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Mathematical Movements:

Bringing Dance into the Classroom

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Abstract

My thesis explores connections between math and dance to evaluate the benefits of movement integration in math classrooms. With an understanding of the different ways humans learn and the neurological process of how we learn, we can appreciate the benefits of kinesthetic teaching and learning. Lately, movement has been welcomed into the classroom in the form of a *brain break*; this paper is designed to push this idea further and encourage the incorporation of dance in classroom lessons. Participants ($N = 22$) signed up for one of two 45-minute classes without knowing the teaching style; one class was a lecture, the other was entirely movement-based. The content covered in the lessons was the same: fractions, percentages, and mentally calculating tips. Participants took a pre-assessment before the lesson and a post-assessment after. Their math skills and overall experience were evaluated. No matter the teaching method, participants showed growth in both their math skills and their confidence in the content. A one-time, 45-minute study does not allow for enough analysis on student growth in any area. Research should be continued in this area to explore how movement integration can be used to introduce new classroom material as well.

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Introduction

Statement of the Problem

The idea that individual humans learn and process information differently is not a new concept. In fact, this was theorized around 330 BC by Aristotle, who said "each child [possesses] specific talents and skills" (Reiff, 1992, p. 7). Many years later, Gardner (1983) published his theory on Multiple Intelligences acknowledging seven different ways for a person to identify themselves as a learner: Logical-mathematical, linguistic, musical, spatial, bodily-kinesthetic, interpersonal, and intrapersonal. His theory has since been refined, and he has added two more intelligences: naturalistic and existential (Gardner, 2011). People often align with more than one intelligence, reflecting their multitude of abilities.

Before understanding the intelligences one has, it is important to understand the process of learning; the neurological acquisition of knowledge. All learning starts with sensory information, which is directed to the brain. The brain requires over 20% of the body's oxygen and nutrients and is often frugal with mental effort in order to preserve these limited resources. In order to work through the sensory information in a conscientious manner, the brain uses the reticular activating system or the RAS. This system filters stimuli, determining which information is most useful and will be let in. From here, the sensory information travels to the amygdala which communicates with the lower and upper brain. Automatic bodily functions and involuntary reactions or primitive responses are the kinds of information that are sent to the lower brain. The area where memory is created is the upper brain, or the prefrontal cortex, which receives information that requires logical thought and emotional self-management (Willis & McTighe, 2019). Understanding this complex system in our brain helps educators identify that when students "are in a state of actual or perceived stress, new information does not freely pass through the amygdala's filter to gain access to the prefrontal cortex. Instead, input is delivered to the lower brain" (Willis & McTighe, 2019, p. 7). For students to truly be able to learn, they must be in an environment that does not induce stress, fear, frustration, anxiety, or boredom. The realization of these environmental impacts on student success can help aid educators in creating the best teaching strategies and experiences for their classrooms.

When looking into the process of how brains take in sensory information and turn it into knowledge, memory, and understanding, it is easy to recognize how the typical math classroom does not create an environment where students can learn well. More often than not, students report that they have anxiety around math as a result of the classroom environment and teaching style (Finlayson, 2014). Anxiety is a factor that will cause content to go straight to the lower brain. This is illustrated in the fact that:

> Neurologically, there is less growth of the brain's neural networks if circuits are activated only by asking students to repeat the same information or perform a process in the same way over and over again—for example, asking them to write a vocabulary term 10 times or solve 30 algebraic equations using the same formula. (Willis & McTighe, 2019, p. 98).

Asking students to repeat algebraic processes multiple times will not help them transfer their learning to new problems or challenges and will likely create a state of boredom, causing more sensory information to never reach the upper brain. In order to combat boredom, but to still ensure students are getting the necessary practice to improve and succeed, it is important to vary question types and format. This not only keeps students from answering the same questions, but tests their transfer of knowledge and allows teachers to identify if students can apply their learning in a new setting.

Educators encourage spreading lessons over multiple days or even weeks as another way to keep students engaged. Studies have shown that students will achieve higher scores on tests when learning opportunities are spread throughout multiple days rather than crammed into one (Carpenter & Agarwal, 2020). In a 2021 study specifically focused on the effects of spaced practice in math classrooms, students were split up into two groups. One group learned the material, did 12 practice problems, spent 4 weeks learning different content, and then took the test. The other group learned the material, did four practice problems, and then spent one week on new material. After that week, they did four more problems and took another week. Then, they did four more problems, and took the same four weeks off as the first group. By the time both groups arrived at the test, the group with spaced practice received higher scores (Emeny et al., 2021). This method of teaching and learning keeps students from getting disengaged with the material as it is spread out over days or weeks. Spaced instruction and practice help to keep students from a state of boredom and, ultimately, helps knowledge pass to the upper brain for long-term memory.

No matter the classroom, subject, or environment where a brain is working hard to take in knowledge, it needs oxygen. After a 20–30-minute period of being inactive, people experience a "drop in glucose and oxygen to the brain, resulting in diminished ability to focus, comprehend, and remember" (Reilly et al., 2012, p. 63). As a result of this, *brain breaks* have become increasingly popular over the years in the classroom. Teachers use brain breaks as a moment for students to get up and take a step away from what they have been studying. These breaks are important for students to get up and move around a classroom as it allows for the oxygen to flow to their brain and reboots their energy and focus. Not only does "movement increase the heart rate and [stimulate] brain function, which facilitates a child's ability to intake information and learn," but intentional moments of movement can also be beneficial for students with attention deficit disorders (Reilly et al., 2012, p. 63). Educators will also often provide their students with fidget toys and different resources which allow students to keep their fingers busy or to wiggle in their seats during lessons. While these can be extremely helpful tools, they can also distract other students in the classroom and limit productivity when a student needs to use their hands to do their work. Understanding the benefit that intentional movement has in the classroom – specifically as it relates to enhancing brain function – is important. Ensuring there are opportunities in a lesson for students to take a break, get up, and move around, helps their ability to learn and is a great classroom tool for engaging all students.

Dance and math have been two things I enjoy doing for as long as I can remember. Both the process of picking up choreography and solving an equation have come easily to me. Growing up, when I would tell people these were the two things I enjoyed and planned to study, I would often hear comments about how different they were, about how I was going to be using both sides of my brain. To me, the two subjects have never been that different. Being introduced to a new mathematical process and beginning to understand how to solve it was just like learning a new move in a dance class. It's necessary to break both down, step by step, and understand all of the pieces that go into the final product. Being able to remember choreography has always felt like learning, practicing, and recalling mathematical formulas like the quadratic equation. For me, math and dance have always been intertwined and I have found that my work in one has always helped my work in the other.

Throughout this paper I will discuss the benefits that any type of dance can have in the classroom, specifically looking at how movement can enhance a lesson in mathematics. The use of the word movement and dance will be interchanged throughout this paper as a way to emphasize that movement is dance and dance is movement. To the outside eye, dance is often pictured as intricate choreography, yet any form of functional, intentional movement can be considered dance. Math and dance are intertwined in many ways and I believe that movement can create a more engaging lesson. Bringing dance into the classroom allows for involvement from every individual in the classroom and reinforces the knowledge of the learner. Students have the opportunity to express themselves through movement while continuing to explore the content of their lessons. This allows for cultural explorations, growth in self-confidence, and confidence in the subject area itself. After exploring the connections between math and dance, I will discuss the benefits of bringing movement into the classroom as a reflection of the lessons I taught.

Movement and Mathematics

Looking at the environments where students are learning math and thinking about how students are neurologically wired to learn, it makes it easy to recognize that math lessons should be enhanced to benefit every student. Typically, new math concepts are taught in a lecture-style classroom; the students have a pencil and paper to take notes while the teacher uses the board to illustrate concepts. After being introduced to the topic, students will complete practice problems and continue the same work for homework. There is little variety in the day-to-day experience of learning in a math classroom. Often, students don't value math or see the connections to their everyday life, which can make it challenging to be a student in a math classroom. Questions are often asked in the same way and specific answers are expected. For students that get a question wrong once, it is easy for them to assume they will get it wrong again (Finlayson, 2014). As an alternative, creating lessons where students are able to explore answers and don't feel pressured to get something right on the first try will help ensure their brains are actively passing information to their prefrontal cortex. There needs to be a change to the assumptions and stigma that many students have about math classes by creating engaging activities and lessons that help students stay focused and deepen their understanding. One way that this can be achieved is through dance, "a magnificent three-dimensional medium for learning concepts that are not always adequately facilitated by traditional language/analytic-based teaching methods" (Hackney, 2006, p. 23). By connecting traditional lecture and hands-on experience through kinesthetic, interactive pedagogy we can allow students to explore and learn through their musical, visual-spatial, interpersonal, intrapersonal, and bodily-kinesthetic intelligences.

In the past decade, there has been a big push for dance education in public schools with all states integrating academic standards for dance as of February 2021 (*About – Dance Education*, NDEO, n.d.). Often, schools will bring in outside organizations like Dancing Classrooms or individual teaching artists like Ashley Hensel-Browning to work with different classes for a certain period of time. There are many benefits to programs like these. Not only do students learn more about themselves and one another, they discover a new form of self-expression and learn about persistence, accountability, collaboration, and much more.

There are many dance educators who are constantly advocating for the continued integration of dance education in schools. Shirlene Blake, Director of Dance for the New York City Department of Education, and Jody Arnhold, Dance Education Laboratory founder, have both been dedicated to creating dance curricula based on their years teaching in New York City public schools. For Arnhold, "dance education isn't fundamentally about dance technique; it's about creativity, emotional development, cooperation, connection with other disciplines, education in the largest sense" (Seilbert, 2023, para. 11). In the simplest terms, Arnhold believes everyone deserves to have a relationship with dance, especially one connected to their education. Blake (personal communication, April 10, 2024) shares a similar sentiment, noting that:

> the idea of arts integration, is that all teachers, no matter what subject they're teaching, need to have an understanding of the importance of the arts in the classroom because there are ways to get young people to think about their work through the lens of dance, of music, and of culture in general.

Even if the student isn't aware, classes and workshops like these improve and develop their "neural synaptic connections [which] will lead to mastery of a mathematical concept" (Hackney, 2006, p. 25). Movement can sharpen a student's mathematical skills even if it isn't directly connected to content.

As someone who loves both math and dance, the connections between them stand out to me. It is easy to see geometry in movement; shapes, translations, reflections, symmetry, and spatial awareness. Music helps create connections between fractions, rhythm, tempo, and the speed of a dancer's movement. Sequence and pattern recognition is also strengthened with every dance class. Hackney (2006) recognizes the neurological similarities between dancing and learning math stating that "dancing involves discipline, precision, and previous knowledge of steps in order to progress. One uses the brain in a very similar way when learning mathematics" (p. 23). Educators can use the elements that dance and math share to their advantage while lesson planning. Bringing dance into the classroom allows for the opportunity to learn in a non-traditional way; it keeps brains awake, engaged, and focused and can help create more meaningful connections to real-world situations. In math, movement can help students visualize what the calculations they are making actually mean by approaching the concept in a fundamental way. Students shouldn't be stuck to a chair; they should be exploring math actively and in ways which engage their myriad learning methods, allowing the brain and body to align and work in symmetry.

Literature Review

Changing Student Attitudes Towards Math: Using Dance to Teach Math

Werner (2001) explored how the integration of math and dance in a classroom affects student attitudes toward learning math. The goal of this project was to "engage students in math in ways that reached students' multiple intelligences and encouraged students to make complex connections and try new problem-solving techniques" (p. 4). This study took a year to complete as the researchers surveyed over 200 students, ranging from second to fifth grade, in the fall of 2000 and again in the spring of 2001. Students were presented with 13 statements on math and math practices and were asked to respond using a three-point scale. Eleven different classrooms participated; six were labeled as dance/math classrooms and five as non-dance/math classrooms. Only six were paired for analysis: two second-grade, two third-grade, and two fifth-grade classrooms were investigated. One classroom in each grade level had a dancer work with them once a week, the other three classrooms did not. It was hypothesized that the "students who worked with a dancer once a week to learn math concepts would become more engaged in mathematics and have more successful and positive experiences with mathematics than the students who did not work with a dancer" (Werner, 2001, p. 4). At the end of the year, the teachers and dancers found their hypothesis to be true. Students in the dance/math classrooms scored significantly higher on the survey in the spring than they did in the fall, indicating that they had a more positive attitude toward math. The results also showed that the scores from the fall to the spring in all six of the dance/math classrooms had either increased significantly or had no significant change, whereas the scores in the five non-dance/math classrooms either had no significant change or decreased significantly.

Not only did the quantitative data support the hypothesis of the teachers and dance educators, but classroom observations supported the hypothesis and mirrored the results as well. Teachers in the dance/math classrooms stated that "their students were better able to make connections among diverse subjects and pieces of knowledge than they were before the project, which made learning math more interesting and applicable to everyday life" (Werner, 2001, p. 4). Here the importance of bringing movement into math classrooms is seen. Students are able to step outside of their typical learning environment and make connections to bigger things, truly participating in experiential learning. For the students in this study, dance helped them have a more positive, engaging experience with math.

Minds in Motion: A Kinesthetic Approach to Teaching Elementary Curriculum

Griss (1998) spent many years exploring a kinesthetic approach to teaching, specifically looking at elementary education. She used this approach to both introduce and reinforce lessons to assist students' understanding of the content. These lessons went past content and intellectual knowledge since "a successful kinesthetic lesson [has] children learning to make use of their own experiences and observations as a foundation for knowledge" (Griss, 1998, p. 7). Empowering students by encouraging them to use their own bodies and minds to reach a conclusion, enhances self-esteem, affirmation, and confidence – attributes that are critical for success both inside and outside of the classroom. In a typical math classroom, with questions and practice problems being presented in the same way, it is easy for a student to quit and stop trying after getting a problem wrong once or twice, damaging their self-esteem and confidence (Finlayson, 2014). With movement, students are free to explore and approach problems from a variety of directions; limiting the rigid expectations of right and wrong. Griss (1998) spoke about how this allows students to integrate their sense of self with the material learned in their classrooms, more simply put, "kinesthetic learning is experiential learning" (p. 2).

If you gave four students the same word problem and asked them to solve it with a pencil and paper, you would get similar attempts and, possibly, the right answer four times. If you gave four students the same word problem and asked them to solve it and show their answer through movement, you would likely get four unique ways of representing the answer; all which would, ideally, be backed up with explanation. When you ask students to solve a problem through movement they experience "the creative process of choreography [which] leads [them] to develop [their ideas] through many stages of brainstorming and exploration, analysis and synthesis, refinement and editing" (Griss, 1998, p. 11). As students work through their own kinesthetic approach, not only do they think about the math problem in a different way, but they can find ways to integrate a sense of self into their response, allowing math to resonate with them on a personal level.

Using movement in the classroom can also help create a more culturally competent environment. Introducing students to different styles of dance and genres of music allows for cultural explorations. The vulnerability, trust, intrapersonal, and interpersonal aspects that come with movement-based work also help create empathetic environments that teach students to value and support one another. Griss (1998) discussed how "bringing physical language into the classroom offers children a rare chance to look at one another, to see each other, and learn how to show respect for each other's differences in a nonthreatening arena" (p. 13). Dance is a non-verbal form of communication, which can be an extremely vulnerable experience for people, but it can also create immense respect and deep connections between one another. While fostering a classroom environment of shared humanity, experiences like these are simultaneously helping students refine their 21st-century skills, something that has been intertwined with lesson plans and learning objectives since the early 2010s (McMilan, 2024). Twenty-first century skills encourage educators to teach lessons in a way that extends past subject-area knowledge and has students gaining confidence in a multitude of areas. Problem solving, innovation, flexibility, motivation, cross-cultural skills, cooperative skills, and interpersonal skills are just a portion of the list which can be addressed through movement integration.

Math Dance with Dr. Schaffer and Mr. Stern

Schaffer and Stern (2001) explored the connections between math and dance many years ago by creating their first stage performance *Dr. Schaffer and Mr. Stern: Two Guys Dancing about Math* in 1990. To them, the exploration of math through movement creates opportunities in a classroom for "when a concept needs to be understood mentally, physically, and emotionally…[and] reach those students whose learning styles are not compatible with traditional methods of teaching" (p. 5). The two have choreographed multiple dances and created both workshops and performances for school settings, ultimately working to show that there are multiple ways to experience and learn both math and dance. Schaffer and Stern (2001) feel that "when choreographing a dance or investigating a mathematical problem, [they] are doing the same thing: creatively exploring patterns in space and time with an eye toward aesthetic potential" (p. 5). Dance allows math to be brought to a comprehensible level. Schaffer and Stern's workshops allow students to explore mathematical problems through dance, enlivening a subject that many students find interesting, but challenging. Probability, symmetry, translation, rotation, reflection, glide, least common multiple, patterns, angels, complex numbers, and modular arithmetic are just some of the topics that they have covered in their workshops and lesson plans. Just as the topics of math are limitless, the styles of dance are as well. Integrating different forms of movement – hip hop, jazz, ballet, tango, salsa, tap, improv, etc. – can allow educators to reach a variety of interests in students as well as encouraging growth in their cross-cultural skills. Many styles of dance, and with them, genres of music, are associated with different cultures and communities; integrating these into a classroom to enhance a mathematics lesson will benefit more than just the students' ability to understand the content.

Schaffer and Stern have highlighted many benefits of combining math and dance: everyone participates, there is deeper spatial thinking, it engages students with a new approach, it helps students cross barriers, allows the aesthetics of dance and math to be appreciated, explores cultures, and expands on each discipline. Ultimately, they see math and dance as subjects that inspire each other; creating opportunities for students to embrace their multiple intelligences and for educators to challenge the ways math is taught.

Dancing Mathematics and the Mathematics of Dancing

belcastro, a mathematician and dancer, has explored how she can combine more complex topics in math with movement. Her dance background is heavily focused in ballet and modern, meanwhile she has a Ph.D. in algebraic geometry and continues to do research in topological graph theory. Through a variety of work, belcastro (2011) has found that:

> One can pay attention to the geometry of the moving body; to the topology of links between dancers, for example, during lifts; to the spatial paths of the dancers…or even to conceptual problems like game theory in a struggle between two dancers. (p. 17).

In 2001, belcastro choreographed a modern dance piece, *Swirly Suite I*, in which she demonstrated the binomial coefficient four-choose-two by having each dancer dance with one another. In the same piece, she mapped two movements – grapevines and balancés – to zero and one, respectively. She had pairs of dancers moving together, ultimately representing the elements of the Cartesian product $Z_2 \times Z_2$. Through her work, belcastro has shown how even complex mathematical concepts can be explained through dance. She is clear when stating that "[she doesn't] view dance entirely through the lens of mathematics—or vice versa" (p. 20). Yet, she has shown how the connections between math and dance expand past elementary and middle school curriculums and can be beneficial for all levels of learning.

Methods

To explore the connections between math and dance, and to look at the benefits of bringing movement into the classroom, I created and taught two lessons (Appendix A). These lessons covered the same mathematical content – fractions, percentages, and mentally calculating tips – but were taught in two different ways. Since I was unaware of the students that would be coming into the classroom, I chose to focus the lesson on fractions and percentages, something everyone has been introduced to by their time in college. It was also a lesson that all students could benefit from as there are many instances in life where calculating percentages is necessary.

One lesson mimicked a typical math classroom – a lecture-style lesson with students following along on a worksheet. The other lesson had the students out of their seats – it was entirely structured around a movement-based, kinesthetic style of teaching and learning with a focus on functional, intentional movement. To ensure that this lesson was accessible and comfortable for all students, every activity that involved dance was first demonstrated by me, something that Griss (1998) encouraged in her work. As movement integration becomes a more regular practice in the classroom, educators can begin to step away from the demonstration, allowing students to cultivate their imagination and improvisation. Students were asked to report any mobility limitations allowing the lesson to be adjusted for their participation.

Participants

The sample consisted of 22 participants ages 18-21 who study at a small liberal arts institution in the Northeast. The majority of participants identified as female (64%), with 32% identifying as male, and 4% identifying as non-binary. All participants had previously taken math classes, some as recently as two days prior to the study, others as long ago as four years prior. The majority of students had previously taken at least one dance class, with only nine participants having never taken a class. This study was approved by the Institutional Review Board at the university and was conducted in its entirety on the university's campus. The majority of participants were recruited through Psychology 101 classes. By participating, they received one credit toward the 3.5 research credits required for the class.

Participants were asked to sign up for one of the two available time slots; they were not aware of which lesson would be taught with movement or without, but they were aware of the parameters of the study. Originally 15 students signed up for the first lesson and 11 for the second. I asked four of my peers to fill up the other slots to create even groups of 15; these participants were not part of a Psychology 101 class, but were also aware of the parameters of the study. Of the 30 students that signed up - 15 for each lesson - 22 showed up. Ten participants attended the first lesson which was taught without movement, while 12 attended the second lesson which was taught with movement. This sample size mimicked that of a small classroom or educational setting.

Materials

Participants took part in a one-time, 45-minute lesson; each group was taught the same content with different teaching styles. The lesson plans for both classes can be found in Appendix A. Participants in the first lesson were taught in a lecture-style class and followed along on a worksheet (see Appendix B). Participants in the second lesson were taught in a movement-based class which explored all of the same questions from the worksheet through movement. I created pre- and post-assessments (see Appendix C) which were distributed to each participant via Qualtrics (www.qualtrics.com).

The pre-assessment (Appendix C) was distributed at the beginning of the lesson before the teaching style was revealed to the students. Participants were asked to answer demographic questions about their age, class year, majors and minors, and gender before answering questions about learning intelligences. Some questions had participants answer their level of agreement surrounding statements like “I like math,” “I believe I am good at math,” “I like dance,” “I believe I am good at dancing” and others. Their responses were reported on a 5-point Likert scale ranging from “strongly disagree” to “strongly agree.”

The second section of the pre-assessment targeted participants’ math skills. Students were given multiple choice questions that asked about fraction/percentage equivalence, tricks for calculating 1% and 10%, word problem percentage scenarios, and “odd” percentage calculations. The “odd” percentages questions had students calculating 15%, 11%, and 18% of 80, 1,234, and 240, respectively. All questions were completed without a calculator and every question had the option for students to answer “I would be guessing” to ensure they would not guess and accidentally get the correct answer. An example question is “if you bought a $700 couch and there is 10% sales tax, how much would the sales tax cost?” Participants would have the possible answers of “$7,” “$14,” “$49,” “$70,” and “I would be guessing.” The math questions in this section mimicked the questions that were discussed and taught throughout the lesson.

The post-assessment (Appendix C) was taken at the end of the 45-minute lesson. The section that targeted their math skills was identical to the pre-assessment, which allowed for an analysis on the change of the participants’ math skills. Rather than demographic questions at the beginning of the post-assessment, students were asked to reflect on the lesson. Using another 5-point Likert scale ranging from “strongly disagree” to “strongly agree,” students were asked to indicate how much the lesson changed their opinion of both math and dance, if the study introduced them to a new way of learning, if they feel more confident in their ability to calculate percentages, and if they enjoyed the lesson. Other short-answer questions provided students with the opportunity to identify the different teaching styles and write down overall reflections and opinions of the lesson. Participants were allowed to skip any question they did not want to answer on both the pre- and post-assessment.

Procedures

Participants entered the classroom without knowing the teaching style of the 45-minute lesson. The participants were assigned a number which they submitted with pre- and post-assessments (Appendix C) allowing for their answers to be compared while keeping their identities confidential. These assessments asked questions regarding personal background, interest, enjoyment, and experience in both math and dance, as well as specific math problems related to the content covered in the lessons. After completing the pre-assessment, students were told which class they were in. There were a few students in both classes that were disappointed they were not in the other class.

The lessons started with an exploration of fractions and their relation to percentages. Students in the non-movement class worked through a worksheet (Appendix B) to split boxes into different portions and write the corresponding fractions and percentages. For the movement class, this was a way to explore the space and become comfortable with moving in a new environment. The students moved throughout the entire space, then the space was split in half, then in fourths, then eighths. As they were dancing throughout the space, the students in the movement class discussed the fraction of the room that was available to move in and the percentage that it was equivalent to. From here, both classes moved forward to work on calculating percentages. The tricks for calculating 1% and 10% were talked through and then students began exploring how to calculate “odd” percentages (e.g., 13%, 18%, 25%).

The lessons were held in a classroom that had moveable desk chairs. For the movement lesson, the desks were rearranged to create the most floor space. Numbers were taped onto the floor so students could physically move as if they were the decimal while calculating a percentage. Participants worked in groups to choreograph unique and individualized processes for solving word problems and to show the solutions to them. After creating movement to show the mathematical process, the groups shared their work with one another. Other groups would comment on what they saw in the movement and guess which problem the group had solved. For students in the non-movement classroom, they solved these problems by following along on their worksheet with a pen or pencil.

To allow participants in the second lesson to feel more comfortable with their movement, music was played on a speaker throughout different parts of the lesson. When giving instructions, the music was paused to help students focus on the task at hand, but when working with groups and brainstorming their choreography, music played lightly in the background. A playlist for this lesson can be found in the movement class lesson plan (Appendix A), but it is encouraged to use a variety of genres or tailor the genre of music to the style of dance. Since this lesson was focused around functional, simple movement, there was no specific genre of music that fit best.

The lessons ended with a reflection on what was covered and the participants were asked to take the post-assessment. Once the final assessment was completed, they were allowed to leave. With 10 questions in the math skills section, each correct question was rewarded with 10 points, allowing students who got every question correct to receive a 100.

Responses to the pre- and post-assessments were treated as follows. The grades on all math sections of the pre- and post-assessments were calculated and compared to show the percent increase and the change in each participant's math skills from attending the lesson. SPSS, a statistical analysis software, was used to conduct independent samples *t*-tests to find statistically significant differences. Student scores were compared to their experience in the classroom, their previous dance experience, and their gender identity. Between classes, comparisons were made on students' level of confidence, growth, and initial starting point. On top of data analyzed with SPSS, qualitative data was collected through classroom observation and student feedback.

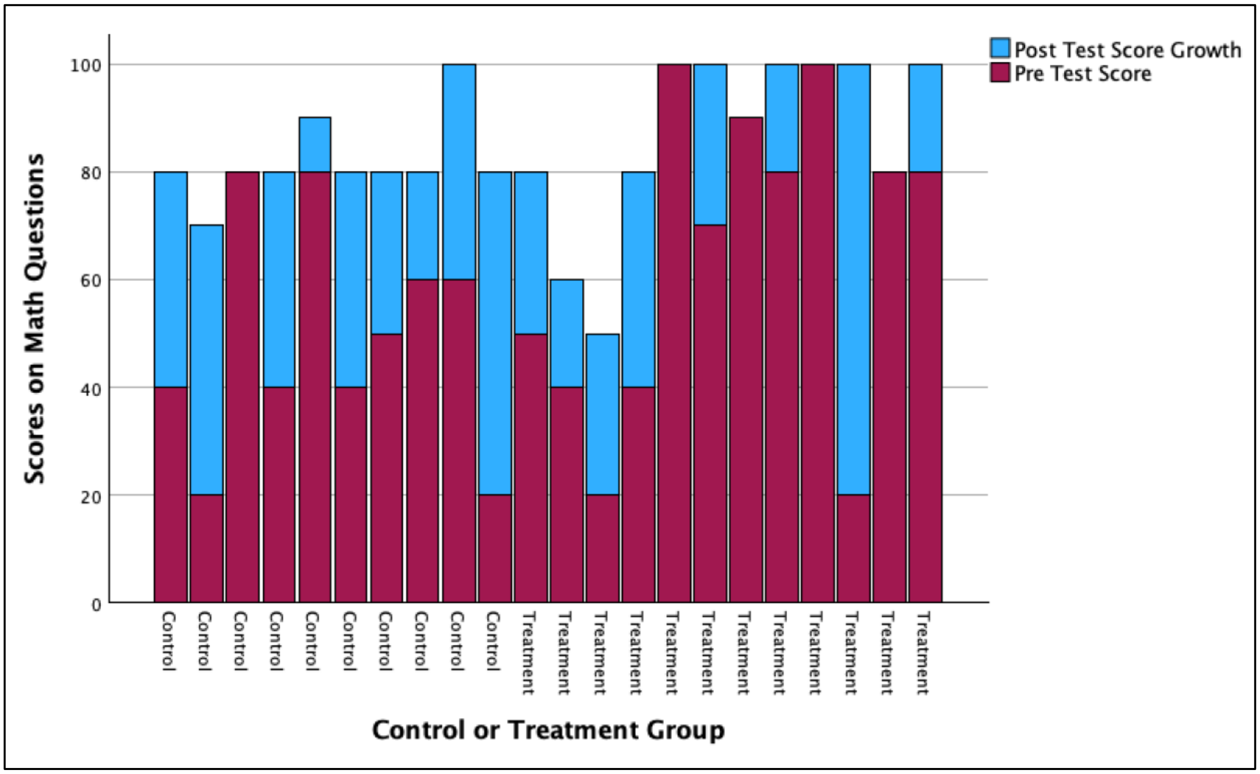
Results

The pre-assessment revealed a diverse group of learners. The majority of participants were first-year college students, although students from freshman to senior year were represented. Thirteen participants said they prefer to learn in a lecture-style classroom, while seven prefer to learn with projects and hands-on activities. Representing a true classroom, this study was filled with a variety of students who have different learning preferences and backgrounds.

The results of participants' pre- and post-assessment math scores were analyzed in SPSS. Figure 1 shows the change in participant scores on the math skills question from the pre-test to the post-test. Independent samples *t*-tests were performed to evaluate student score growth and to compare enjoyment, confidence, previous experience, and self-identified intelligences to participant success. The *p*-value is used to determine if something is statistically significant while depending on the sample size. Cohen's *d* indicates the degree of the effect, independent of sample size, and is often thought of as a measure of practical significance (Weinberg & Abramowitz, 2016). Percent increase is calculated by computing the following: (post-test value – pre-test value)/pre-test value.

Figure 1

Change in Participants' Scores on Math Skills Questions



Note. This graph shows every participant's pre-test score in red and their difference score in blue. Together, the two scores represent the participant's post-test score. Participants that have no blue bar, received the same score on their pre- and post-assessments.

Comparisons Between Classes

A comparison was drawn between the control and treatment group for the following categories.

Average Scores

An independent samples *t*-test was performed to determine whether the average of the difference between the post-test and the pre-test was the same for the control ($M = 32.00$, $SD = 20.44$) and treatment ($M = 22.50$, $SD = 23.01$) groups. The results indicated that there was no statistical significance between the groups in terms of the average difference score; $t(20) = 1.01$, $p = 0.32$. However, according to Cohen's *d* (0.43), the average score increase is higher for the control group, a weak to moderate effect.

The treatment group had three participants who scored a 90 or above on the pre-test. An additional independent samples *t*-test was run to look at the average difference between the post-test and pre-test only for students with an initial performance below 90. The test resulted in no statistically significant difference between the control ($M = 32.00$, $SD = 20.44$) and treatment ($M = 30.00$, $SD = 21.79$) groups in terms of the average difference score; $t(17) = 0.21$, $p = 0.84$. Cohen's *d* (0.09) indicates that the average score increase is higher for the control group little to no effect.

In hopes of finding statistically significant data, the next test was run on the difference score by only looking at the students whose initial performance was below 80. The independent samples *t*-test between the control ($M = 40.00$, $SD = 11.95$) and treatment ($M = 38.33$, $SD = 21.37$) groups with this modification resulted in no statistically significant difference between the groups as well; $t(12) = 0.18$, $p = 0.86$. Cohen's *d* (0.10) reflects that the average score increase is higher for the control group by little or no effect.

To determine the average percent increase from the pre-test to the post-test, an independent samples *t*-test was performed. The results indicated no statistically significant difference between the control (*M* = 1.01, *SD* = 0.99) and treatment (*M* = 0.71, *SD* = 1.13) groups in terms of the percent difference; $t(20) = 0.65$, $p = 0.52$. According to Cohen's *d* (0.28), the average percent increase is higher for the control group, a weak effect.

Typically, with random assignment to the control and treatment groups, one can assume the initial ability is similar, allowing any differences identified in the post-test to be attributed to the treatment. Since random assignment was not used, an independent samples *t*-test was performed to determine the initial difference in the pre-test scores between the control (*M* = 49.00, *SD* = 21.32) and treatment (*M* = 64.17, *SD* = 29.06) groups. The results indicated that there was no statistically significant difference between the groups in terms of their pre-test scores; $t(20) = -1.37$, $p = 0.19$. However, according to Cohen's *d* (0.59), the pre-test score is higher for the treatment group, a moderate effect.

Confidence

The confidence of participants was analyzed in a few ways. When taking the pre- and post-assessments, participants had the option to answer questions with "I would be guessing." An independent samples *t*-test was performed to determine whether the average difference between the questions answered with "I would be guessing" on the post-test and pre-test was the same for the control (*M* = -3.80, *SD* = 2.15) and the treatment (*M* = -1.92, *SD* = 2.19) group. The results nearly indicated a statistically significant difference between the groups on the difference score, $t(20) = -2.02$, $p = 0.06$. According to Cohen's *d* (0.87), students in the control group were less likely to be guessing after the lesson than the treatment group, a large effect.

To analyze this data in another way, an independent samples *t*-test was performed to determine whether the average of the percent difference between the post-test and pre-test was the same for the control (*M* = -0.92, *SD* = 0.17) and treatment (*M* = -0.86, *SD* = 0.26) groups. The results reflected no statistically significant difference between the groups in terms of the percent difference; $t(16) = -0.58$, $p = 0.57$. Cohen's *d* (0.28) indicates that the average percent difference is higher for the control group, a weak effect.

To consider if both groups started with the same ability, an independent samples *t*-test was performed to determine whether the average number of questions answered with "I would be guessing" on the pre-test was the same for the control (*M* = 4.10, *SD* = 2.23) and the treatment (*M* = 2.42, *SD* = 2.61) group. The results indicated that there was no statistically significant difference between the groups in terms of the average difference score; $t(20) = 1.61$, $p = 0.12$. However, according to Cohen's *d* (0.69), the average number of questions answered with "I would be guessing" is higher for the control group, a moderate effect.

On the post-assessment, students were asked to rate how much they agreed with the statement "I feel more confident in my ability to calculate percentages" on a Likert scale from strongly disagree to strongly agree. Table 1 shows the number of students who responded to each agreement, organized by group. To determine whether the average level of confidence after the lesson was the same for the control (*M* = 4.20, *SD* = 1.23) and treatment (*M* = 4.00, *SD* = 1.13) groups an independent samples *t*-test was performed. The results indicated no statistically significant difference between the groups in terms of confidence level, $t(20) = 0.40$, $p = 0.70$. According to Cohen's *d* (0.17), the level of confidence for the control group is higher, little to no effect.

Table 1

Responses to "I feel more confident in my ability to calculate percentages"

Control or Treatment Group	"I feel more confident in my ability to calculate percentages"				
	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
Control	1	0	0	4	5
Treatment	1	0	1	6	4
Total	2	0	1	10	9

Note. This table shows the number of student responses, spilt up by group, in agreement to the phrase "I feel more confident in my ability to calculate percentages" ranging from strongly disagree to strongly agree.

Comparisons Between Individual Identities

A comparison was drawn to compare outside factors – dance experience and logical-mathematical intelligence – to student score increases. A comparison between gender identity and participant experience was also analyzed.

Dance Experience

For the participants in the movement class, an independent samples *t*-test was performed to evaluate whether the average of the difference between the post-test and pre-test was the same for participants in the treatment group with (M = 27.50, SD = 25.50) and without (M = 12.50, SD = 15.00) dance experience. The results indicated that there was no statistically significant difference between participants' score increase in terms of their previous dance experience, $t(10)$

= -1.07, $p = 0.31$. However, according to Cohen's *d* (0.66), the average score increase is higher for participants with dance experience, a moderate effect.

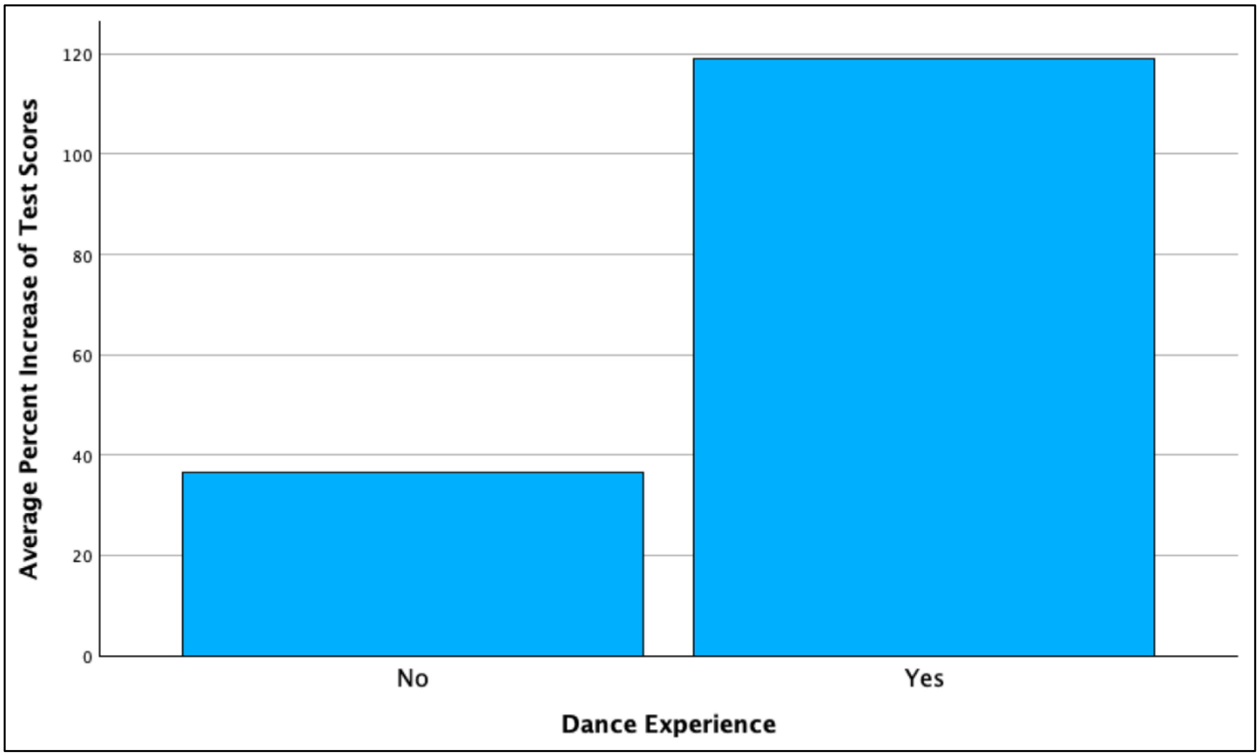
To evaluate the average of the percent increase in terms of previous dance experience, an independent samples *t*-test was performed. When looking at only the participants in the treatment group with ($M = 0.17$, $SD = 0.21$) and without ($M = 0.98$, $SD = 1.32$) dance experience, the results indicated no statistically significant difference between the groups in terms of percent difference; $t(10) = -1.19$, $p = 0.26$. However, according to Cohen's *d* (0.73), the average percent increase is higher for the participants with dance experience, a moderate effect.

Without regard to the teaching style, an independent samples *t*-test was performed to evaluate whether the average of the difference between the post-test and the pre-test was the same for participants with ($M = 32.31$, $SD = 23.15$) and without ($M = 18.89$, $SD = 18.33$) previous dance experience. The average percent increase of participant's test scores in terms of previous dance experience is shown in Figure 2. The results indicated that there was no statistically significant data between participants' scores in terms of their previous dance experience, $t(20) = 1.49$, $p = 0.16$. However, according to Cohen's *d* (0.63), the average score increase is higher for participants with dance experience, a moderate effect.

To evaluate the average of the percent increase in terms of previous dance experience, an independent samples *t*-test was performed. Regardless of the lesson they took, the results of students with ($M = 32.31$, $SD = 23.15$) and without ($M = 18.89$, $SD = 18.33$) previous dance experience in terms of percent increase did not indicated statistically significant data, $t(20) = 1.95$, $p = 0.07$. However, according to Cohen's *d* (0.84), the average score increase is higher for participants with dance experience, a large effect.

Figure 2

Average Percent Increase of Test Scores for Participants with and without Dance Experience



Note. This figure represents wide levels of dance experience. Anything ranging from one lesson to multiple lessons every week for 15 years counted as previous experience.

Logical-Mathematical Identified Intelligence

On the pre-assessment, students stated which of Howard Gardner's nine intelligences they identified with. Seven of the 22 participants identified as having a logical-mathematical intelligence. An independent samples *t*-test was performed to determine whether the average difference between the post-test and pre-test score was the same for the participants with logical-mathematical ($M = 18.57$, $SD = 15.74$) and non-logical-mathematical ($M = 30.67$, $SD = 23.74$) intelligences. The results indicated no statistically significant difference between the groups;

t(20) = 1.22, *p* = 0.24. However, according to Cohen's *d* (0.56), the average score increase is higher for the participants who did not identify with a logical-mathematical intelligence, a moderate effect.

While performing an independent samples *t*-test to determine whether the average of the percent increase between the participants with logical-mathematical (*M* = 0.34, *SD* = 0.36) and non-logical-mathematical (*M* = 1.08, *SD* = 1.20) intelligences was the same, there was no indication of statistically significant results; *t*(20) = 1.57, *p* = 0.13. Yet, according to Cohen's *d* (0.72), the average percent increase is higher for the participants who did not identify as logical-mathematical learners, a moderate effect.

Gender Identity and Participant Experience

An independent samples *t*-test was performed to determine whether the average level of enjoyment was the same for female- (*M* = 4.21, *SD* = 1.12) and male-identifying (*M* = 4.00, *SD* = 0.89) participants. On the pre-assessment, they were asked to state their gender. On the post assessment, participants ranked how much they agreed with the following statement on a Likert scale from strongly disagree to strongly agree: "I enjoyed how this lesson was taught." Table 2 shows the number of students who responded to each agreement, organized by gender identity. The results of the *t*-test indicated that there was no statistically significant difference between participants' enjoyment in the lesson in terms of their identified gender, *t*(18) = 0.41, *p* = 0.34. Cohen's *d* (0.20) implies that the average level of enjoyment was higher for female-identifying students, a weak effect.

Table 2

Identified Gender Compared to Assessment Response "I enjoyed how this lesson was taught"

	"I enjoyed how this lesson was taught"				
Identified Gender	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
Female	1	0	1	5	7
Male	0	0	2	2	2
Transgender Male	0	0	0	1	0
Transmasc Nonbinary	0	0	0	0	1
Total	1	0	3	8	10

Note. Table shows the number of student responses, organized by gender identity, in agreement to the phrase "I enjoyed how this lesson was taught," ranging from strongly disagree to strongly agree.

Discussion

Representativeness of the Sample

The sample consisted of a variety of students. Of the 22 participants two students had not chosen their major, with the rest of the population having Anthropology (2), Art (1), Art History (1), Biochemistry and Molecular Biology (1), Biology (2), Computer Science (1), English (1), History (1), Marketing (1), Math (2), Media and Communications (1), Political Science (1), Psychology (8), Public Health (1), and Spanish (2) majors. Of the 20 students with declared majors, six of them were double majors. There were a multitude of minors represented as well. It is not shocking that a large group of students are majoring in psychology as the majority of students were recruited through Psych 101 classes. The plurality of participants self-identified as possessing a linguistic intelligence on Howard Gardner's Theory of Multiple Intelligences. These are learners who like "finding the right words to express what [they] mean" (Vital, 2016).

Quantitative Data

The data that was analyzed in SPSS did not indicate any statistical significance, yet conclusions can still be drawn. Participant answers to the math skills questions on both the pre- and post-assessment can be found in Appendix D. On the pre-test, the non-movement class scored an average of 49%, while the movement class scored an average of 64%. Both groups showed growth – the non-movement class ended with an average of 81% on their post-assessment and the movement class scored an average of 87%. It appears that the non-movement group showed more growth, improving by 101% whereas the movement group only improved by 71%. Yet, it is important to note that the initial ability of the classes was different. Overall, the pre-test score was higher for the movement group, a moderate effect according to Cohen's *d*. Six of the twelve students in the movement group scored an 80 or above on the pre-test, meaning they could only improve by a maximum of 20 points. Four of these students showed no growth. On the pre-test two of them scored a 100, one scored a 90, and the other scored an 80, they received the same scores on their post-test. There were only two students in the control group who scored an 80 or above. The non-movement group as a whole had more opportunities to show their growth since their scores started lower.

When looking at individual students, the largest single score increase was in the movement class, going from a 20 to a 100 - an increase of 400%. There were two students in the non-movement class who scored a 20 on their pre-test, yet only scored a 70 and an 80 on their post-test. None of these three students identified as having a logical-mathematical intelligence. No students in either class decreased in score.

On the pre- and post-assessments, students had to answer the following questions: "When the denominator of a fraction gets bigger, the percentage gets…" "Do you know the trick for finding 10% of a value?" and "Do you know the trick for finding 1% of a value?" All of these questions were answered correctly by every student on the post-assessment. When asked for the trick of finding 10% of a value, only half of all participants got the question right on the pre-assessment. When asked about finding 1%, only six participants got it right, but after the lesson, all 22 participants had marked the correct answer for both. If the students had not done well on these questions, it would be difficult for them to succeed on the rest of the assessment as these questions provided a base-line understanding for the questions involving computations. Questions like these were testing student's memory and general understanding as opposed to their ability to transfer knowledge and show their skills in a new way. Understanding and evaluating the transfer of students' knowledge is not applicable after just one lesson.

The confidence of every student improved as a result of attending both lessons. From the pre-assessment to the post, there was a decrease in the number of questions that were answered with "I would be guessing." Students believed they understood and had the knowledge to solve the problem, regardless of the class they participated in. According to Cohen's d, the control group was less likely to be guessing after the lesson to a large effect. This implies there was more growth in confidence amongst these students. Yet, the students in the control group started with a higher average number of questions answered with "I would be guessing," thus these students would appear to have more growth in confidence.

When looking only at the students who attended the movement lesson, we saw greater score growth in students who have previous dance experience. Again, this data was not statistically significant, but Cohen's *d* indicated a moderate effect, which can happen when results are important but the sample size is small. Since dance can be a very vulnerable experience for people, this makes sense. Students that do not have previous dance experience are not as comfortable opening up and moving around a space, especially when they do not know one another. In the instance of our one-time, 45-minute lesson, the participants were not familiar with one another, like students are when they have class together every day. As dance is implemented in the classroom, it is easy to imagine how students will begin to build their own movement vocabulary, making lessons like these more beneficial. As students gain dance experience, they will be able to apply it and ultimately gain more from the lesson.

Regardless of the lesson students participated in, there was a greater growth in the score of students who had any form of previous dance experience. Hackney (2006) discusses how movement can improve a student's mathematical skills even if it is not directly connected to content. For some students, this previous experience was a one-time program at school, for others dancing is a regular hobby. In any case, when compared to the students who had no previous dance experience, the growth from the pre-test to the post-test was greater for students with dance experience. Even though this data was not statistically significant, Cohen's *d* indicated a large effect implying important results for a small sample size.

Interestingly enough, the percent increase and average score increase was higher for the students who did not identify with having a logical-mathematical intelligence. One would imagine that students who self-identify as having a logical intelligence would show more growth than their peers when in a math class. First, two of the seven students who identified with this intelligence received a 100% on both their pre- and post-assessment and thus could not have shown any growth in the calculated data. Second, it is important to acknowledge that a kinesthetic-style of teaching supports and activates many different intelligences, something Griss (1998) discusses in her work. Incorporating dance into lessons allows students who may not posess the logical-mathematical intelligence to succeed in math classrooms, which can explain why our results point in this direction.

Gender had no effect on participant enjoyment in these lessons. Between the movement and non-movement classes, participants, no matter the gender, had a similar experience and level of enjoyment. Both math and movement can be for everyone. Typically, there is a lack of representation of female-identifying people in the STEM world (Beede et al., 2011) and male-identifying people in the dance world (Oliver & Risner, 2017). In both cases, the lack of representation causes hesitation among individuals of all ages to explore these areas themselves. Combining math and dance in a classroom lesson helps bridge that gap and create engaging activities where students can explore both.

The quantitative data analyzed in SPSS ultimately shows that both classes improved as a result of the lesson. Across the board, students showed improved confidence in regards to the content no matter their preferred learning style. The differences in the average student growth from pre-assessment to post-assessment were not statistically significant, but we can draw other conclusions about the benefit of the lessons from qualitative data.

Qualitative Data

Instructor Perspective

From the instructor's perspective, there are many benefits to using dance throughout the lesson. In the first class I taught, when students were following along on a worksheet, very few students participated in the conversation. When I would pose a question to the class as a whole, the same two or three students would raise their hand. Although there were minimal interactions between students throughout the lesson, for the most part they still seemed engaged in the content. That said, it was difficult to see if students were really understanding what I was teaching them. Another challenge came from pacing the lesson appropriately. Since only a few students were answering, it was difficult to tell if the lesson was moving too quickly or too slowly. A few students appeared to be jumping ahead on the worksheet whereas others were actively following along at the pace I was teaching.

The class which incorporated movement was much easier to gauge from an instructor's perspective. Every student participated. There was individual work as well as group work and in every instance all students were participating. It looked different for each individual as they were only moving in ways that they felt comfortable with, but it was noticeable from an instructor's perspective that everyone was participating. As I observed students participating in groups, I was able to see students learn from one another. As they physically moved to solve problems, their peers could see the process and understand the fundamental process of solving the problem. Their group work not only helped them complete the math problem, but worked on 21st-century skills while communicating, being flexible, and collaborating with one another. Having them answer questions through movement allowed them to approach the problems in different ways.

This truly allowed them to explore the chorographical process while showing their understanding of the mathematical process. After creating their own work, they had the opportunity to interpret one another's work which allowed them to see the unique ways that individuals can interpret and approach math problems.

Using movement to enhance a lesson can be very beneficial, but it is important to know the students in the classroom well. There are a multitude of factors to consider. How comfortable are they incorporating movement? Is it necessary to demonstrate the expectations? What style of movement should be used? If music is being played, what genre? Just as an educator needs to understand their students to teach a successful lesson, they need to understand their students to integrate movement into the lesson.

Participant Perspectives

On the post-assessment, students were encouraged to leave comments about the lesson and their experience. Eight of the 10 students in the non-movement class did not leave a comment. The two students who did said "It was informative and I learned something new" and "it was educational to learn how to calculate quick percentages in your head," both sharing a positive outlook on the class. Six of the 12 students in the movement class chose to leave a comment. Showing that their participation extended past the lesson as they voluntarily reflected on their experience. Some of the responses were short, sharing that they "had fun" and "enjoyed the lesson" but a few of the other responses share how beneficial it can be to bring dance into the classroom. One student said "I loved this lesson. I'm not the biggest fan of math but adding movement made it more fun for me and easier to learn and comprehend information." Another student commented saying "I think it is incredibly helpful keeping interest and engaging the class! I would be interested to see [movement] incorporated in contexts of new content." While students' responses may have been affected by knowing the parameters of the experiment, the combination of these responses highlighting the educational benefits of intentional movement with others describing a more fun and dynamic learning environment shows the multiple ways that including dance in a classroom is beneficial.

When asked specifically how the lesson changed their perception of math and/or dance, most students reflected on feeling more confident in their ability to calculate percentages and were proud to acknowledge the subconscious math tricks they already knew. A student in the movement class said "I feel better about math. [The class] made me feel less nervous to learn and practice math because everyone was engaged and participating." When reflecting on dance, the same student responded saying "I love dance, so for movement to be included in academic learning made it fun and comfortable for me." Another student in the movement class reflected on their experience by sharing that they feel "[math] is not as difficult or boring as [they] perceived it to be" and dance "is more useful to [their] learning process than [they] previously thought." The students in the movement class appeared to give more thoughtful responses, something that I believe is a reflection of the lesson and the supportive, engaging environment created by the participants. One student reflected on their experience by saying "I am still not fully comfortable [with dancing] but it made me feel better being in such an open and accepting room." In our one-time, 45-minute class, the participants felt comfortable enough to try new things and branch out of their comfort zone, something that is extremely important for any classroom to support.

When asked if students in the movement class would do it again five said yes, three said no, and four said maybe. When asked if students in the non-movement class would be interested in trying a class with movement two said yes, four said no, and four said maybe. Students who experienced the lesson with movement were more open to learning with movement again. Allowing dance to be regularly incorporated into the classroom will help students become more comfortable with movement and improve both their math skills and their 21st-century skills, all while creating an environment that supports each student, inspires joy, and encourages creative exploration.

Not every student is comfortable with dancing, which is something that is important to recognize. One student, who had previous dance experience from elementary school, said the lesson was “awkward” and that they would not want to be taught like that again. For educators who hope to incorporate movement into their classrooms, identifying students who are uncomfortable with movement and adjusting for their individual needs is essential for creating a safe, respectful, and enjoyable learning environment. However, one benefit of using movement in the classroom is that the output can be different for every student, something which allows them to create or choreograph answers that reflect their level of comfort. To demonstrate their understanding of a math problem, one does not need to create an elaborate dance. The flexibility that comes with this style of teaching is not something that is often found in a typical math classroom. As an educator, one can implement dance into their lessons without making the entire lesson movement-based, or allowing students optionality in how they choose to answer a particular problem. This provides multiple access points to the content and ensures that students are not missing out on knowledge as a result of being uncomfortable.

Upon reflection of the lesson, students were asked to use one word to describe the class they took. The following list is from the non-movement lesson: normal, informative (x3), enlightening, helpful (x2), interesting (x2), and simple. The next list comes from the movement lesson: awkward, movement, interpersonal, engaging, enthusiastic, goofy, funny, creative, effective, interactive, and fun. I think a big goal for educators is to create a classroom environment that allows students to express themselves, connect with one another, and have fun all while learning content. Incorporating movement into lessons allows for a classroom environment like this; it creates a space where students can explore content in new ways.

Limitations & Further Explorations

There are a few limitations to the research I completed. Normally, a study like this would have been completed with random assignment, increasing the chance that the two groups are initially the same, on average. When looking at the pre-assessments, the treatment and control groups did not have the same starting ability. The students all had different backgrounds in math – some were math majors; some had not taken a math class in multiple years – which does not mimic the environment of a typical math classroom where students usually share a similar ability. Thus, the differences in the post-test cannot be entirely attributed to the movement implementation in the lesson.

The movement class had four students who did not participate for credit in a Psych class, but were selected to participate by myself in order to make the groups the same size. These students were arguably more open to movement being incorporated in a lesson. They were provided with the same information as the Psych students, yet were participating just as a favor to me – it would have been easier to say no if they did not have any interest since there was no benefit for participation.

Due to time constraints, the students in the movement class were not able to answer all of the questions that the non-movement class did. They spent more time doing group work and exploring the choreographed answers with one another. Since their work was more time-consuming, they ultimately got less practice in each area.

Additionally, this was a one-time class. It is nearly impossible to evaluate and analyze student growth, confidence, and enjoyment from just one 45-minute lesson. With the small number of students in each group, it is also hard to get statistically significant data.

To further explore this topic, I would encourage a research study over the course of a year- or semester-long class. This would allow for students to become more comfortable with movement, one another, and the content of the class. This would also allow the researcher(s) to explore what topics can be enhanced with movement and which cannot. Having the same students take two classes with two different teaching styles would also be an interesting way to further explore this topic.

Calculating percentages was not a new topic to any student in the room as it is something introduced in elementary school. This study really looked into the benefits that movement can have when reviewing or deepening understanding as opposed to introducing a new topic. These results are not conclusive for teaching a lesson in calculus or geometry. Continued research is necessary to explore how different mathematical content can or cannot be enhanced through movement integration. Further research also allows the question of if movement is more helpful for introducing a new topic or for solidifying and deepening a student's understanding of a topic to be explored.

Despite the limitations, this study has not only provided a template for continued research, but has emphasized the many benefits that movement integration in a math classroom has in regards to student success, classroom engagement, and real-world connections.

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Appendix A

Lesson Planning Documents

Non-Movement Lesson Plan

Lesson Plan Template **Single Lesson**

This planning template is based upon **Understanding By Design – Backwards Design Process** developed by Grant Wiggins and Jay McTighe (2002).

Lesson Overview		
Lesson Title: Fractions + Percentages with Movement	**Grade Level: college (1st-4th years)**	**Content Area: Mathematics**

Context for Learning, Student and Community Assets
The students I am working with are coming from a variety of backgrounds. Because I don't know their math skill levels, this lesson is structured to support any and every student. All of these students are in college, which means they have some math background. Working with fractions and percentages is something they are familiar with, even if they are not confident in it/don't use them often (or don't think they do!). I don't know who these students are as learners, so I have to have a flexible lesson plan that I can adjust on the spot as I observe the classroom. Overall goal: have students make connections between fractions and percentages and become more confident in calculating tips mentally.

Stage 1 – Desired Results	
Content Standard(s): Not applicable for this research lesson.	
Understanding(s)/goals Students will understand: • why a percentage gets smaller as the denominator of a fraction gets bigger • the connection between fractions and percentages	**Student objective(s) (outcomes):** Students will be able to: Students will be able to calculate a variety of percentages mentally by manipulating the hints used to calculate 1% and 10%.

<table>
<tr><td>

- the tricks for calculating both 1% and 10% of a number
- how you can extend those tricks to more challenging percentage values

</td><td>Students will be able to interpret world problems and calculate the tips left at a restaurant, without a calculator.</td></tr>
<tr><td colspan="2" align="center">Stage 2 – Assessment Evidence</td></tr>
<tr><td>

Formative Assessment: (checks for understanding)
After students take their pre-assessment (distributed on Qualtrics, example here), I will ask them how they felt about the questions. This will allow me to get a better understanding of where the students in my classroom are at, since I don't know anything about them!

Throughout the lesson I will be calling on students to answer questions. I will use their facial expressions and engagement in the lesson as a small, formative assessment. Along with that, when they are working on individual or partner work, I will walk around the room to check in with them.

Questions will be asked throughout the lesson to get verbal confirmation of their understanding and push their learning further: *What do you notice about the relationship between the fraction's denominator and the space (or percentage) that we are moving in? Do you know the trick for calculating 10% of a fraction? How about 1%? Do you think you could calculate 7% or 18% without a calculator? I'll show you that you CAN!*

</td><td>

Summative Assessment: (performance task)

Section 5 on the worksheet (linked below in materials) will act as part of their summative assessment. The rest of the worksheet will be completed as a class or in pairs, but this will be done individually.

Students will be asked to complete the post-assessment (distributed on Qualtrics, questions typed here) for the final part of their summative assessment.

</td></tr>
<tr><td colspan="2" align="center">Stage 3 – Learning Plan</td></tr>
<tr><td colspan="2">

Learning Activities:

Materials & Resources: Pre- and post-assessments (distributed to students via Qualtrics), notecards with numbers 1-15 on them for confidential student responses to assessments, laptops, (brought by students), printed worksheets, and pens/pencils (I will have extras in case students forget).

Introductory Activities: Students will start with the pre-assessment which includes the consent form (allow 5 minutes for this). After that, we will have a quick check-in about how the math questions on the assessment felt for them. From here, I will introduce that they are not in the movement class and outline what that will look like for them.
Our lesson will begin with a conversation about fractions and percentages (this should take about 3-5 minutes). Students will follow along on their worksheets as I demonstrate on the board. As we complete section one, we will talk about how as the number of spaces have

</td></tr>
</table>

gotten bigger, the percentage has gotten smaller. The number of spaces in the room represent the denominator in a fraction. As it increases, the percentage decreases.

Then we will flip the question, rather than creating fractions, we will visually represent the percentages. From here, we will identify the fractions associated. Students will see that fractions and percentages go hand-in-hand. This will also allow us to discuss how fractions can be reduced. This should take another 5 minutes.

Students should be completing everything that is done on the board on their worksheets.

Developmental Activities: Next, we will begin talking about the tricks you can use to calculate percentages. I will ask students if anyone knows the trick (move the decimal twice for 1% and once for 10%). Once we have discussed the trick we will work through the examples. I will do a few on the board before asking students to try themselves or with a partner. Allow this to take 5-7 minutes.

Next, we will work through the ideas in section four. I will challenge students to explain to me how they could use the tricks to calculate "odd" percentages like 13% or 52%. Students can discuss these ideas with people sitting near them and then we will talk about it as a group. After we've discussed how you can use the same tricks but do some multiplication, addition, and subtraction to help, we will work through the examples in section 4. Students will work with partners for this to encourage conversations of different methods. I will walk around and ask questions to challenge learning (e.g., *If you're taking 18% you could find 1%, multiply it by 8 and add it to 10%, but is there another way? (Yes! 20%-2%))* and answer questions to help clarify the task. Allow this to take 10 minutes.

Closing Activities: The final activity (before the post-assessment) will be done individually. Students will complete section 5 by themselves to challenge their understanding and prepare them for the final post-assessment. Students will be encouraged to ask questions throughout their work and I will walk around to see where students are getting stuck. After students have completed this final section, we will go over the tricks that were introduced today. We will talk about how students can use these in the real world to help them calculate sales tax and the tip left at a restaurant.

After our conversation has wrapped up, students will be instructed to complete the post-assessment. Once completed, they are allowed to leave the study.

Movement Lesson Plan

Lesson Plan Template **Single Lesson**

This planning template is based upon **Understanding By Design – Backwards Design Process** developed by Grant Wiggins and Jay McTighe (2002).

Lesson Overview		
Lesson Title: Fractions + Percentages with Movement	**Grade Level: college (1st-4th years)**	**Content Area: Mathematics**

Context for Learning, Student and Community Assets
The students I am working with are coming from a variety of backgrounds. Because I don't know their math or dance skill levels, this lesson is structured to support any and every student. All of these students are in college, which means they have some math background. Working with fractions and percentages is something they are familiar with, even if they are not confident in it/don't use it often. Some students may have a dance background whereas others may not. I don't know who these students are as learners, so I have to be open and willing to have a flexible lesson plan that I can adjust on the spot as I observe the classroom. Overall goal: have students make connections between fractions and percentages and become more confident in calculating percentages and tips mentally (and using movement to do so!).

Stage 1 – Desired Results	
Content Standard(s): Not applicable for this research lesson.	
Understanding(s)/goals Students will understand: • why when the denominator of a fraction gets bigger the percentage is getting smaller • the connection between fractions and percentages • the tricks for calculating both 1% and 10% of a number • how you can extend those tricks to more challenging percentage values	**Student objective(s) (outcomes):** Students will be able to: Students will be able to calculate a variety of percentages mentally by manipulating the hints used to calculate 1% and 10%. Students will be able to interpret world problems and calculate the tips left at a restaurant, without a calculator.

<table>
<tr><th colspan="2">Stage 2 – Assessment Evidence</th></tr>
<tr><td>Formative Assessment: (checks for understanding)

After students take their pre-assessment (distributed on Qualtrics, example here), I will ask them to use a thumbs-up, down, and in the middle to show me how they felt about the questions. This will allow me to get a better understanding of where the students in my classroom are at, since I don't know anything about them!

There is some form of movement incorporated into each section of my lesson which will allow me to visually see the students' understandings and misconceptions. This is a huge benefit to having movement in the classroom as an instructor.

Questions will be asked throughout the lesson to get verbal confirmation of their understanding and push their learning further: What do you notice about the relationship between the fraction's denominator and the space (or percentage) that we are moving in? Do you know the trick for calculating 10% of a fraction? How about 1%? Do you think you could calculate 7% or 18% without a calculator? I'll show you that you CAN!</td><td>Summative Assessment: (performance task)

Students will be split into groups and encouraged to make dances that involve different percentages. Each group will be assigned a specific word problem (from section 5 of the worksheet) and they will be asked to represent that through movement. There is no need for the final pieces to be longer than 15 seconds and there is no need for the movement to be intricate. It is entirely up to their interpretation; they can show percentages by the number of people moving, by their use of levels, by the speed of their movement, the style of dance, or any other way they can imagine. There will be performances at the end of the lesson where the other students in class will guess the percentage assigned to the group, and then the group will share what their percentage was.

Students will be asked to complete the post-assessment (distributed on Qualtrics, questions typed here) for the final part of their summative assessment.</td></tr>
<tr><th colspan="2">Stage 3 – Learning Plan</th></tr>
<tr><td colspan="2">Learning Activities:

Materials & Resources: Pre- and post-assessments (distributed to students via Qualtrics), notecards with numbers 16-30 on them for confidential student responses to assessments, laptops, (brought by students), painter's tape, speaker*, open space or moveable desks, printed worksheets, and pens/pencils (I will have extras in case students forget).

*The speaker is not necessary, but it is nice to have some music playing as you have students become more and more comfortable with movement. This is good for the warm-up where students are exploring the whole space and for the summative assessment when students are asked to put together movement. Using music from this playlist.</td></tr>
</table>

Introductory Activities: Students will start with the pre-assessment which includes the consent form (allow 5 minutes for this). After that, we will have a quick check-in about how the math questions on the assessment felt for them. I will ask them to show how they felt with either a thumbs up, down, or somewhere in the middle. From here, I will introduce that they are in the movement class and outline what that will look like for them. We will start with a quick warm-up, just to get their blood flowing; it will allow me to see how they all feel with moving. This warm-up could include some jumping jacks, high knees, light stretches, etc. it does not need to be extensive (2 minutes).

Our lesson will begin with an exploration of the space (this should take about 3-5 minutes). Students will have the entire room to walk, dance, explore etc. We will talk about how they are moving throughout 100% of the room. Then, we will use the moveable desks to create a straight-line down half of the room. Students will be asked to, again, explore the space they have available through some form of movement. Now students are using 50% of the room. We will cut the room in half again (by using the desks as dividers). Now students are using 25%. And again. Now students are using 12.5%. Together we will discuss how as the number of spaces has gotten bigger, the percentage has gotten smaller. The number of spaces in the room represent the denominator in a fraction. As it increases, the percentage decreases.

To continue to warm up students' bodies, I will then ask them to move 80% of their body. There are no right or wrong answers. People may interpret this as moving their head, arms, and one leg but keeping the other still (⅘ of their "limbs" (if you count your head as a limb)). Other students might interpret this as moving everything beneath their shoulders because they view their neck and head to be about 20% of their body. Allow students to become comfortable with the idea that there is no wrong answer to movement. I will go around the room and ask students to explain to me how their movement represents 80%. We will come together and talk about what 80% looks like as a fraction (8/10 will be the most likely answer, can it be reduced?). Then, ask students to do the same thing with 33% and 10%. This should take another 5 minutes.

Allow students time to jot down these answers on their worksheet, although it is not necessary.

Developmental Activities: Students can return to their seats as we begin talking about the tricks you can use to calculate percentages. I will ask students if anyone knows the trick (move the decimal twice for 1% and once for 10%). Once we have discussed the tricks and done an example or two on the board (pick a 10% and 1% question from the worksheet) students will stand up for the next movement activity. Using the question from section three on the worksheet, I will write values on the board. I will ask students to show me (by moving one step to the left or two steps to the left) how they would calculate 10% or 1% of the number on the board. The movement will have the students mimic what the decimal is doing. Once all students have taken their steps, I will ask for students to give me the calculated value (e.g., if i ask for 10% of 500, the student will answer 50). Allow this to take 5-7 minutes as well.

Next, students will be split up into pairs or trios. We will work through the ideas in section four. I will challenge students to explain to me how they could use the tricks to calculate “odd” percentages like 13% or 52%. Students can discuss these ideas with their pairs/trios and then we will talk about it as a group. After we’ve discussed how you can use the same tricks but do some multiplication, addition, and subtraction to help, they will move onto their next activity. In their pairs and trios, the students will move around the room to different numbers. The numbers will be taped on the floor (do this as you set up for the class) and students will physically move their bodies to represent the decimal moving. Together the partners will be figuring out what numbers will be multiplied (e.g., if the question asks for 20% of 245, the student should move once to represent 24.5 and then they will multiply that value by two to get 49). Students will move through different stations. I will walk around and ask questions to challenge learning (e.g., *If you’re taking 18% you could find 1%, multiply it by 8 and add it to 10%, but is there another way? (Yes! 20%-2%))* and answer questions to help clarify the task. Allow this to take 10 minutes.

Closing Activities: The final activity (before the post-assessment) will be done in groups as well. Students will be split up into 5 groups of 3. Students will have 5 minutes to come up with a small dance. There is no time length and no requirements for the movement they use, but they will all be assigned something specific to represent through movement. Groups will be assigned a word problem, which first they must solve. Then they will be challenged to represent it choreographically. There are no limits to this, it is entirely up to their interpretation. We will have 2 minutes at the end for every group to show and share what their word problem is. Students from other groups can chime in about what they saw and what percentage was represented. I will first give an example where my word problem is “My restaurant bill was $30 and I want to give a 20% tip, how much do I owe?” I will show them how I solve the problem, by calculating 10% ($3) and multiplying it by 2 to get $6. I will show them different ways to represent this. The first way will be by creating a short 10 second dance where 20% is slow movements and the other 80% is fast movements. The second way will be by doing three movements back-to-back and then repeating them to represent the final answer of 6. Students are allowed to come up with more ways to interpret their word problem and represent it with movement, but they must be able to explain what they did.

After all groups have shared, students will be asked to complete the post-assessment questionnaire and they will be allowed to leave the study.

Appendix B

Student Worksheet

Mathematical Movements Thesis Study Worksheet
Please show your work for all of the following questions!

SECTION ONE - fractions to percentages

Split this box in half and shade one section.

How do you represent the box as a fraction? —

What percentage of the box is shaded? ______%

Split this box in fourths and shade one section.

How do you represent the box as a fraction? —

What percentage of the box is shaded? ______%

Split this box in eighths and shade one section.

How do you represent the box as a fraction? —

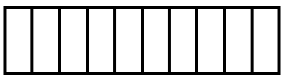
What percentage of the box is shaded? ______%

What do you notice about the relationship between the fraction's denominator and the percentage? As the denominator gets bigger, what happens to the percentage?

____
____
____

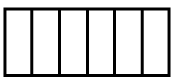
SECTION TWO - percentages to fractions

Shade in 80%



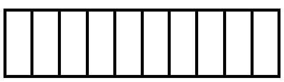
How can you represent this as a fraction? — Can it be reduced? —

Shade in 33%



How can you represent this as a fraction? — Can it be reduced? —

Shade in 10%



How can you represent this as a fraction? — Can it be reduced? —

SECTION THREE - calculating 10% and 1%

*Calculating 10% – multiplying by 0.10 – HINT: move the decimal one spot to the left
*Calculating 1% – multiplying by 0.01 – HINT: move the decimal two spots to the left

What is 10% of 345? ____________

What is 10% of 27? ____________

What is 10% of 9? ____________

What is 1% of 246? ____________

What is 1% of 38? ____________

What is 1% of 2? _____________

SECTION FOUR - calculating “odd” percentages

*Calculator - convert to decimal form and multiply (e.g., 56% → 0.56, 3% → 0.03, 100% → 1.00)
*No calculator?! Use the tips from above and do some extra math (multiplying, adding, and subtracting!)

What is 20% of 245? ___________
– Hint: 10% multiplied by 2

What is 7% of 100? ____________
– Hint: 1% multiplied by 7

What is 11% of 36? __________
– Hint: 10% + 1%

What is 18% of 50? ___________
– Hint: 20% - 2%

What is 13% of 20? __________

What is 4% of 500? ___________

SECTION FIVE - word problems

You bought a $550 couch, how much would a 10% sales tax cost you?

Your bill at a restaurant totaled $75, your service was great, but not exceptional, so you tip 18%. How much did you tip?

You and four friends spent $120 at a restaurant. You each want to tip 4%, leaving a 20% tip in total. How much money does each person spend on the tip? How much money was the entire tip?

If you want to leave 20% tip on your restaurant bill, how can you calculate it without a calculator?

____

*These following calculations can be approximated.
I want to leave a 20% at a restaurant, how much do I owe if…

The meal cost: $45.62

The meal cost: $23.50

The meal cost: $143.28

Appendix C

Pre- and Post-Assessments

Pre-Assessment

1. SUMMARY and KEY INFORMATION

You are invited to participate in a research study about bringing dance into math classrooms. Your participation is voluntary. You were selected as a possible participant because of your involvement in the Psychology 101 classes. The purpose of this study is to explore bringing movement into classrooms and identify the benefits it can have on students' learning. The research will last 45 minutes.

As part of the study, you will complete pre and post assessments and participate in either a movement-based lesson or a lecture-style lesson focused on calculating percentages. If you are in the movement-based lesson, you may experience physical injury. These risks are similar to those in daily life; tripping, stumbling, etc. You do not have to participate in any portion of the lesson if you do not feel comfortable. The benefits of participation are a deeper understanding of the connections between fractions and percentages, as well as how to calculate percentages in real-life experiences. For participants in the PSYCH101 classes, this study will help satisfy your course requirement.

The study is being conducted by a Drew University Mathematics student for the purpose of completing a Baldwin Honors Thesis. We ask that you read this document and ask any questions you may have before agreeing to be in the study.

2. BACKGROUND

The purpose of this study is to explore the benefits that come with incorporating movement into a lesson. Research has been done addressing the advantages of brain breaks and giving students opportunities to move around the room. These studies show positive effects as movement improves brain function, student focus, and engages learners. Bringing dance into a classroom can also help to create a culturally competent classroom that supports every learner as an individual. This study is looking at the benefits that come from incorporating dance into a math classroom, specifically looking at how movement can be used to enhance a lesson about percentages.

3. DURATION

The length of time you will be involved with this study is forty-five minutes.

4. PROCEDURES

If you agree to be in this study, we will ask you to do the following things: Both a pre and post-assessment. On both assessments, you are permitted to leave any questions that you do not want to answer blank. There will be personal background questions about who you are as a student and your involvement with both math and dance, as well as fraction and percentage problems for you to solve. In between the pre and post assessments you will either be following a lesson presented by the instructor and working individually, with a partner, or in groups to solve a worksheet, or you will be involved in a movement-based lesson that explores the worksheet problems throughout the classroom space.

The movement-based lesson will involve standing up and moving throughout the room; if you have mobility restrictions, please clearly state them to the instructor. They will adjust the lesson to make sure you can participate fully. At any point throughout the study, participants are allowed to remove themselves from a specific part of the lesson or end their entire participation. There will be no consequence or penalty to these participants.

5. RISKS/BENEFITS

This study has the following risks: Physical injury while moving throughout the room. Even while doing the simplest of movements there is a possibility of tripping over oneself or others (just as there is in day-to-day life when you walk around). A warm up will be administered to ensure that all bodies are prepared to move throughout the lesson. You do not have to do any movement that you do not feel comfortable doing.

The benefits of participation are: A deeper understanding about the connection between fractions and percentages, how to calculate percentages - specifically in real-world applications like tipping at a restaurant and calculating sales tax. For students in the Psychology101 classes, participating in this study will help satisfy a course requirement.

6. PARTNERING AGREEMENT

While this study is not intended to include physical partner work, it is something that is common in movement practices. Participants may be asked to work in small groups with one another, but are not permitted to physically touch one another without permission - this is a verbal yes. Gaining permission from partners will help prevent injuries throughout the study. Again, there will be no requirements or expectations of physical partner work; it is strongly discouraged for the purpose of the study and the safety of all participants. By signing this consent form you are also agreeing to having a conversation with partners before physically working with them.

7. CONFIDENTIALITY
Your name will be recorded in case anyone needs to be contacted after the study has ended and to give credit to Psych101 students, but your name will not show up in the final, published thesis. All pre and post assessment data will be analyzed and discussed in terms of numbers not names. You will be assigned a number at the beginning of the study and will use that number to fill out all data-collecting forms. These forms will be stored on secure, password-protected servers at Qualtrics.com. Only the researcher and Faculty Advisor will have access to the data. Any information from the "Personal Background" section of the assessments will be presented as combined data to preserve anonymity; no information that would make it possible to identify individual participants will be included in the published thesis. As a reminder, web-surveys do have the potential for security breaches. The researcher has taken all accountable measures to protect your identity and your responses but email and the internet are not 100% secure. It is suggested that you clear the computer's cache and browser history to protect your privacy after completing the online assessments.

8. VOLUNTARY NATURE OF THE STUDY
Your decision whether or not to participate in this research will not affect your current or future relations with Drew University. If you decide to participate in this study, you are free to withdraw from the study at any time without affecting those relationships and without penalty.

9. CONTACTS AND QUESTIONS
At the end of the study, you will be given a debriefing form. This form will remind you of the purposes, methods, and offer more resources to explore the topic of this research. The debriefing form will include the same contact information as below. If you have any questions about the results, or want to be removed from this study at any point, do not hesitate to contact the researcher.

The researcher conducting this study is Angelae Wunderle (she/her). You may ask any questions you have right now. If you have questions later, you may contact the researcher at awunderle@drew.edu or the Faculty Advisor, Dr. Sarah Abramowitz at sabramow@drew.edu. If you have questions or concerns regarding this study and would like to speak with someone other than the researcher or Faculty Advisor, you may contact the current IRB chair, Alex de Voogt, at adevoogt@drew.edu.

10. STATEMENT OF CONSENT
Please verify the following: The procedures of this study have been explained to me and my questions have been addressed. I understand that my participation is voluntary and that I may withdraw at any time without penalty. Completion and return of the survey indicates consent to

participate. If I have any concerns about my experience in this study (e.g., that I was treated unfairly or felt unnecessarily threatened), I may contact the Chair of the Drew Institutional Review Board regarding my concerns.

- I am at least 18 years old and I agree to consent
- I am not 18 years old and/or I do not consent to participate

Section One: Please fill out this pre-assessment to the best of your ability. As a reminder, your answers are confidential.

Q1: Please write your assigned number (given by instructor)

Section Two: Personal Background. This information will be used to describe the group of participants in this study. Short answer questions can be responded to in a few words or one sentence.

Q1: How old are you?

Q2: What year are you?

- First-year
- Second-year
- Third-year
- Fourth-yeah

Q3: What is your gender?

Q4: What are your major(s)? Minor(s)?

Q5: Are you an athlete?

- Yes
- No

Q6: Have you ever experienced movement incorporated into a lesson before? (this can be movement in the simplest form, not necessarily elaborate dancing)

- Yes
- No
- Maybe

Q7: Please indicate how much you agree with the statements below.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
• I like math					
• I like doing math					
• I like dance					
• I like dancing					
• I believe I am good at math					
• I believe I am good at dancing					

Q8: When was the last time you took a math class?
Q9: When was the last time you took a dance class? If never, please write "N/A"
Q10: How do you prefer to learn? (e.g., lecture-style, textbook readings, videos, projects, etc.)
Q11: The nine categories below are from Howard Gardner's Theory on Multiple Intelligences. The categories describe different ways people learn and acquire information. Which one (or two) do you identify with the most?

- Musical: discerning sounds, their pitch, tone, rhythm, and timbre
- Logical-Mathematical: quantifying things, making hypotheses and proving them
- Existential: tackling the questions of why we live, and why we die
- Interpersonal: sensing people's feelings and motives
- Bodily-Kinesthetic: coordinating your mind with your body
- Linguistic: finding the right words to express what you mean
- Intra-personal: understanding yourself, what you feel, and what you want
- Spatial: visualizing the world in 3D
- Naturalist: understanding living things and reading nature

Section Three: Fractions and Percentages. If you do not know an answer and would be guessing, please select "I would be guessing." A calculator is not allowed for this section.

Q1: ¼ is equivalent to which percentage?

- 0.25%
- 0.5%
- 25%
- 50%
- I would be guessing

Q2: When the denominator of a fraction gets bigger, the percentage…

- Gets bigger
- Gets smaller
- Stays the same
- I would be guessing

Q3: Do you know the trick for finding 10% of a value? If yes, please write it below. If no, please write "I would be guessing."
Q4: Do you know the trick for finding 1% of a value? If yes, please write it below. If no, please write "I would be guessing."
Q5: If your restaurant bill is $52.00 (and you had excellent service!) what would your 20% tip be?

- $5.20
- $10.40

- $20.80
- I would be guessing

Q6: If you bought a $700 couch and there is a 10% sales tax, how much would the sales tax cost?

- $7
- $14
- $49
- $70
- I would be guessing

Q7: If you and a friend wanted to split a 20% tip on a $70 meal evenly, how much would you each pay?

- $70
- $10
- $14
- $21
- I would be guessing

Q8: What is 15% of 80?

- 8
- 12
- 16
- 20
- I would be guessing

Q9: What is 11% of 1,234?

- 123.40
- 126.74
- 132.40
- 135.74
- I would be guessing

Q10: What is 18% of 240?

- 24.20
- 43.20
- 44.20
- 48.20
- I would be guessing

Post-Assessment
Section One: Please fill out this pre-assessment to the best of your ability. As a reminder, your answers are confidential.

Q1: Please write your assigned number (given by instructor)

Section Two: Personal Background. This information will be used to describe the group of participants in this study. Short answer questions can be responded to in a few words or one sentence.

Q1: What is one word you would use to describe today's lesson?

Q2: Which of the nine categories below (from Howard Gardner's Theory on Multiple Intelligences) do you think represents today's lesson the best? Please choose as many as you see fit.

- Musical: discerning sounds, their pitch, tone, rhythm, and timbre
- Logical-Mathematical: quantifying things, making hypotheses and proving them
- Existential: tackling the questions of why we live, and why we die
- Interpersonal: sensing people's feelings and motives
- Bodily-Kinesthetic: coordinating your mind with your body
- Linguistic: finding the right words to express what you mean
- Intra-personal: understanding yourself, what you feel, and what you want
- Spatial: visualizing the world in 3D
- Naturalist: understanding living things and reading nature

Q3: I participated in…

- The class that did not involve movement
- The class that involved movement

Q4: You participated in the class that incorporated movement. Would you want to be taught like this again?

- Yes
- Maybe
- No

Q5: You were in the class without movement. Would you be interested in learning math through movement?

- Yes
- Maybe
- No

Q6: Please indicate how much you agree with the statements below.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
• This study changed my opinion of math					
• This study changed my opinion of dance					
• This study introduced me to a new way of learning					
• I feel more confident in my ability to calculate percentages					
• I enjoyed how this lesson was taught					

Q7: After today's lesson, how do you feel about math?
Q8: After today's lesson, how do you feel about dance?

Section Three: Fractions and Percentages. If you do not know an answer and would be guessing, please select "I would be guessing." A calculator is not allowed for this section.

Q1: ¼ is equivalent to which percentage?

- 0.25%
- 0.5%
- 25%
- 50%
- I would be guessing

Q2: When the denominator of a fraction gets bigger, the percentage…

- Gets bigger
- Gets smaller
- Stays the same
- I would be guessing

Q3: Do you know the trick for finding 10% of a value? If yes, please write it below. If no, please write "I would be guessing."

Q4: Do you know the trick for finding 1% of a value? If yes, please write it below. If no, please write "I would be guessing."

Q5: If your restaurant bill is $52.00 (and you had excellent service!) what would your 20% tip be?

- $5.20
- $10.40
- $20.80
- I would be guessing

Q6: If you bought a $700 couch and there is a 10% sales tax, how much would the sales tax cost?

- $7
- $14
- $49
- $70
- I would be guessing

Q7: If you and a friend wanted to split a 20% tip on a $70 meal evenly, how much would you each pay?

- $70
- $10

- $14
- $21
- I would be guessing

Q8: What is 15% of 80?

- 8
- 12
- 16
- 20
- I would be guessing

Q9: What is 11% of 1,234?

- 123.40
- 126.74
- 132.40
- 135.74
- I would be guessing

Q10: What is 18% of 240?

- 24.20
- 43.20
- 44.20
- 48.20
- I would be guessing

Section Four: Final Comments.

Q1: Is there anything else you would like to share/comment on about this lesson?

End of Survey

1. PURPOSE OF THE STUDY

The study in which you just participated was designed to provide students with alternative ways of learning in a math classroom. More specifically, using dance and movement to deepen students' understanding of mathematical concepts. The hypothesis that was being tested: does using movement and dance in the classroom help students learn and retain information better than traditional classroom methods. This study is important because it can provide educators with more ways to create inclusive, engaging lessons. Bringing movement into the classroom and allowing for stretching and brain breaks is a topic that has been explored through research previously, showing a positive result on students' brain function.

2. METHODOLOGY
In this study you were asked to complete pre- and post-assessments which asked you general background questions and questions about percentages, leaving a tip at a restaurant, etc. In between the assessments, you were reminded of the connections between fractions and percentages and worked individually, with partners, or in groups to show and solve multiple examples.

3. ADDITIONAL RESOURCES
For more information on the topic of this research, read *Minds in Motion: A Kinesthetic Approach to Teaching Elementary Curriculum* by Susan Griss, listen to NPR's short talk "Deskercise: Staying Jazzed and Focused at School," and watch TEDxTalks by Michael Kuczala "The Kinesthetic Classroom: Teaching and Learning through Movement" and "Why Movement Works for Learning" by Ali Golding.

4. CONTACT INFORMATION
If you are interested in learning more about the research being conducted, or the results of the research of which you were a part, please do not hesitate to contact the principal investigator, Ange Wunderle (awunderle@drew.edu), or the faculty advisor, Dr. Sarah Abramowitz (sabramow@drew.edu).

5. PSYCHOLOGY 101 CREDIT
If you participated in this research study to gain credit for your Psych101 class, please ensure the instructor has recorded your attendance.

Thank you for your help and participation in this study

Appendix D

Answers from Pre- and Post-Assessments

The participant responses to math questions asked on the pre- and post-assessments are organized below. A green highlighted box means their answer was correct, orange represents incorrect, and grey has the response "I would be guessing."

	¼ is equivalent to which percentage?	When the denominator of a fraction gets bigger, the percentage…	Do you know the trick for finding 10% of a value? If yes, please write it below. If no, please write "I would be guessing."	Do you know the trick for finding 1% of a value? If yes, please write it below. If no, please write "I would be guessing."	If your restaurant bill is $52.00 (and you had excellent service!) what would your 20% tip be?	If you bought a $700 couch and there is a 10% sales tax, how much would the sales tax cost?	If you and a friend wanted to split a 20% tip on a $70 meal evenly, how much would you each pay?	What is 15% of 80?	What is 11% of 1,234?	What is 18% of 240?

Non-Movement Class										
PRE	25%	gets smaller	I would be guessing	I would be guessing	$10.40	$70	$14	16	I would be guessing	I would be guessing
POST	25%	gets smaller	moving decimal to the left once	move decimal to the left twice	$10.40	$70	$7	12	126.74	44.2
PRE	0.25%	gets smaller	I would be guessing	I would be guessing	I would be guessing	$70	I would be guessing	I would be guessing	I would be guessing	I would be guessing
POST	0.25%	gets smaller	Move the decimal point 1 to the left	Move the decimal point 2 to the left	$10.40	$70	$7	12	I would be guessing	I would be guessing
PRE	25%	gets smaller	Multiple a fraction by 10/100	I would be guessing	$10.40	$70	$14	12	I would be guessing	43.2
POST	25%	gets smaller	Move the decimal point 1 place to the left	Move the decimal point 2 places to the left	$10.40	$70	$7	I would be guessing	123.4	44.2

PRE	25%	gets smaller	I would be guessing.	I would be guessing.	$10.40	$70	I would be guessing	16	I would be guessing	I would be guessing
POST	25%	gets smaller	Yes, move the decimal place once to the left.	Yes, move the decimal place twice to the left.	$10.40	$70	$7	12	126.74	48.2
PRE	0.25%	gets smaller	Multiply the number by 0.1	Multiply the number by 0.01	$10.40	$70	$7	12	I would be guessing	43.2
POST	0.25%	gets smaller	Multiply by 0.1/move decimal to the left once	Multiply by 0.01/move the decimal to the left twice	$10.40	$70	$7	12	135.74	43.2
PRE	0.25%	gets smaller	i would be guessing	i would be guessing	$10.40	$70	I would be guessing	12	I would be guessing	I would be guessing
POST	25%	gets smaller	shift the decimal 1 spot to the left	shift the decimal 2 spots to the left	$10.40	$70	$7	16	135.74	44.2

PRE	0.25%	gets smaller	You move the decimal to the left two times	You move the decimal once to the left	$10.40	$70	$7	12	I would be guessing	I would be guessing
POST	0.25%	gets smaller	You move the decimal to the left once	You move the decimal to the left twice	$10.40	$70	$14	12	135.74	43.2
PRE	0.25%	gets smaller	I would be guessing	I would be guessing	$10.40	$70	$7	12	135.74	I would be guessing
POST	0.25%	gets smaller	move the decimal point to the left once	move the decimal point to the left twice	$10.40	$70	$14	12	135.74	43.2
PRE	25%	gets smaller	multiply number by .1	"I would be guessing."	$10.40	I would be guessing	$7	12	I would be guessing	I would be guessing
POST	25%	gets smaller	move decimal once to the left	Move decimal twice to the left	$10.40	$70	$7	12	135.74	43.2

PRE	25%	I would be guessing	I would be guessing.	I would be guessing.	I would be guessing	$70	I would be guessing	I would be guessing	I would be guessing	I would be guessing
POST	25%	gets smaller	Move the decimal to the left once	Move the decimal to the left twice	$10.40	$70	$14	8	135.74	43.2
Movement Class										
PRE	0.25%	gets smaller	Move the decimal place over one space to the left	I would be guessing	$10.40	$70	$14	12	126.74	44.2
POST	0.25%	gets smaller	Move decimal place once to the left	Move decimal place twice to the left	$10.40	$70	$14	12	135.74	43.2

PRE	0.25%	gets smaller	I would be guessing	I would be guessing	$10.40	$70	$7	I would be guessing	I would be guessing	I would be guessing
POST	25%	gets smaller	Move the decimal over to the left one place	Move the decimal over to the left two places	$10.40	$70	$14	I would be guessing	I would be guessing	I would be guessing
PRE	0.25%	gets smaller	I would be guessing	I would be guessing	I would be guessing	$70	I would be guessing	16	I would be guessing	I would be guessing
POST	0.25%	gets smaller	yes, you move the decimal point once! ex: 250, 2.5%	yes, you move the decimal point twice! ex: 250, .25%	$10.40	$70	$14	I would be guessing	I would be guessing	I would be guessing

PRE	25%	gets smaller	I would be guessing.	I would be guessing.	$10.40	$70	I would be guessing	16	I would be guessing	I would be guessing
POST	25%	gets smaller	Move the decimal point one place value to the left.	Move the decimal point two place values to the left.	$10.40	$7	$7	12	126.74	43.2
PRE	25%	gets smaller	move the decimal point one place to the left	move the decimal point two places to the left	$10.40	$70	$7	12	135.74	43.2
POST	25%	gets smaller	move the decimal point one place left	move the decimal point two places left	$10.40	$70	$7	12	135.74	43.2

PRE	25%	gets smaller	Divide by 10	I would be guessing	$10.40	$70	$7	12	132.4	44.2
POST	25%	gets smaller	Moving the decimal point over 1 digit	Moving the decimal point over 2 digits	$10.40	$70	$7	12	135.74	43.2
PRE	0.25%	gets smaller	Yes, move the decimal one place to the left	Move the decimal two places over	$10.40	$70	$7	12	135.74	43.2
POST	0.25%	gets smaller	Yes move decimal to left once	Yes move decimal to left twice	$10.40	$70	$7	12	135.74	43.2
PRE	25%	gets smaller	Moving the decimal point one to the left	I would be guessing	$10.40	$70	$7	12	I would be guessing	43.2
POST	25%	gets smaller	Move the decimal one to the left	Move the decimal two to the left	$10.40	$70	$7	12	135.74	43.2

PRE	25%	gets smaller	Yes, it is moving the decimal place over to the left one spot.	Same thing as 10% just two spots this time.	$10.40	$70	$7	12	135.74	43.2
POST	25%	gets smaller	Yes, move the decimal place over one place to the left	Yes, move the decimal place over two spots to the left	$10.40	$70	$7	12	135.74	43.2
PRE	25%	gets smaller	I would be guessing	I would be guessing	$20.80	I would be guessing	I would be guessing	I would be guessing	I would be guessing	I would be guessing
POST	25%	gets smaller	Move the decimal point one place to the left	Move the decimal point two places to the left	$10.40	$70	$7	12	135.74	43.2

PRE	25%	gets smaller	Move decimal place to the left one digit	Move decimal to the left two digits	$10.40	$70	$7	16	135.74	44.2
POST	25%	gets smaller	Move decimal left one place	Move decimal left two places	$10.40	$70	$7	16	135.74	44.2
PRE	25%	gets smaller	You move the decimal place to the left once	You move the decimal place to the left twice	$10.40	$70	$7	12	I would be guessing	I would be guessing
POST	25%	gets smaller	Move the decimal to the left once	Move the decimal to the left twice	$10.40	$70	$7	12	135.74	43.2