These results show that science students do not show a higher level of Mathematical Intelligence as GPA increases and

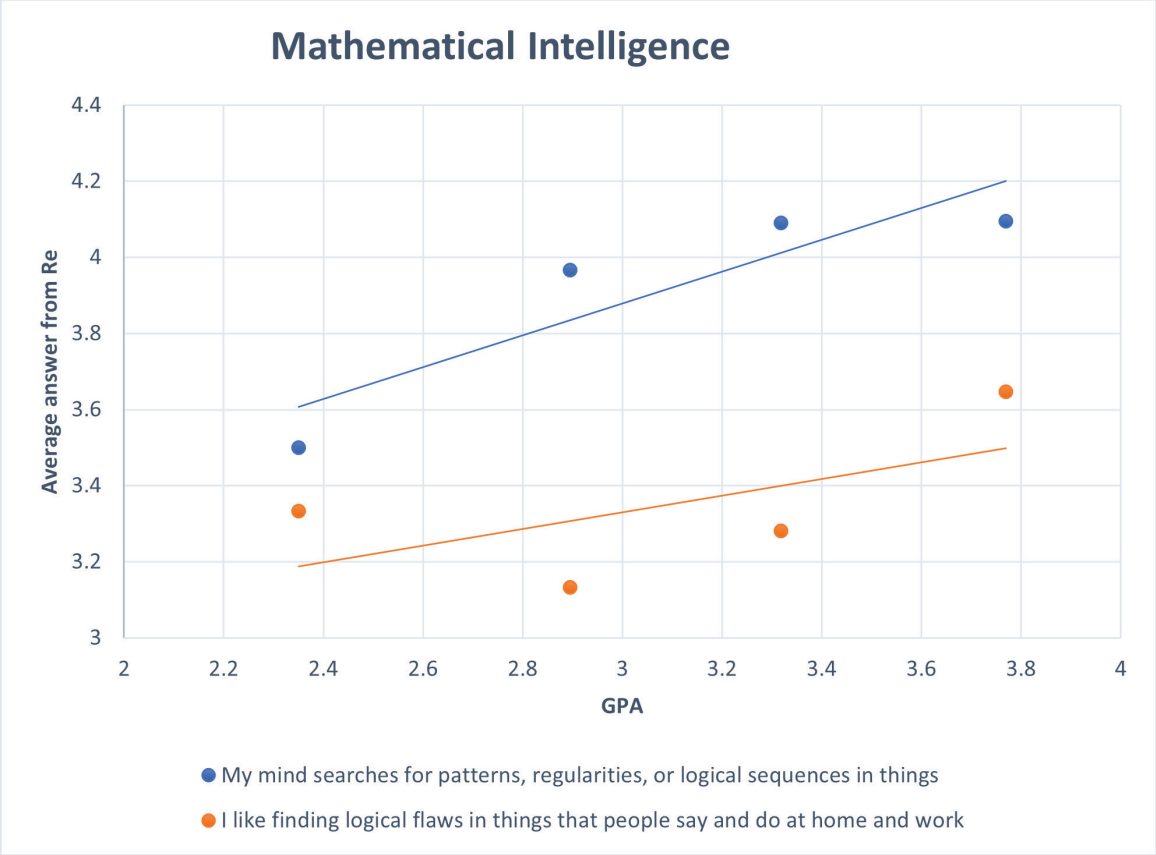

Figure 4: Average responses of students GPA to Likert-type questions in our survey about Logical/Mathematical intelligence. All the correlations in this graph are positive. The score of the answers were as follows: Strongly disagree=1, Disagree=2, Neutral=3, Agree=4, Strongly agree=5.

Mathematical Intelligence may not be a factor in helping science students learn. Science students had a higher rate of having Musical Intelligence compared to having Mathematical Intelligence as GPA increased.

The graph in figure 4 shows the various statements that, if answered a 5 on the Likert Scale shows Logical/Mathematical Intelligence. According to the trendline of the various statements, these are all positively correlated. Our data shows that as student's GPA increases, students minds are more likely to search for patterns, regularities, or logical sequences in things, and are more likely to like finding logical flaws in things that people say and do at home and work.

The question asked about whether or not the student searches for patterns, regularities, or logical sequences is a similar question and is an overlap between Mathematical and Musical Intelligence questions. Previously it was noted that as GPA increased, the student's ability to pick up on patterns increased. This aligns with the ability to use the chunking method when learning a scientific concept using a musical tune. Although this was a question related to Mathematical Intelligence, this characteristic shows that it can help students learn science.

The data obtained from this research project suggests that there are more positive correlations in Musical Intelligence when compared to Mathematical Intelligence. Out of the 13 questions asked that scored Musical Intelligence, compared to 11 that scored Mathematical Intelligence, six had a positive correlation with GPA in Musical Intelligence compared to two in Mathematical Intelligence. Alternatively, seven questions had a negative correlation with GPA in Musical Intelligence compared to nine questions in Mathematical Intelligence. This data may support the idea that Musical Intelligence has a more positive effect on science students compared to Mathematical Intelligence.

The graph in Figure 5 shows that there is a positive correlation with GPA and having learned a scientific concept using a musical tune. This is not representative of if the student actually wanted to learn a scientific concept using a musical tune, but if they were ever taught this way during their education. This can be attributed to the benefit of music in science education regardless of the student's level of Musical Intelligence. Based on the data, learning a scientific concept using a musical tune increased as GPA increased.

Previous research has shown that there is also a positive correlation between content-rich songs in science and student engagement and learning. Students enjoyed the material more and were more engaged. There was little off task behavior (Governor, 2013). As well as this, there was also a significant increase of 34% of scores of mean daily quiz scored by students who received instruction using choral responding and mnemonic devices (Haydon et al., 2017). Another study showed that participants recalled a list of new words much easier and had a lower rate of pause detection when the words were presented with familiar music. Participants were able to recall ~7% more new words through music (Tamminen et al., 2017). This is in line with our results in that students answering the survey agreed that learning a musical tune helped their learning experience in science, and this was correlated with higher GPA. A higher GPA can signify that students learn better using a musical tune

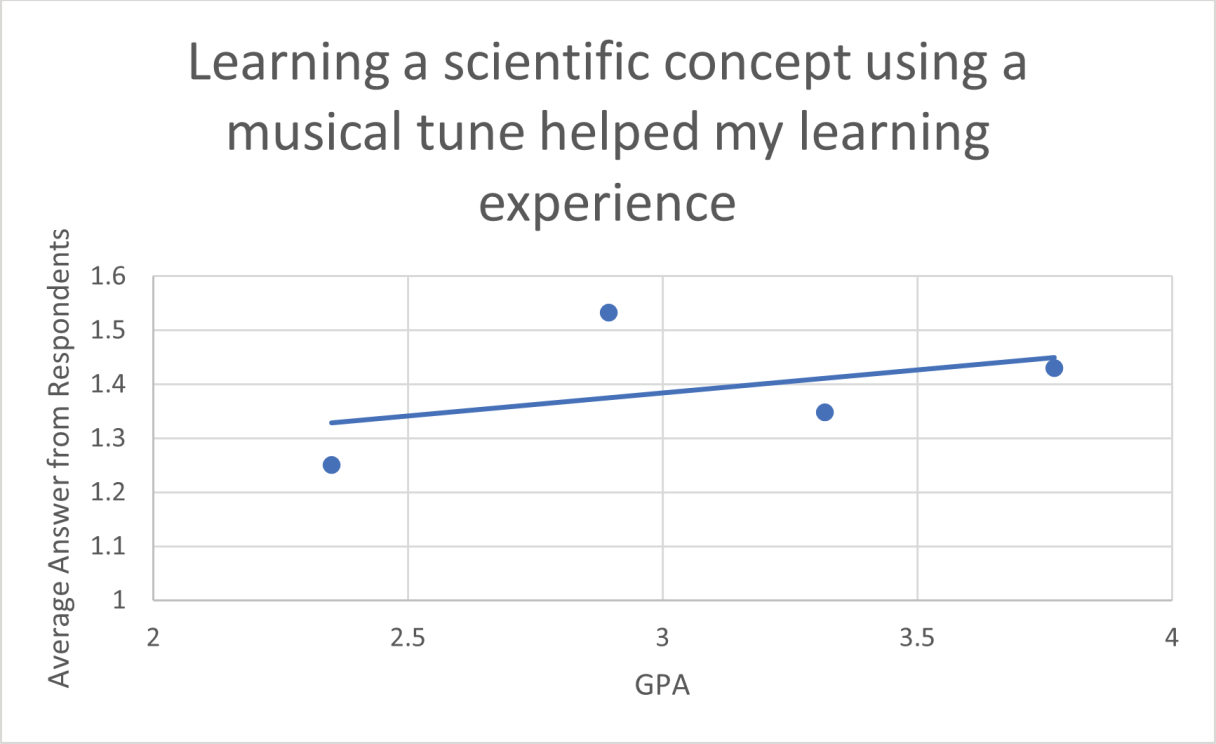

Figure 5: Graph of student's response to having learned a scientific concept using a musical tune. In the graph, an average answer of 1 meant the students have never experienced learning a scientific concept using a musical tune, and an average response of 2 meant the students have experienced learning a scientific concept using a musical tune.

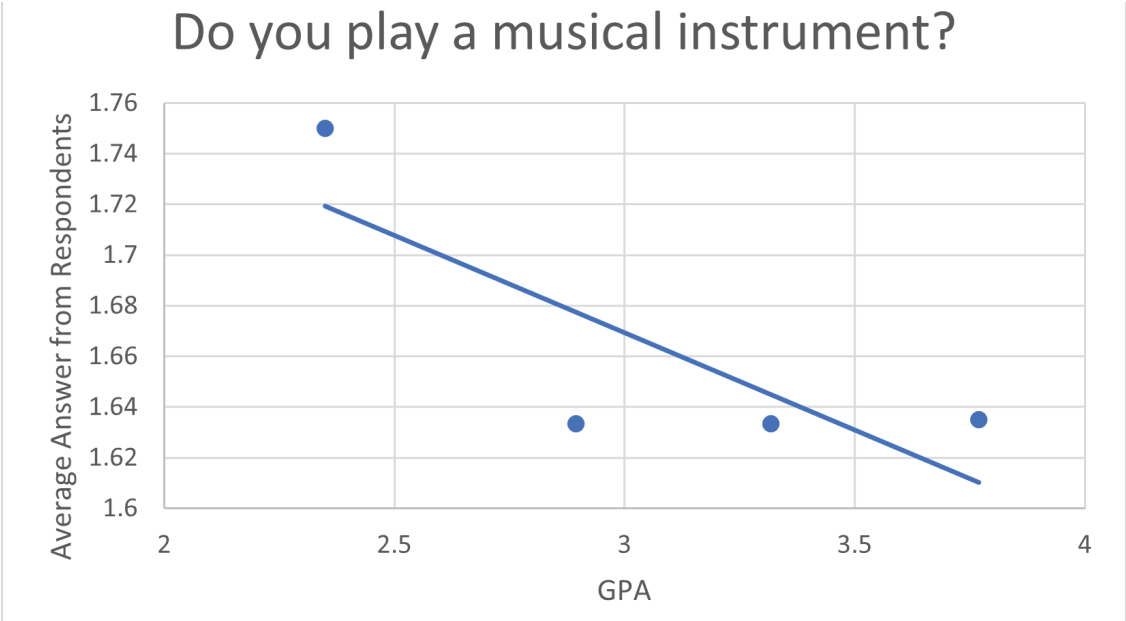

Figure 6: Graph of student's response to playing an instrument. An average answer of 1 meant the students have never experienced playing an instrument, and an average response of 2 meant the students have experienced playing an instrument.

to help them while learning and studying.

The graph in Figure 6 shows that there is a negative correlation with GPA and having played an instrument. The data also showed that students that had a higher GPA had a less likely chance to play a musical instrument compared to students with low GPAs. According to past research, cognitive performance seems to be improved from playing a musical instrument (Luiz, 2009). Another past study shows that meta-cognition, attention, and working memory, which are all cognitive mechanisms, are most likely important for efficient intentional practice and learning (Ullen et al., 2016), and also show significant correlations with intelligence (Schwiezer, 2004).

Our results are not in line with the results of previous research as students with a lower GPA had a higher rate of playing an instrument, while higher GPA students had a lower rate of playing an instrument. There is a similar result in Figure 2 that depicts a negative correlation between students who have played an instrument when they were younger and GPA. A possible reason for this inconsistency with past research can be that GPA may not be an adequate marker for measuring cognitive thinking. A study done in a high school in Southern California showed that the overall GPA of music students was 3.59/4 while the GPA of non-music students was 2.91/4 (Michela, n.d.) . Although this study was measuring the GPA of music students, our study focused on science students who were not necessarily majoring in music.

The graph in Figure 7 shows that there is a positive correlation with GPA and believing that learning a musical instrument can help when learning science. Students with a higher GPA had a higher perception of the effect of a musical instrument on science education. This may be attributed to student's being aware of the benefits of learning a musical instrument.

However, compared to the negative correlation between students that played an instrument and GPA, students with a higher GPA believed that there was a correlation between learning a musical instrument and learning science. This opposition may be because of a difference in assumption an nd reality. There are many studies that show instruction of a musical instrument significantly increases spatial-temporal performance (Rauscher, 2000, Sarnthein, 1997). Although there may be an assumption by science students that learning a musical instrument has an effect on learning science, this has been shown to not be true by the results. It may be that learning a musical instrument may have an effect on other performance tasks, such as mathematical concepts, but not with scientific concepts. This idea can be strengthened by our results that found Mathematical Intelligence only had two positive correlated questions with GPA.

Limitations

For one, science GPA may not be a good indicator of how a student excels and their intelligence. Another limitation was having the students answer the questions and rate themselves. According to the Dunning-Kruger effect, poor performers greatly overestimate and have a much higher positive impression of their performance (in real world settings as

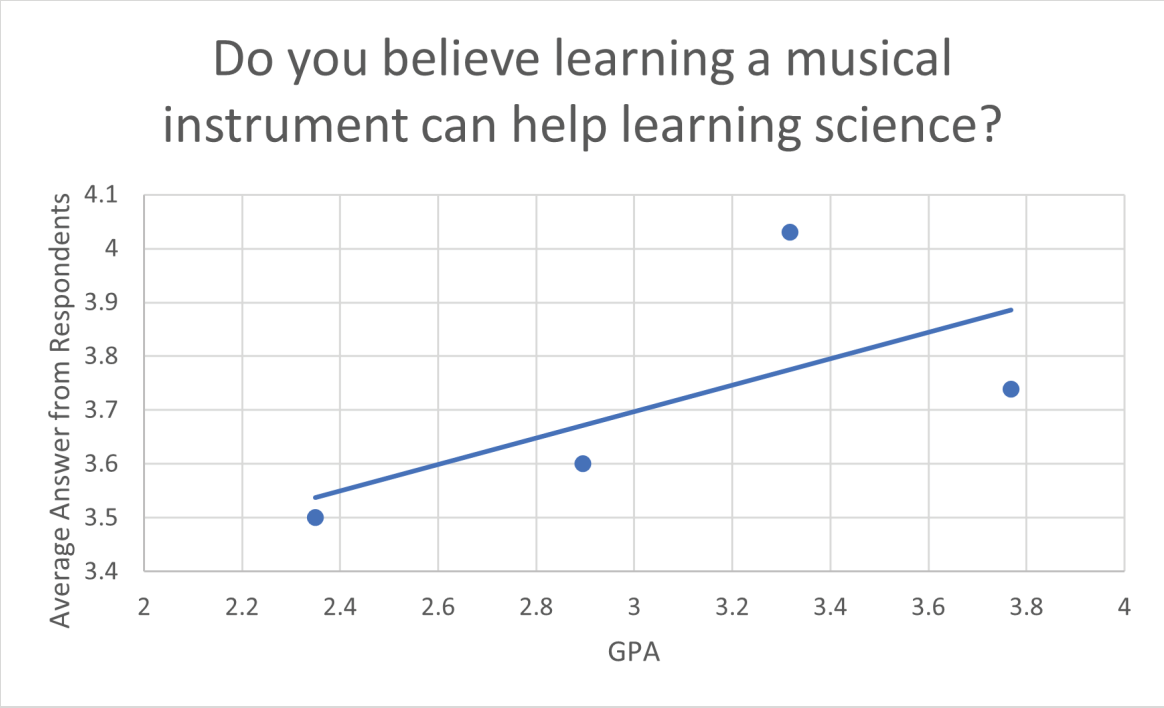

Figure 7: Graph of student's response to their opinion on whether they believe learning a musical instrument can help when learning science. An average answer of 1 meant the students did not believe learning a musical instrument can help when learning science, an average answer of 3 meant that they maybe thought a musical instrument can help when learning science, and an average response of 5 meant the students did believe a musical instrument can help when learning science.

well) because they do not have the skill to recognize their deficits due to their incompetence (Ehrlinger et al., 2008). This effect can be seen in certain questions that have negative correlations: I like finding logical flaws in things that people say and do at home and work for positive correlation and Mathematical Intelligence, Math and/or science are among my favorite subjects in school, problem solving comes easy to me, I can complete calculations quickly in my head, Things have to make sense to me or I am dissatisfied, I feel more comfortable when something has been measured, categorized, analyzed, or quantified in some way for negative correlation and Mathematical Intelligence, I played a musical instrument when I was younger, I easily pick up on patterns, I played a musical instrument when I was younger, my life would be poorer if there were no music in it, listening to sounds in nature can be very relaxing for negative correlation and Musical Intelligence.

Although playing an instrument when younger is a yes or no question that cannot be considered as a part of an incompetency when answered, the other questions most certainly can be. There are ½ of the questions for Mathematical Intelligence that have a positive correlation, 5/9 questions for Mathematical Intelligence that have a negative correlation, and 5/7 questions that have a negative correlation for Musical Intelligence. Assessing the

students own understanding of the questions and being aware of the inconsistency of confidence in students with lower GPAs provides insightful information for the effect of Musical Intelligence in science education. The negative correlation may be skewed because of the Dunning Kruger effect in students with the lower GPA. Therefore, this may support that Musical and Mathematical Intelligence actually have a positive effect on GPA. The effect was only seen in 1 question with positive correlation in Mathematical Intelligence, but no positive correlation questions in Music Intelligence.

Conclusion

The results showed that there are more positive correlations in Musical Intelligence when compared to Mathematical Intelligence. Our data suggests science students with a higher GPA have more Musical Intelligence compared to Mathematical Intelligence. Science students with a higher GPA were more likely to use a musical tune to help with learning scientific concepts. The questions that measured Musical Intelligence and that were positively correlated to GPA were questions that were aligned with understanding and learning a musical tune. These questions asked about remembering song lyrics and knowing the tunes to multiple songs. It can be suggested that science students have a Musical Intelligence that is ideal for learning a musical tune. This musical tune can be a popular song the student already knows, but changing the lyrics so that they are learning scientific concepts. This may be a more beneficial way for students to learn science and understand the information taught to them. Students with a higher GPA believe that music can have a positive impact on learning, whether through learning a musical instrument or listening to a musical tune. When students are offered a variety of learning experiences they may become more engaged and invested in their individual learning process. If students become engaged in learning science and develop positive attitudes towards science, they is a greater chance that they develop higher scientific literacy. The results of this study can be employed as an applied knowledge to improve the quality of education to be provided for future science students. Future research might explore the potential effects of Musical Intelligence on other majors, such as mathematics or physics. This would be important to address to understand the availability that Musical Intelligence can have on education as a whole.

References:

Abdi, A. et al. (2013) 'The Effect of Teaching strategies based on multiple intelligences on Students' Academic Achievement in Science Course'. *Universal Journal of Educational Research*, 1(4). DOI: 10.13189/ujer.2013.010401

Ahvan, Y. R., & Pour, H. Z. (2016). The Correlation of Multiple Intelligences for the achievement of secondary students. *Educational Research and Reviews*, 11(4), 141- 145.

Afaneh, I., & Khazendar, N. (2004). Learning strategies of multiple intelligences and its relationship with some variables of the students' teachers' specialty Mathematics in Gaza. In Fifteenth conference of the Egyptian Association for Curriculum and Instruction,

Education curriculum and preparation of contemporary life, Ain Shams University guesthouse (Vol. II, 218-235).

Boyer, E. L. (1983). High School: A report on secondary education in America. (Sponsored by the Carnegie Foundation for The Advancement of Teaching.) New York: Harper & Row.

Campbell, B. (1990). The research results of a multiple intelligences classroom. New Horizons for Learning Electronic Journal. Retrieved April 1,1999, from http://www.newhorizons.org/art_mireserch.html

Elbert, T. et al. (1995) `Increased cortical representation of the ®ngers of the left hand in string players'. Science, 270, 305±7; cited in Robertson, I. (2000) Mind Sculpture. London: Bantam Books.

Ehrlinger, J., Johnson, K., Banner, M., Dunning, D., & Kruger, J. (2008). Why the Unskilled Are Unaware: Further Explorations of (Absent) Self-Insight Among the Incompetent. *Organizational behavior and human decision processes, 105*(1), 98–121. https://doi.org/10.1016/j.obhdp.2007.05.002

Ferreri, L., Bigand, E., Bard, P., & Bugaiska, A. (2015). The Influence of Music on Prefrontal Cortex during Episodic Encoding and Retrieval of Verbal Information: A Multichannel fNIRS Study. *Behavioral Neurology, 2015*, 1–11. https://doi-org.ccny-proxy1.libr.ccny.cuny.edu/10.1155/2015/707625

Gardner, H., & Hatch, T. (1989). Educational Implications of the Theory of Multiple Intelligences. Educational Researcher, 18(8), 4–10. https://doi.org/10.3102/0013189X018008004

Governor, D., Hall, J., & Jackson, D. (2013). Teaching and learning science through song: Exploring the experiences of students and teachers. *International Journal of Science Education, 35*, 3117–314.

Graziano, A., Peterson, M. & Shaw, G. L. (1999) `Enhanced learning of proportional math through music training and spatio-temporal training'. *Neurological Research*, 21, 2, 139±53

Haydon, T., Musti-Rao, S., & Alter, P. (2017). Comparing Choral Responding and a Choral Responding Plus Mnemonic Device during Geography Lessons for Students with Mild to Moderate Disabilities. *Education and Treatment of Children*, 40(1), 77–95.

Langstaff, J., & Mayer, E. (1996). Music: exercise for the brain. Learning. March/April, pp. 62-64.

Luiz, C., Coimbra, D., and Silva, C. (2009). Musical learning and cognitive performance. International Symposium on Performance Science, pp. 2-6.

Mickela, T. (n.d.) Improve your brain. Music Education Online. http://vvww.childrensmusicworkshop.com/advocacy/studentdevelopment.html

Rauscher, F., Shaw, G. & KY, K. (1993) `Music and spatial task performance'. Nature, 365, 6447, 611.

Rauscher, F. & Zupan, M. A. (2000) `Classroom keyboard instruction improves kindergarten children's spatial-temporal performance: a ®eld experiment'. Early Childhood Research

Quarterly, 15, 215±28.
Reinhard, J. (2015). Howard Gardner's MULTIPLE INTELLIGENCES: A Minority View: Musical Intelligence. Music Scholarship / Problemy Muzykal'noj Nauki, (4), 38-42. doi:10.17674/1997-0854.2015.4.038-042
Ribeiro, F. S., & Santos, F. H. (2017). Enhancement of numeric cognition in children with low achievement in mathematic after a non-instrumental musical training. Research in Developmental Disabilities, 62, 26-39. doi:10.1016/j.ridd.2016.11.008
Ruthsatz, J., Detterman, D., Griscom, W. S., and Cirullo, B. A. (2008). Becoming an expert in the musical domain: it takes more than just practice. Intelligence 36, 330–338. doi: 10.1016/j.intell.2007.08.003
Sarnthein, J., Stein, A. von, Rappelsberger, P., Petsche, H., Rauscher, F. & Shaw, G. L. (1997) `Persistent patterns of brain activity: an EEG coherence study of the positive effect of music on spatial temporal reasoning'. Neurological Research, 19, 2, 107±17.
Schweizer, K., & Moosbrugger, H. (2004). Attention and working memory as predictors of intelligence. Intelligence, 32(4), 329-347
Tamminen, J., Rastle, K., Darby, J., Lucas, R. & Williamson, V. (2017). The Impact of music on learning and consolidation of novel words. Memory. (25), 107–121.
Tervaniemi, M. (2001). Superior formation of cortical memory traces for melodic patterns in musicians. Learn. Mem. 8, 295–300. doi: 10.1101/lm.39501
Weber, E. W., Spychiger, M. & Patry, J. L. (1993) Music Makes the School. Available at http://www.sksm.ch/E/publications/mms.htm.
Yalamanci, S. (2013). The Effects of Multiple Intelligence Theory Based Teaching on Students' Achievement and Retention of Knowledge. International Journal on New Trends in Education and Their Implications, 4(3), 27-34.