A PARADIGM FOR TEACHING MATH AND COMPUTER SCIENCE CONCEPTS IN K-12 LEARNING ENVIRONMENT BY INTEGRATING CODING, ANIMATION, DANCE, MUSIC AND ART

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Abstract – **A paradigm for teaching math and computer science concepts in K-12 education integrating coding, animation, dance, music and art is presented. This teaching paradigm introduces an effective learning tool to teach math and computer science concepts to K-12 students as well as increase the interest of K-12 students in STEM classes and their interest to pursue a career in STEM fields. We taught a "MathDance&Music" program to seventh grade students using the Scratch 2.0 creative learning environment. Students were given assessments before and after the MathDance&Music program. The assessment results show that the MathDance&Music program improved students' ability in math and computer science significantly as well as increased students' interest in STEM classes and interest in pursuing a career in STEM. Students who repeated the MathDance motions and coded the music for the dance did better on the math and computer science test in the assessment with statistically significant p-value than those students who did not repeat the MathDance motions and did not code the music for the MathDance.**

Index Terms – Computer science education, dance, Scratch, coding, animation, music, STEM education, integrated curriculum, visual learning, kinesthetic learning.

INTRODUCTION

The presence of computer science curricula in K-12 education has increased in the United States in recent years [1]. In 35 States and the District of Columbia computer science can count toward a high school graduation requirement in math or science [2]. Few states in the United States require computer science instruction [3], whereas, several countries around the globe require computer science instruction as part of their core curriculum [4]. In addition, the presence of math has increased because skill in mathematics is crucial for students so they can better be engaged in our society especially nowadays with the increase of technological presence and digitalization [5].

To increase students' academic performance in math and computer science, and increase their interest in STEM classes and STEM careers, we suggest an effective integrated learning tool using coding, animation, dance, music and art to introduce math and computer science concepts into classrooms. The name of our integrated learning tool is "MathDance&Music". The idea of integrating coding, animation, dance, music and art to introduce math and computer science concepts in the classroom is based on an integrated curriculum framework [6][7]. Studies show that integrated lessons help students make connections between different subjects [6] [7]. In our MathDance&Music program students first learned various dance movements and music beats and then illustrated and animated the dance movements and music by writing code in Scratch. These activities have helped students to make connections between physical movements, music, and mathematics and computer science concepts.

We integrated dance, music and art to teach math and computer science concepts because research shows benefits in the use of arts in science education in a K-12 learning environment as well as postsecondary education [8]. Art is a good complement to traditional pedagogy and training approaches in the sciences because it allows students to exercise creativity and innovative thinking [9]. In addition, several research outcomes show that dance can help learning, improve academic performance, and enhance students' motivation [10] - [12].

Music also plays an important role in improving academic performance in math and computer science [13] – [16]. Music is similar to coding in the way it works. They both use a formal international language made up of sequence, repetition, and selection [13]. Sequence, repetition, and selection are the basis of computational thinking to solve daily problems. Moreover, music enhances student's understanding of mathematics concepts because of the connection between music and math [15], [16]. For example in our MathDance music code we set the beat- music speed- to 0.5 (half speed) and asked the students to make it faster by using the division operation as shown in FIGURE I.

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FIGURE I
MATHDANCE MUSIC CODE FOR WARMUP & SLOW DANCE MOVES

We used coding to teach math and computer science concepts because scholars at the University of California Davis who have researched for many years how to use computing to teach math and other STEM subjects concluded that "teaching math with computer programming can give mathematical concepts context and relevance while still requiring the same amount of rigor as traditional mathematics instruction, and it presents an opportunity to improve the success of all students and close the math achievement gap" [17].

The aim of our education tool, MathDance&Music, is to maximize students' learning ability, enhance performance in mathematics and computer science, and increase interest in STEM classes and STEM careers. Thus, we combined coding, dance, animation, music and art to teach mathematics and computer science to the students. By integrating coding, dance, animation, music and art we hoped to achieve similar results to the combination of the three learning modalities, auditory, visual, and kinesthetic that were introduced by Walter Barbe and his colleagues[18]. The MathDance&Music model focuses on integrating all three Modalities, Auditory, Kinesthetic and Visual learning to teach math and computer science concepts effectively [19]. In our MathDance&Music teaching model, we first taught a MathDance that is based on the MathDance introduced as "Beautiful Dance Moves" in [20]. Then we taught basic music theory and explained how to create both a two dimensional animation of the dance and the rhythm of the music to the dance using the Scratch 2.0 creative environment, which is a well-known program that has been used world-wide to teach coding to young students [21]. After completion of the animation and music coding we allowed the students to decorate their dance stage in Scratch and make changes to the music code as they wished. Then we conducted the post assessment as shown in Appendix B and Appendix C.

MATHDANCE&MUSIC WORKSHOP METHODOLOGY

We brought two 7th grade classes from the University Prep Science & Math Middle School, which is based in Detroit, on different days, to Lawrence Technological University to participate in our MathDance&Music workshop. Nineteen 7th grade students attended our first MathDance&Music workshop. We set up the robotics lab for the program beforehand. As the students arrived we divided them into pairs, and assigned each group a laptop. Due to the uneven number of students we had one student who worked alone. Before we started the MathDance&Music workshop we conducted a pre-assessment test as shown in Appendix A. The pre-assessment includes math questions, which ask the students to match the shown graph to its corresponding equation, and computer science questions that incorporate the concepts of variables, nested loops and if statements. The pre-assessment also includes three common questions that measure the students' interest in STEM classes and STEM career shown in Appendix C. Once the students completed the pre-assessment, we taught them the MathDance moves and they performed the actual MathDance as shown in FIGURE II. Then, we taught them basic coding concepts such as variables, loops, nested loops, and conditional loops, as well as more advanced Scratch tools such as custom blocks and operations. To create the MathDance animation and the music we first introduced basic coding tasks to the students to do in Scratch.

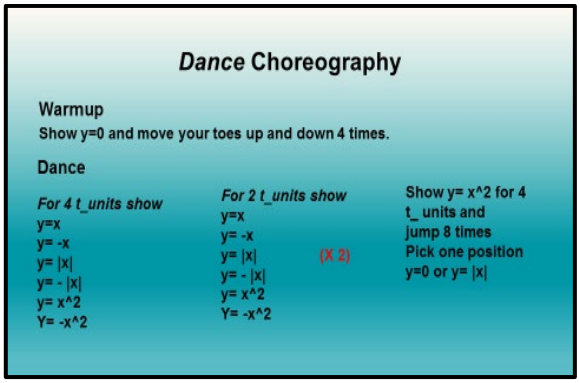

FIGURE II
MATHDANCE – CHOREOGRAPHY NOTES

After the basic tasks were completed the students performed the actual MathDance for the second time. Then, we reviewed for ten minutes mathematical concepts, in which we taught graphs and equations, that the students were using in their MathDance animation. After that the students performed for the third and last time the actual MathDance. After the dance performance, the students moved to their next task, taking pictures of themselves in seven different poses. Each pose represents a mathematical function as shown in FIGURE III. After the students took their pictures, we taught them how to remove the background of the photos in Microsoft PowerPoint, and how to import them into Scratch

as a Sprite, an object capable of performing actions within Scratch, and New Costume, different appearances for sprites.

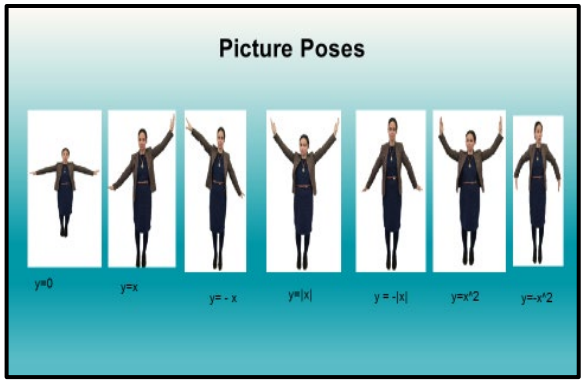

FIGURE III
SEVEN EQUATIONS AND POSES

After the students inserted their photos to Scratch, we explained the dance choreography as shown in FIGURE II and basic music theory, which included notes, beats and octaves. For the complete MathDance&Music, we showed and assisted them with the first steps in creating the MathDance animation code and the music for the dance. Then, we let them complete the MathDance animation and music project on their own. Once they finished the MathDance&Music project we allowed the students to change the music and decorate their stage in Scratch. At the end of the event, we gave them a post-assessment with a similar difficulty level to the pre-assessment, and the same common questions as shown in Appendix B and Appendix C.

Our second group consisted of different set of students. Twenty 7th grade students from the same Middle School in Detroit attended our second MathDance&Music workshop. They were given the same setup as Group One. However, this group did the music module before we reviewed the graphs' equations. We believe that this change has not interfered with our results.

Our control group is a group of eighteen 7th grade students from the same Middle School in Detroit who attended a different workshop in October 2017 at Lawrence Technological University [22]. Like Groups 1 and 2, we set up the robotic lab beforehand, and once they arrived we divided them into teams of two, with one laptop computer assigned to each team. Then, we gave them a pre-assessment test as shown in Appendix A and common questions as shown Appendix D. Once all the pre-assessments were complete, we taught them about graphs and functions. After that, we walked them through basic coding concepts and had basic tasks to prepare the students for creating their own MathDance animation in Scratch. After the basic tasks, we sent them to have their pictures taken in nine different poses. Each pose again represented a mathematical function. After that, we taught them how to remove the background of the photos in Microsoft PowerPoint, and then import the nine photos into Scratch as a New Sprite and New Costumes. Then they were shown how to begin creating the MathDance animation, and after that we allowed them to complete it on their own. The control group neither coded the music for the dance nor performed the dance. YouTube videos of MathDance&Music animations can be accessed at the following internet links:
https://youtu.be/BuubQ2z4TMA
https://youtu.be/Ipj1L_K-lRA
https://youtu.be/lpkw9OAD0ZQ

ANALYSIS OF ASSESSMENT DATA

The main goal of this research project is to show that our MathDance&Music teaching model incorporating coding, animation, dance, music and art improves mathematics and Computer Science learning outcomes and that students who practice the MathDance and code the music for the dance would do better on a mathematics and computer programming test than those students who do not. The secondary goal of this project is to show that our MathDance&Workshop teaching model increases interest in STEM classes and future STEM careers.

After grading the tests, we compared their pre and post-test scores, and after all groups had been graded, we compared each group's post-test scores. The differences between the control group and Groups 1 and 2 were that Groups 1 and 2 had slightly more students (Group one had 19 students, Group two had 20 students, and the control group had 18 students), Groups 1 and 2 repeated the dance three times as explained in the previous section, and coded the music for the dance. While the control group did not perform the dance and used a pre-recorded music loop, called "drum_jam", to code the MathDance. In addition, only GroupS 1 and 2 answered the reflection question about the workshop.

The Control Group improved its scores from the pre-test to the post-test by 104.8% (from an average score of 1.17 out of 5 to an average score of 2.39 out of 5). By a paired t-test, the p-value of the two tests was less than 0.0001, which is under 0.05, and thus considered extremely significant. There were 18 students in this group and none got a score of zero on the post-test.

Group 1, the first group that did repeat the dance and code the music for the dance, improve its scores from the pre-test to the post-test by 121.43% (from an average score of 1.47 out of 5 to an average score of 3.26 out of 5) as graphed in FIGURE IV. By a paired t-test, the p-value of the two tests was 0.0001, which is less than 0.05, and thus considered extremely statistically significant. There were 19 students in this group and none scored zeros on the post test.

We did an unpaired t-test for the control group and Group 1 to determine whether preforming the actual MathDance in class and coding the music for the dance improved the student's learning or not. The unpaired t-test showed a p-value of 0.0294. This is statistically significant, and it may indicate that preforming the actual MathDance and coding the music for the dance did indeed improve the students' performance.

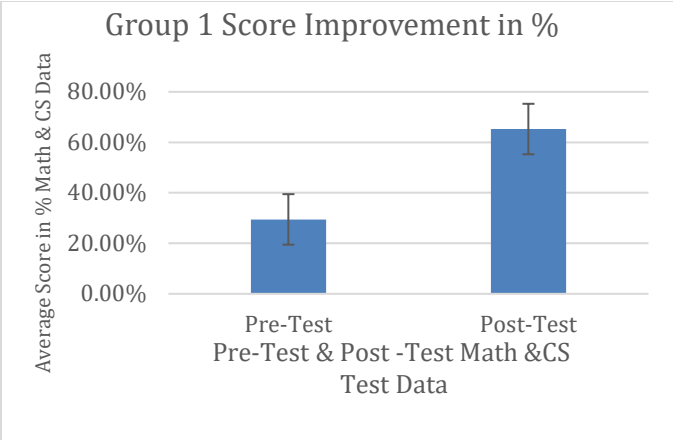

FIGURE IV
COMPARISONS OF GROUP 1 PRE & POST MATH &CS TEST DATA

Group 2, the second group that did repeat the dance and coded the music for the dance, improved its scores from the pre-test to the post-test by 253.85% (from an average score of 0.65 out of 5 to an average score of 2.3 out of 5) as graphed in FIGURE V. By a paired t-test, the p-value of the two tests was 0.0001, which is considered extremely statistically significant. There were 20 students in this group and only one student scored zero on the post test. Side by side compression among the Control Group, Group 1 and Group 2 is detailed in FIGURE VI.

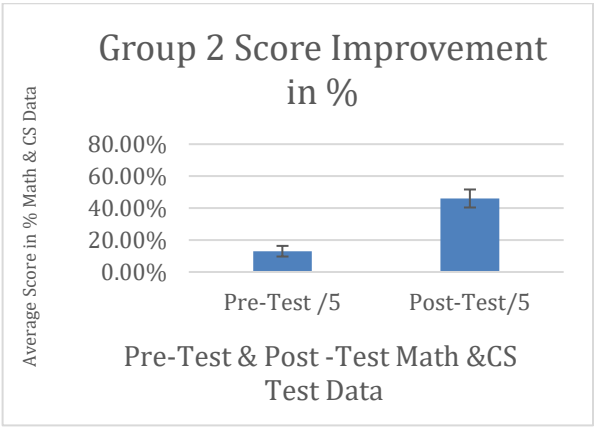

FIGURE V

COMPARISONS OF GROUP 2 PRE & POST MATH &CS TEST

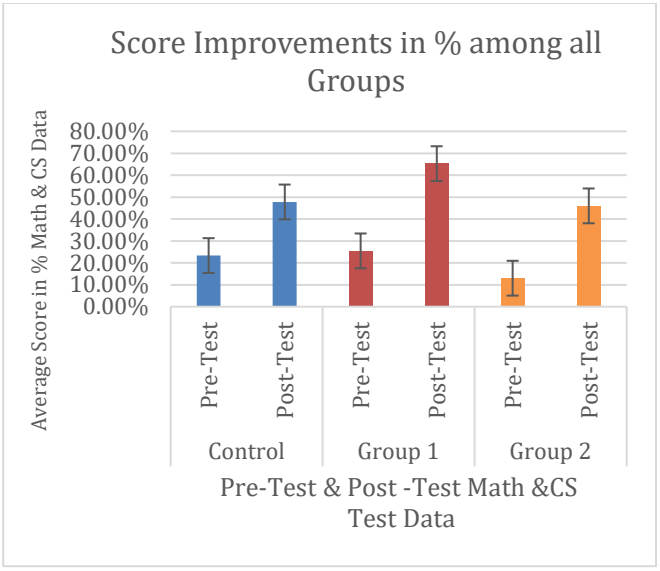

FIGURE VI
COMPARISON OF PRE-AND POST MATH &CS TEST SCORES OF ALL THREE GROUPS

We did an unpaired t-test for the Control Group and Group 2 to determine whether preforming the actual MathDance in class and coding the music for the dance improved the student's learning or not.

The unpaired t-test shows a p-value of 0.8366, which is not statistically significant. However, it does not mean that preforming the actual MathDance in class and coding the music for the dance do not improve students' performance, because the high p-value is the result of no big difference between the Control Group post-test math and computer science test results and Group 2 post-test math and computer science test results. In addition, we did a One-Way ANOVA Test between the Control Group, Group 1 and Group 2. This test shows a p-value of 0.0302 between the groups, which is statistically significant, and may indicate that preforming the MathDance in class and coding the music for the dance did indeed improve the student's performance and learning in math and computer science.

All of the groups showed an increase in their interest in STEM classes and STEM careers. The Control Group shows an increase of 2.78% (from an average of 6.38 to 6.667) in their interest in STEM classes and 7.22% (from an average of 5.2 to 6) in their interest in pursuing STEM careers, whereas, Group 1 shows an increase of 7.37% (from an average of 6.363 to 7.105) in their interest in STEM classes and 4.21% (from an average of 6.157 to 6.578) in their interest in pursuing STEM careers. Group 2 shows an increase of 7% (from an average of 5.85 to 6.55) in their interest in STEM and 3.5% in their interest in pursuing STEM careers (from an average of 6 to 6.35). We ran the unpaired t-test for the Control Group and Group 1 and the Control Group and Group 2, even though, we did not find statistically significant difference between the groups, we can determine that students

who performed the MathDance and coded the music for the dance had a lager increase in their interest in STEM than the Control Group. It is possible that we have not find a statistical significant in the likeness of STEM classes because the students are already enrolled in a Science & Math school Middle School, which may indicate that they like STEM classes. It is also possible that we have not find a statistical significant in their interest in pursuing STEM careers because the environment in which one grows up has a significant influence of whether to peruse or not a career in STEM. In addition, all of the students who answered the third question in the common questions section said that they enjoyed the workshop and some of them said that they would like to come back to learn more. One student said that "the coding part was his favorite part", and another student said that he is "more interested in coding and hope to take more classes in the future".

SUMMARY AND CONCLUSIONS

It seems that MathDance&Music is an effective learning tool in K-12 learning environment. With this tool students learn math and computer science concepts using coding, animation, dance, music, and art in the classroom. It is an integrated model that can improve academic performance in math and computer science and can increase interest in STEM classes and STEM careers. The MathDance&Music program used coding, animation, dance and music to teach middle school students mathematics and computer science concepts. As we expected, the assessment results show that the students' knowledge in math and computer science significantly increased in Groups 1 and 2, which did the actual dance and coded the music for the dance. We believe this is due to the integration of coding, animation, dance, music and art. While we recommend the implementation of this program into curricula, to come to a definite conclusion we will have to conduct more workshops in the future so we can have a bigger sample group of students.

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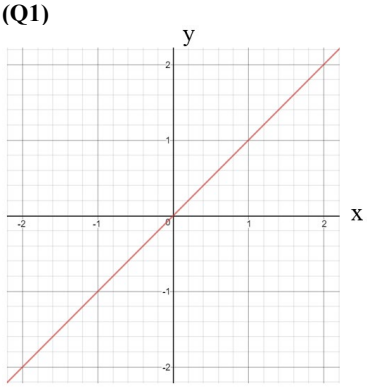
APPENDIX A: PRE ASSESSMENT QUESTIONS

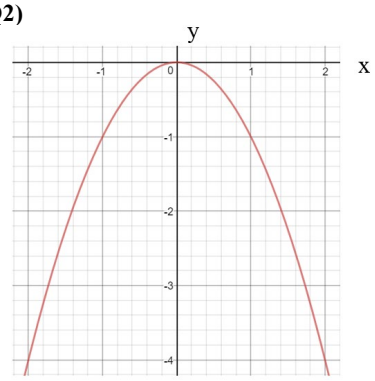
Choose the equation of each function graphed on the left.

(Q1)



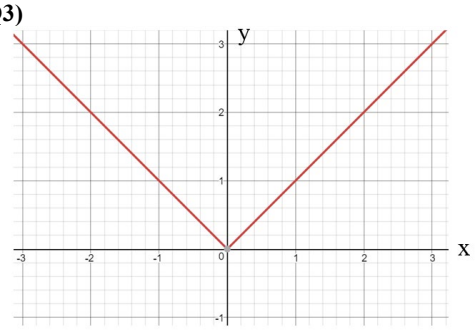
a. $y = x^2$
b. $y = -x$
c. $y = x$
d. $y = -x^2$
e. I don't know

(Q2)



a. $y = 0$
b. $y = -x^2$
c. $y = |x|$
d. $y = x^2$
e. I don't know

(Q3)



a. $y = x$
b. $y = |x|$
c. $y = x^2$
d. $y = -|x|$
e. I don't know

(Q4)

How many steps will be moved according to this program?

```
Repeat the following Begin-end block 2 times:
    Begin:
        Repeat the following Begin-end block 3 times:
            Begin:
                Move 5 steps.
            End
    End
```

(Q5)

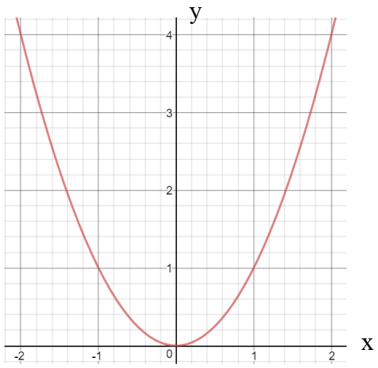
The current temperature `t` is 28 degrees in Fahrenheit. How many steps will be moved according to this program?

```
If t > 32 then:
      Move 4 steps.
Otherwise:
      Move 10 steps.
```

APPENDIX B: POST ASSESSMENT QUESTIONS

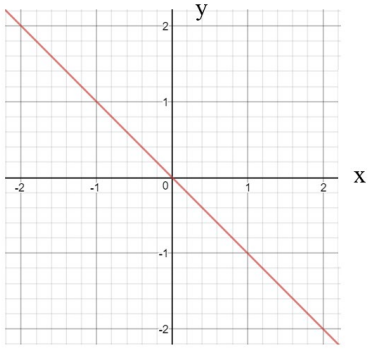
Choose the equation of each function graphed on the left.

(Q1)



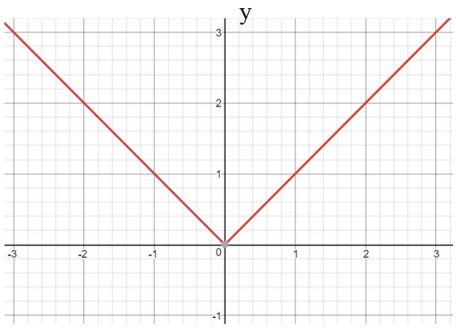
a. $y = -x$
b. $y = x^2$
c. $y = |x|$
d. $y = 0$
e. I don't know

(Q2)



a. $y = -|x|$
b. $y = x$
c. $y = x^2$
d. $y = -x$
e. I don't know

(Q3)



a. $y = x$
b. $y = |x|$
c. $y = -|x|$
d. $y = -x^2$
e. I don't know

(Q4)
How many steps will be moved according to this program?

```
Repeat the following Begin-end block 3 times:
    Begin:
        Repeat the following Begin-end block 2 times:
            Begin:
                Move 4 steps.
            End
    End
```

APPENDIX D: COMMON ASSESSMENT QUESTIONS

Do you like Science, Computer Science, Technology, Engineering, and/or mathematics (STEM) related classes? Please circle a number that best represents how you feel on a scale of 0 to 9.

Do **not** like STEM classes 0 1 2 3 4 5 6 7 8 9 Love STEM classes

Are you interested in a future career involving Science, Computer Science, Technology, Engineering, and/or mathematics (STEM)? Please circle a number that best represents how you feel on a scale of 0 to 9.

Not interested at all 0 1 2 3 4 5 6 7 8 9 Very much interested

(Q5)
The current temperature `t` is 75 degrees in Fahrenheit. How many steps will be moved according to this program?

```
If t > 32 then:
    Move 4 steps.
Otherwise:
    Move 10 steps.
```

APPENDIX C: COMMON ASSESSMENT QUESTIONS

Do you like Science, Computer Science, Technology, Engineering, and/or mathematics (STEM) related classes? Please circle a number that best represents how you feel on a scale of 0 to 9.

Do **not** like STEM classes 0 1 2 3 4 5 6 7 8 9 Love STEM classes

Are you interested in a future career involving Science, Computer Science, Technology, Engineering, and/or mathematics (STEM)? Please circle a number that best represents how you feel on a scale of 0 to 9.

Not interested at all 0 1 2 3 4 5 6 7 8 9 Very much interested

Did you enjoy today's MathDance workshop? Your comments are appreciated: **Asked only for POST ASSESSMENT**