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Coupling K-12 Music Education with Science, Technology, Engineering and Math (STEM) Curricula: Implementation of a STEMusic Outreach Program

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Coupling K-12 Music Education with Science, Technology, Engineering, and Math (STEM) Curricula: Implementation of a STEMusic Outreach Program

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by

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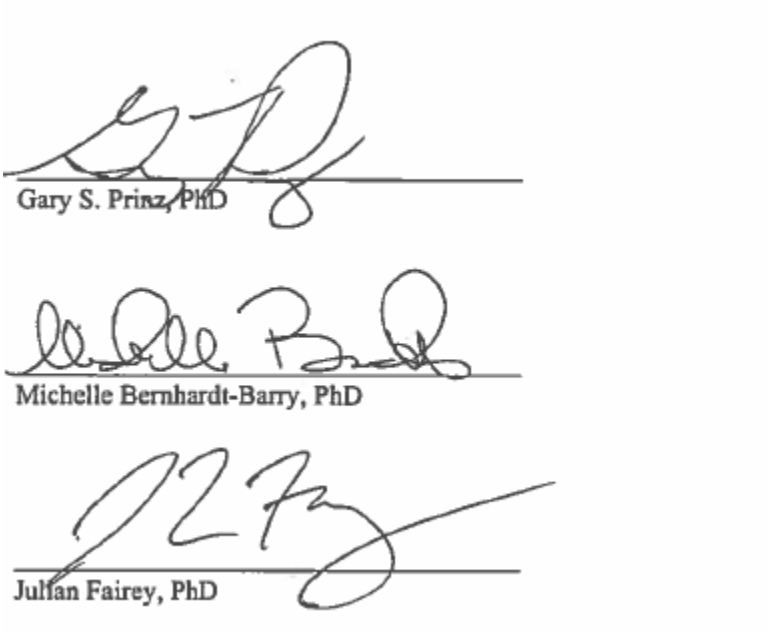

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1. Introduction

Many studies have investigated the effects of music on evoking human emotions and diverse types of brain responses (see Table 1) [1-5]. One study by Juslin and Vastfjall [6] indicates that hearing music can stimulate brain stem reflexes, create emotional contagion, recall episodic memories and provoke visual imagery. Due to the influence music has on human brain waves [5], researchers have been studying the effect of music on enhancing the spatial abilities of young students. Science, Technology, Engineering and Math (STEM) professions rely heavily on spatial skills. Research on the connection of music with spatial skills proposes that when the brain processes rhythm a "mental rotation" occurs, which stimulates the brain's spatial-temporal ability [7]. Also suggested, is that music enhances learning due to the multiple types of thinking that are required to make and learn music. Creating music requires an extended practice of musical, visual-spatial, mathematical, interpersonal, intrapersonal and kinesthetic intelligences [8] and when students make music they will be practicing and enhancing these abilities [7].

Table 1. Overview of studies exploring emotional responses to music [6]

Measure	Description*	Study
Psychomotor		
Writing speed	Shorter time for writing down numbers from 100 to 1	Pignatiello et al. 1986
Count time	Shorter time to count from 1 to 10	Clark & Teasdale 1985
Distance approximation	Smaller distances estimated	Kenealy 1988
Motivational		
Incentives	Higher ratings of willingness to participate in social activities	Wood et al 1990
Information processing		
Word association	Shorter time to produce associations to words	Kenealy 1988
Coding speed	Shorter time to complete a symbol-coding procedure	Wood et al. 1990
Decision time	Shorter time to decision	Kenealy 1988
Judgmental/Behavioral		
Subjective probability	Higher estimates of probability of success and lower estimates of failure	Teasdale & Spencer 1984
Evaluative judgments	More positive evaluations of ads	Gorn et al. 2001
Purchase intentions	Lower in-store purchase intentions	Bruner 1990
Sexual arousal	Stronger sexual arousal	Mitchell et al. 1998
Physical attraction	Higher ratings of attraction	May & Hamilton 1980
Emotion perception	More happiness and less sadness perceived in facial expressions	Bouhuys et al. 1995

Note. Description refers to effects of positive (happy) as compared to negative (sad) emotions.

This study develops an innovative K-12 outreach program and explores the effects of coupling music-education with STEM specific curricula through songwriting workshops, termed *STEMusic workshops*. The goal of the STEMusic outreach program is to promote creativity, conceptual understanding and

retention of STEM specific concepts at the elementary level through the alternative cognitive process of creating music. Traditional methods of teaching engineering concepts do not involve emotional learning processes. By combining songwriting, rhythm and performance art with STEM principles, students are exposed to an emotional musical experience that may create long-term memories of the curricula and help with retention of the STEM concepts.

2. Overview of STEMusic K-12 Outreach and Method of Assessment

The STEMusic outreach program combines the creation of musical beats, rhythms and lyrics with an interactive STEM themed demonstration. The STEMusic program is set up to follow a 3-step process. The goal of the first step is to provide the elementary students with a clear verbal explanation of engineering concepts combined with physical and visual STEM themed technical demonstrations. The second step is to have students participate in a song-writing workshop where they will be divided into small groups and asked to write lyrics explaining the newly learned STEM concept. After completing their songs, each group will perform what they have written in front of their peers. The final step of the program is to assess comprehension and retention following completion of the outreach workshop.

A trial version of the STEMusic program was performed as an experiment, comparing two separate groups of elementary students (one control group without music and one experimental group with music). Both the control and experimental group had to be of similar demographic, therefore each group was composed of fifth grade students who attend McNair Elementary in Fayetteville, Arkansas. Each group participated in the first and third step of the STEM program; however, only the experimental group participated in the second, songwriting, step.

The first STEMusic workshop spanned the course of 3 days for each group and followed the general program outlined in Table 2.

Table 2. STEMusic program outline

	Group 1 (experiment)	Group 2 (control)
Day 1	-Introductions -Verbal discussion of lesson topics -Hands-on demonstrations	-Introductions -Verbal discussion of lesson topics -Hands-on demonstrations
Day 2	-Brief recap of day 1 -Short hands-on demonstration ***-Begin song-writing workshop***	-Brief recap of day 1 -Hands-on demonstrations ***- Write a journal entry explaining what they learned***
Day 3	-Repeat discussion from day 2 ***-Song-writing workshop*** ***-Group performance of songs*** -Assessment	-Repeat discussion from day 2 -Assessment

2.1. Description of STEMusic Outreach Workshop with Group 1 (experiment)

Day 1: To begin the first workshop day and to provoke an excitement and interest in engineering and other STEM related topics, students were encouraged in the first 2 to 3 minutes to stand up and dance to an upbeat song along with the instructors (myself and Dr. Gary Prinz). This incorporated a kinesthetic learning style along with the linguistic and auditory-musical learning styles explored throughout the program.

The next five to ten minutes of the class period were used to explain what different disciplines of engineering do and how they benefit society. The students were then asked questions about the different disciplines of engineering. This was a way to assess student awareness of engineering before the program and to expand student knowledge of engineering as a career.

The remainder of the first lesson was dedicated to verbal explanation and hands-on demonstrations regarding the topic of Newton's first law of motion (the law of inertia). The verbal explanation focused on examples of inertia in our daily lives. Students were encouraged during this time to raise their hands to share thoughts and ideas on the topic of inertia.

Two hands-on demonstrations of inertia were then performed. In the first demonstration, students were asked to hold each end of a steel bar parallel to the ground with a large mass tied to the middle of the bar by a thin wire. The demonstration was performed multiple times with Dr. Prinz changing the acceleration at which he pulled on the wire and altering the outcome of the wire break location. The goal of this

demonstration was to actively involve students in the lesson as well as provide a visual representation of Newton's first law of motion. Figure 1 shows the student excitement and willingness to volunteer for the demonstration and Dr. Prinz breaking the wire at differing locations using the law of inertia.

Figure 1. Suspended mass demonstration during inertia discussion

In the second demonstration, each student was given two light-weight plastic cups and a sheet of construction paper. The cups were stacked directly over each other between the single sheet of paper. The students were told to pull the sheet of paper out as fast as they could while keeping it parallel to the table. Figure 2 shows the students exploring the second inertia demonstration. This demonstration investigates the inertia of the top cup and the tendency of objects that are already at rest, to stay at rest and resist motion. Students were asked to predict if the cup would fall straight down or fly away with the paper and then able to test their predictions. This allowed a hands-on inertia experience (which the students enjoyed).

Figure 2. Stacked cup demonstration during inertia discussion

Day 2: The second day of the workshop incorporated the auditory-musical learning style to the program, along with the verbal and visual learning styles from day 1. Students were again encouraged in the first 2 to 3 minutes to stand up and dance to an upbeat song along with the instructors. This was followed by a 10-minute verbal overview of the topics covered on day 1. One hands-on demonstration of the law of inertia was performed by the instructors to allow for student interaction and provide a visual reminder of the lesson from day 1. During the review, the keywords involved in the lesson were written on a whiteboard to aid in the song-writing process.

The students were then randomly divided into groups of 3 and 4 members to begin the song-writing portion of the outreach program. The students were instructed to write a song about what they had learned from day 1 with the assistance of instructors as well as the McNair Elementary music teacher, Mrs. Adrienne Hapgood. The students used the remaining 30 minutes of the lesson to plan and write a song. Students were encouraged to brainstorm lyrics with the keywords written on the whiteboard during the review. Students were given creative freedom in regards to the writing process. Most of the groups focused on rhyming patterns with keywords, followed by the incorporation of a rhythm or melody to the lyrics. A couple of the groups chose a popular song melody first and then began writing lyrics to follow the rhythm of the song.

Mrs. Hapgood was available to the students to assist with the musical aspects of the workshop. She reminded the students of beats and rhyming patterns they had discussed in class and encouraged them to incorporate that knowledge into their songs.

Day 3: The final day of the workshop began with a short interactive verbal review with the students to cover the topics from day 1. The students then broke into their respective groups for 10-minutes to finalize their songs from day 2 and prepare to perform in front of the class. Groups were encouraged by instructors to add choreography to their performance as a kinesthetic learning style. Each group of students then performed the song they wrote. Figure 3 shows the student group writing process as well as a student group performing their choreographed song. Figure 4 shows an example song written on the law of inertia.

After the performances, students were given a multiple-choice quiz. The quiz was meant to assess student comprehension of the concepts discussed from day 1 and 2, as well as their opinions of the STEMusic outreach program.

Figure 3. Students writing songs and performing

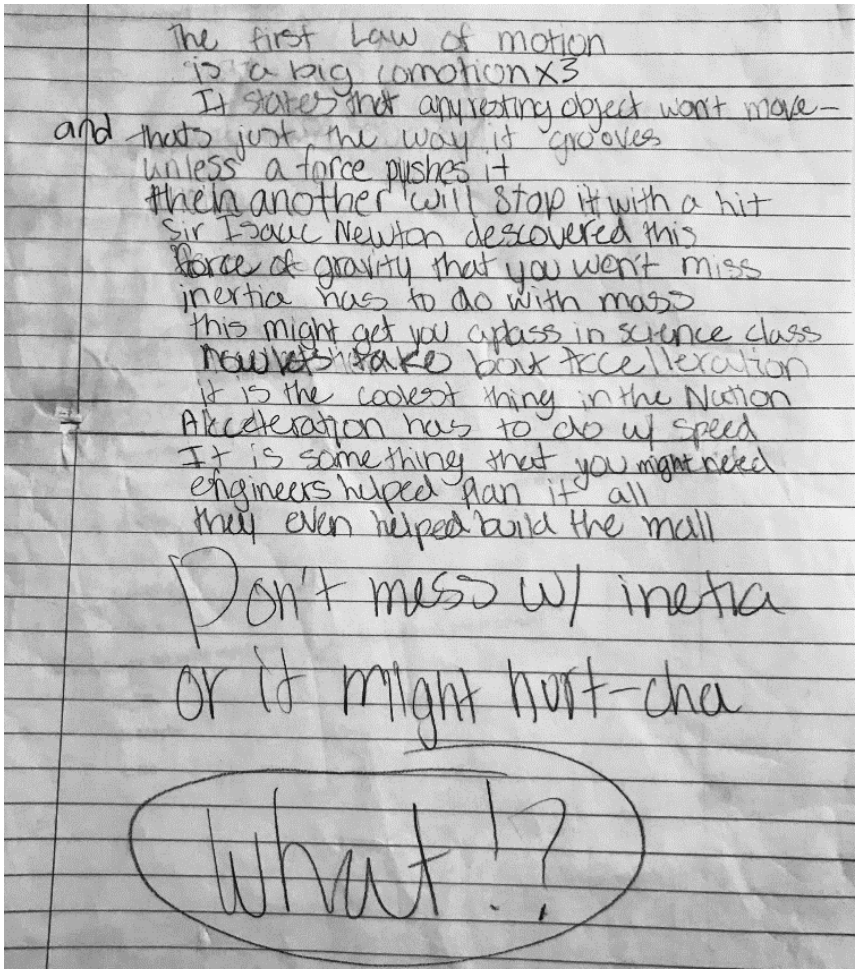

Figure 4. Example song on Newton's first law of motion written by 5th grade McNair Elementary School children

2.2. Description of STEMusic Outreach Workshop with Group 2 (control)

Day 1: The first day of the workshop was identical for the students in Group 2 as Group 1. The same topics and hands-on demonstrations were performed as in day 1.

Day 2: In the second day of the workshop students were again encouraged in the first 2 to 3 minutes to stand up and dance to an upbeat song along with instructors. This was followed by a 10-minute verbal discussion and review of the topics covered on day 1. Two additional hands-on demonstrations of the law of inertia were performed. The first was a physical representation of the relationship between mass and the amount of inertia an object has. Students were asked to kick two identical boxes labeled "A" and "B" with different masses and discuss the reasoning behind the resulting movement of each box. The second demonstration was another representation of Newton's first law of motion and a more elaborate variation of the plastic cup demonstration from day 1.

Following the demonstrations, the students were asked to write a journal entry paragraph about what they had learned during the workshop. They were instructed to write as if they were explaining the concepts to someone who knew nothing about engineering or inertia. Students were also encouraged to draw visual representations of their explanations if desired. An example journal entry by one of the Group 2 students is presented in Figure 5.

Day 3: For the final day students were involved in a short interactive review of the topics discussed throughout the workshop followed by a quiz. The conceptual assessment questions were identical to those asked of Group 1. The quiz also included opinion questions regarding the workshop and the effects of writing a journal entry on their comprehension.

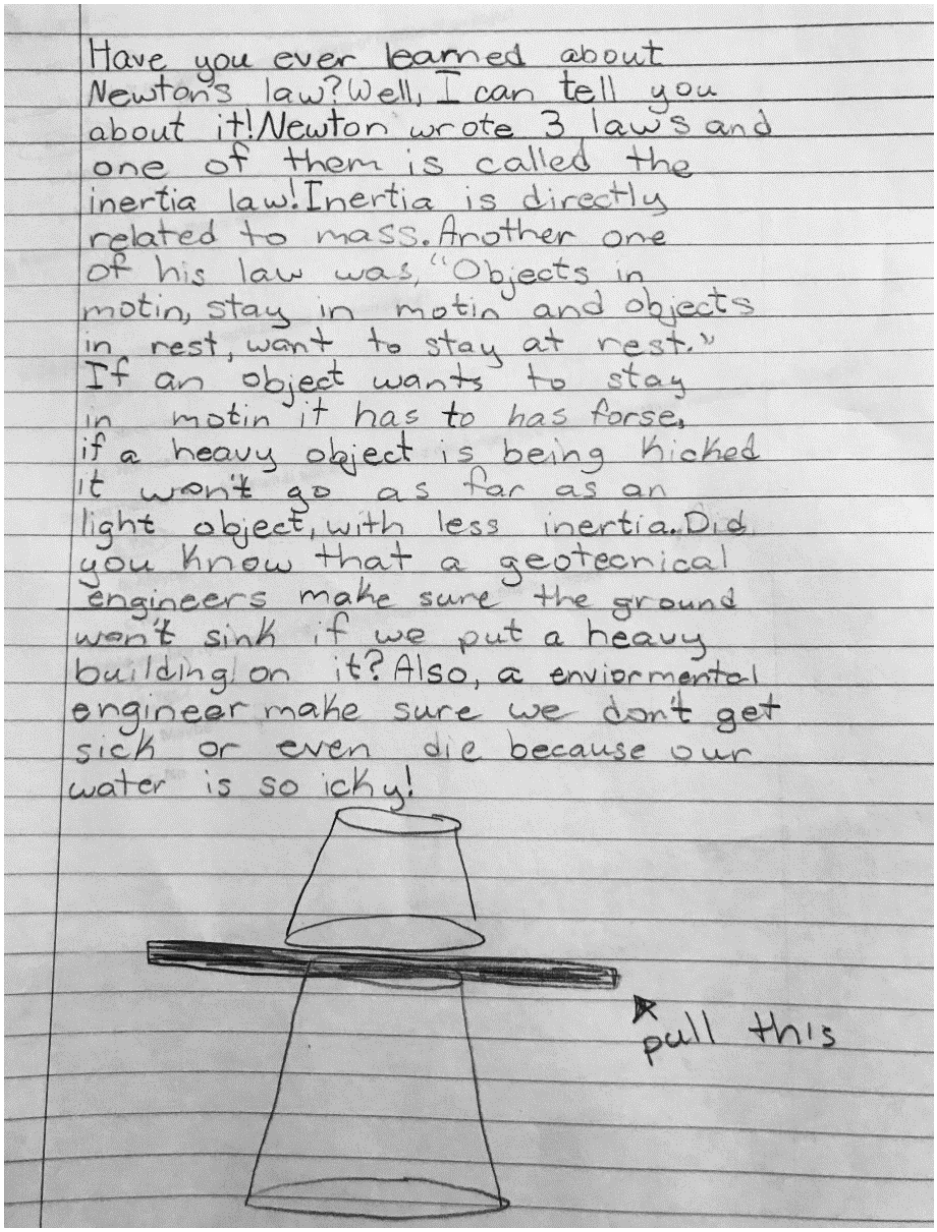

Figure 5. Example journal entry written about the law of inertia.

3. Assessment of Student Retention and Interest in STEM Topics

The assessments for each group were broken into two parts: 1) an initial assessment and 2) a follow-up assessment gauging retention of the STEM topics discussed. The first assessment occurred on the final day of the workshops to test immediate understanding of the topics and to provide a baseline for assessing retention. A multiple-choice quiz was used which included 5 conceptual questions regarding the inertia

lesson and 3 opinion questions regarding the STEMusic outreach program. The STEMusic assessment questions were as follows:

1. The less mass an object has, the more inertia it has.
    a. True
    b. False
2. An object at rest stays at rest and an object in motion stays in motion unless acted upon by an unbalanced force is defined by
    a. Newton's first law
    b. Newton's second law
    c. Newton's third law
3. The resistance of an object to any change in its state of motion (it's speed, direction, or rest) is
    a. Mass
    b. Inertia
    c. Force
4. _____ is a push or pull that can change the state of motion of an object.
    a. Force
    b. Inertia
    c. Mass
5. A bowling ball has more inertia than a soccer ball.
    a. True
    b. False
6. Do you think science and math are fun and interesting?
    a. Yes
    b. Sometimes
    c. Not really
7. Do you think writing your song helped you better understand Newtons Law of Inertia?
    a. Yes
    b. Maybe
    c. No
8. Would you like to do more engineering projects like this one in school?
    a. Yes
    b. Maybe
    c. No

The second, follow-up, assessment occurred 6 months after the STEMusic activities, to test student long-term retention. The responses from the second assessment were compared to assessment 1 for each group to compare the retention levels. The conceptual questions from the second multiple-choice assessment provided to the students were the same as the first assessment.

4. Results and Discussion from Student Assessments

4.1. Short-term Assessment Results

Group 1 was comprised of a total of 22 students from a music class with a cumulative 110 conceptual questions answered (5 per student). The results from the concept questions of the first assessment for Group 1 are displayed in Table 3 below. The overall average quiz grade for the class was 85% with more than half of the students scoring 100%. The total number of questions answered incorrectly was 16; however, if the single outlier quiz with a score of one is removed then the total number of questions missed drops to 12. This would mean that, excluding the outlier, the representative average quiz score would be 88.5% for Group 1.

Table 3. Group 1 concept question responses

Concept Question	Correct	Incorrect	% of class incorrect	% of class correct
1	20	2	9.09%	90.91%
2	16	6	27.27%	72.73%
3	17	5	22.73%	77.27%
4	21	1	4.55%	95.45%
5	20	2	9.09%	90.91%
Total	94	16	14.55%	85.45%

Figure 6 shows the Group1 responses to the opinion questions assessing their interest in STEM subjects. The responses to the opinion based questions were positive overall for Group 1. When asked if they *"found science and math to be fun and interesting"* the students' responses were divided evenly between "yes" and "maybe". Most of the students also selected that they would be interested in doing more STEM related projects similar to the ones demonstrated during the workshop throughout their school year. When the group was asked if they believe writing a song about what they learned increased their understanding of the topics, over 33% of the students said yes, leaving 45% undecided.

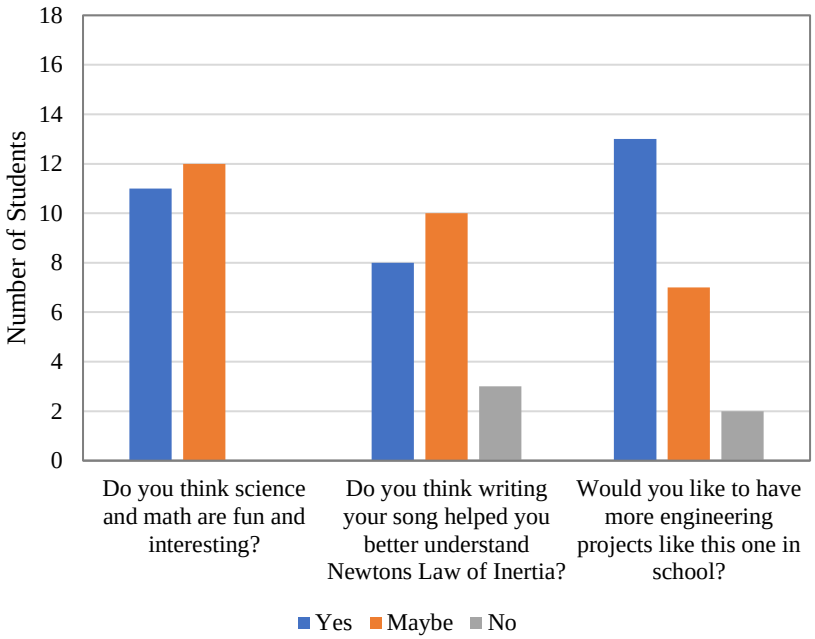

Figure 6. Group 1 responses to opinion questions

Group 2 was comprised of a total of 19 students from a science class with a cumulative 95 conceptual questions answered (5 per student). The results from the first assessment for Group 2 are displayed in Table 4. The overall average quiz grade for the class was 87% with more than half of the students scoring 100%. The total number of questions answered incorrectly was 12 out of the 95 total answers.

Table 4. Group 2 concept question responses

Concept Question	Correct	Incorrect	% of class incorrect	% of class correct
1	18	1	5.26%	94.74%
2	18	1	5.26%	94.74%
3	12	7	36.84%	63.16%
4	18	1	5.26%	94.74%
5	17	2	10.53%	89.47%
Total	83	12	12.63%	87.37%

Figure 7 shows the Group 2 responses to the opinion questions assessing their interest in STEM subjects. The responses to the opinion based questions were also positive overall for group 2. When asked if they “found science and math to be fun and interesting”, over half of the students responded with “yes” and the remainder were undecided. Just over 80% of the group also selected that they would be interested

in doing more STEM related projects during their school year. When the group was asked if they believed writing a journal entry about what they learned increased their understanding of the topics, over half of the students said “yes”, leaving the other half divided between “undecided” and “no”.

Both groups had an overall positive response to the workshop and the idea of incorporating more engineering focused projects into their classes.

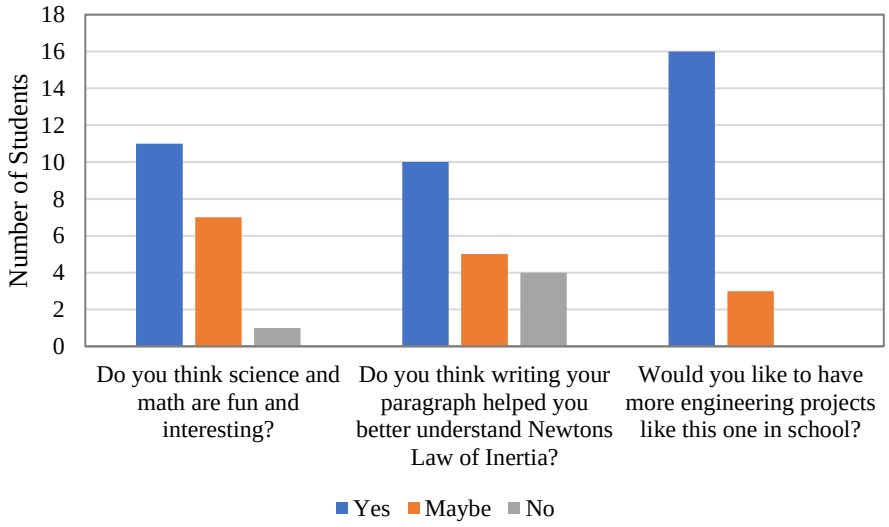

Figure 7. Group 2 responses to opinion questions

4.2. Long-term Assessment Results

The results from the second assessment for Group 1 are provided in Table 5. In the second assessment, a total of 19 of the original 22 students from Group 1 returned for the second assessment, resulting in a cumulative 95 conceptual questions answered (5 per student). The overall average quiz grade for the class was 55%. The total number of questions answered incorrectly largely increased from the short-term assessment to 43 out of the 95 answered. Figure 8 compares the responses to the exact same conceptual questions, the short-term taken immediately after the workshop and the long-term taken 6 months later. Correct answers for questions 2 and 5 both decreased by more than half on the long-term assessment. However, questions 3 and 4 only dropped slightly for the long-term assessment with the percent of correct answers remaining above 65% of the class.

Table 5. Group 1 concept question responses from follow-up assessment

Concept Question	Correct	Incorrect	% of class incorrect	% of class correct
1	11	8	42.11%	57.89%
2	6	13	68.42%	31.58%
3	13	6	31.58%	68.42%
4	17	2	10.53%	89.47%
5	5	14	73.68%	26.32%
Total	52	43	45.26%	54.74%

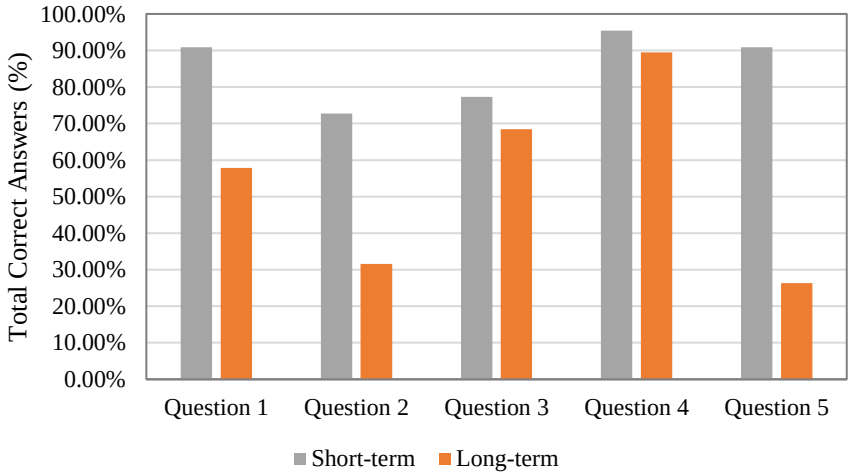

Figure 8. Comparison of short-term and long-term concept question performance for Group 1

Two of the opinion based questions from the second assessment were identical from the first assessment; however, the last opinion question changed to address the students' memories regarding the song they wrote during the workshop. The responses to the opinion based questions leaned more negative in the long-term assessment overall for Group 1 as shown in Figure 9. When asked 6 months after the workshop if they "found science and math to be fun and interesting" almost 80% of the students responded with "maybe" and only 20% said "yes". When the group was asked if they believed writing a song about what they learned increased their understanding of the topics, only 26% of the students chose "yes", while 58% selected "maybe". The new opinion question, inquiring if the students remembered any of the song they wrote, resulted in approximately 60% of the class responding "no" and 10% responding "yes". The remaining 25% of students were unsure if they would be able to remember any of their song. Something to

consider when analyzing the negative response to the final opinion question is that the students were given no time to review or think about their song before taking the quiz. If the students were able to get in their groups for 5 mins and discuss their song before the second assessment, it may have been beneficial in sparking their memories. It should also be noted that Group 1 shows less interest in science and math topics than Group 2, as will be discussed in the following paragraphs.

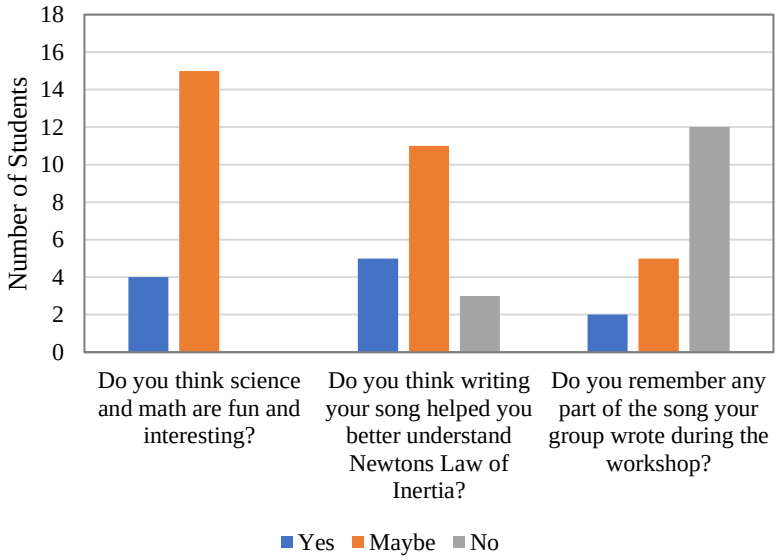

Figure 9. Opinion responses from second assessment for Group 1

A total of 14 of the original 19 students from Group 2 returned for the second assessment, resulting in a cumulative 70 conceptual questions answered (5 per student). Table 6 shows the results from the second assessment given to Group 2. The overall average quiz grade for the class was 55%. The total number of questions answered incorrectly largely increased from the short-term assessment to 31 out of the 70 answered. Figure 10 compares the responses to the exact same conceptual questions, the short-term taken immediately after the workshop and the long-term taken 6 months later. Correct answers for questions 1 and 3 both decreased by more than half on the long-term assessment. However, questions 2 and 4 only dropped slightly for the long-term assessment with the percent of correct answers remaining above 70% of the class.

Table 6. Group 2 concept question responses from follow-up assessment

Concept Question	Correct	Incorrect	% of class incorrect	% of class correct
1	6	8	57.14%	42.86%
2	10	4	28.57%	71.43%
3	4	10	71.43%	28.57%
4	11	3	21.43%	78.57%
5	8	6	42.86%	57.14%
Total	39	31	44.29%	55.71%

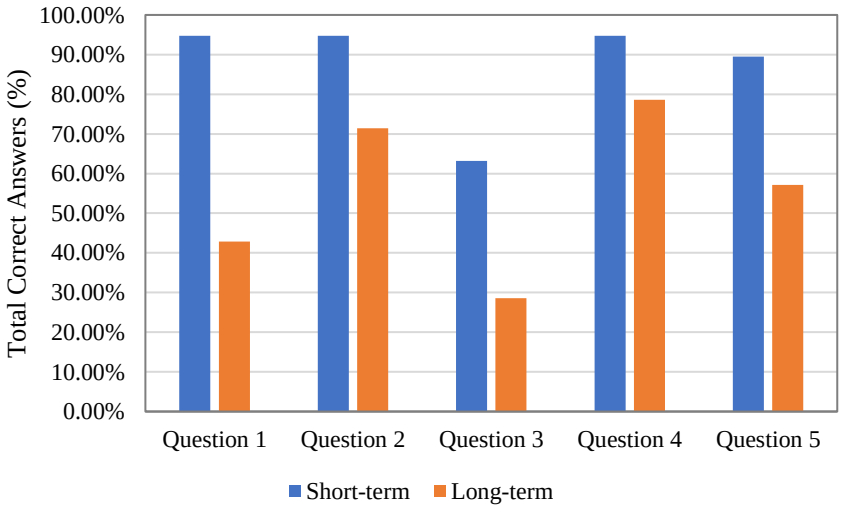

Figure 10. Comparison of short-term and long-term concept question performance for Group 2

Two of the opinion based questions from assessment two remained the same from assessment one; however, the last opinion question changed to address the students' memory regarding the paragraph they wrote during the workshop. The responses to the opinion based questions leaned more positive in the long-term assessment overall for Group 2 as shown in Figure 11. When asked 6 months after the workshop if they "found science and math to be fun and interesting" almost 80% of the students responded with "yes" and only 20% said "maybe". When the group was asked if they believed writing a paragraph about what they learned increased their understanding of the topics, 43% of the students chose "yes", while 57% selected "maybe". The new opinion question, inquiring if the students believed writing about what they learned in the workshop increased their memory of the topics, resulted in approximately 36% of the class responding "no" and 43% responding "yes". The remaining students were unsure if writing a paragraph

during the workshop helped them remember what they learned. It should be noted that Group 2 has a much higher interest in science and math subjects than Group 1, and that the Group 2 subjects were taken from a science class at the time of assessment.

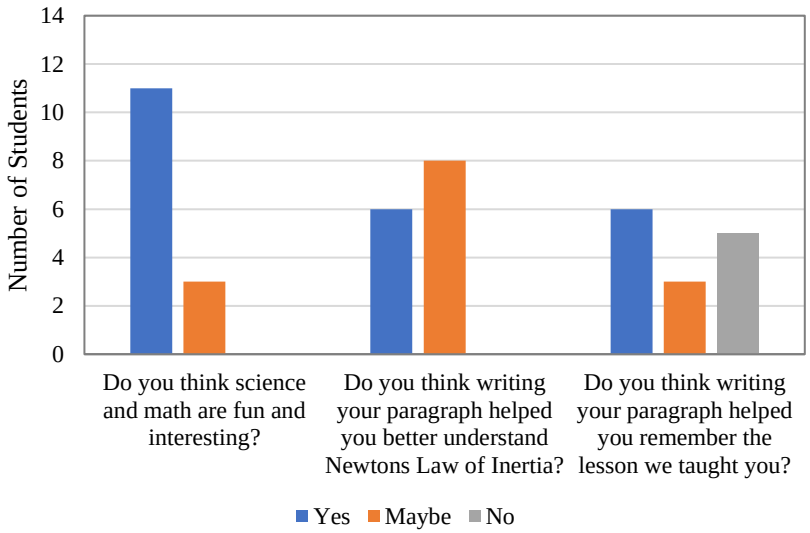

Figure 11. Opinion responses from second assessment for Group 1

Overall long-term retention for both Group 1 and Group 2 based on the responses to the conceptual questions was below average on a traditional grading scale, with both groups having a 55% quiz average. There are multiple factors to consider when determining why the quiz grades decreased for the long-term assessment. Note that the students had not been exposed to the topics from the workshop for over 6 months and received no review before taking the second assessment. It is to be expected that the average quiz grade would drop from the first assessment, which occurred immediately after discussing the subject matter. Additionally, the students were asked to take the long-term quiz at 7:45 am before starting their school day. The fact that they had just woken up within the hour and were handed a quiz without any warning could have negatively affected their quiz performance. It should also be noted that not all the students from each group participated in the second assessment.

5. Conclusions and Future Development of the *STEMusic* Outreach Program

A STEMusic outreach program was developed and implemented at the elementary school level to promote creativity, conceptual understanding and retention of engineering concepts at the elementary level through the process of creating music. Based on the assessment results from both the experimental and control groups, the program was successful in promoting creativity and encouraging the continuation of similar STEM related projects in school. Short-term conceptual understanding of the topics discussed was high for both groups. Retention for both the song writing group and the paragraph writing group was lower than anticipated but identical for both the control and test group. Most students who participated in the songwriting workshop stated it was helpful or they were unsure if it was helpful regarding their conceptual understanding of the lesson. The STEMusic outreach program shows potential in positively impacting the exposure, understanding and retention of STEM topics at the elementary level; however, a larger student sample size is needed to make conclusive arguments.

The data collected from the first installment of the STEMusic program will contribute to the improvement and future implementation of the program within the next few years. As the program continues, the organization and scheduling of the program will shift to maximize success. As an example improvement for future STEMusic activities, it may be beneficial to students if they were allotted more time to brainstorm and write their songs. The use of instruments could also be incorporated into the program to appeal to more students and promote creativity. It is also possible that the program should test long-term retention at 3 months, 6 months, 9 months, etc. This would ensure repetitive exposure to the STEM concepts discussed and allow for consistent assessment of retention as time passes. The students should also be given time before long-term assessments to break into their song writing groups and attempt to remember their songs. This would allow students time to recall what their song was about and hopefully improve their quiz scores. The program will also continue to promote representation of minorities in STEM fields by involving undergraduate participation from women, African American, and Chicano/Latino students. It's important for elementary students to witness these underrepresented groups involved in Science, Technology, Engineering and Math related fields.

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