HARNESSING THE POWER OF MATHDANCE TO BROADEN CULTURAL HORIZONS

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ABSTRACT

Educators are challenged to introduce some form of an integrating factor that holds things together to encourage students to think in whole systems and see the connections. Despite the seeming differences that separate mathematics and dance as distinct disciplines, it can be demonstrated that they are not mutually exclusive sets, but rather, interestingly intersecting. While exploring the linkage between the fascinating field of mathematics and the delightful world of dance, cultural dimensions also come into the picture.

The cognitive and aesthetic similarities between mathematics and dance are examined. Mathematical concepts involved in dance are identified and illustrative examples are given to highlight the presence of abstract patterns in picturesque physical movement. Possible activities are suggested for the teaching of mathematics using movement and rhythm.

This experimental step taken towards an inter-disciplinal approach to learning is a recognition of the role played by multiple intelligences in today's mathematics classrooms and a response to the need of making mathematics accessible for all students with varied learning styles.

Key words: mathematics, dance, math dance, science of patterns, cultural enrichment

INTRODUCTION

When he was Dean of Faculty at the Stony Brook School, D. Bruce Lockerbie delivered a speech at William Floyd High School in New York, reproduced in the March 1982 issue of Vital Speeches of the Day. He keenly observed that "education has been compartmentalized and departmentalized into pigeonholes and cubicles, little areas of knowledge cut off from each other and from the full resources of all that may be known. We are fast becoming a civilization of specialists restricted to seeing their tiny place in the universe in isolation from everyone else."

The challenge for teachers is to make students see the great connections, to provide an integrating factor that holds things together. Integration, or anti-differentiation, is a very powerful operation in calculus that lends itself to analysis of real world problems. In layman's terms, the concept of integration is the opposite of fragmentation. Integration can be employed to exhibit an underlying unity in two or more fields of study.

The integration of math concepts and dance skills is modeled by "Math In Your Feet" (MIYF). The product of the collaborative endeavors of professional dancer Malke Rosenfeld and Presidential award-winning math specialist Jane Cooney, Young Audiences of Indiana, and the Pike Township School District, Indianapolis, USA, MYIF is grounded in both National Council of Teachers of Mathematics principles and standards and national dance standard (www.mathinyourfeet.com/index.html). Documentation shows that 4^{th} and 5^{th} graders have immensely enjoyed investigating math concepts that have come alive in their feet and bodies. Learners are brought to cross-disciplinal intersections where relevance is encountered.

In May 2008, *Discoveries and Breakthroughs Inside Science*, a syndicated science and engineering news service for local television newscasts all over the United States, featured the Math Dance program of mathematician-dancer-educator Dr. Karl Schaffer and actor-dancer-composer-teacher Erik Stern. Math Dance pioneers discussed how this approach can help students who have trouble relating to mathematics. Mr. Stern commented that, "many math-phobic adults and children are put off by math because they are given symbols before they have a real solid experience on which to base it on." To which Dr. Schaffer added, "For many people, having a kinesthetic experience of an abstract idea is extremely helpful in understanding what that abstract idea is." They explained that in the process of creating dances, mathematical problem-solving is usually incorporated which can even inspire new mathematics. It was reported that in many cases, the choreographic ideas easily translate to classroom activities usable in college math classes. Some of the topics explored are polyhedral geometry, symmetry, the mathematics of rhythm, and variations on dissection puzzles such as tangrams. In this alternative way of knowing, mathematical symbols and patterns are translated into choreography and, conversely, dance patterns are translated into math.

To the creators and advocates of Math Dance, the question is not "Why combine cognitive mathematics and creative dance in class?" but rather "Why were they ever separated in the first place?"

EXPLORING THE INTERSECTIONS

G*ödel, Escher, Bach: an Eternal Golden Braid* (1989) is a Pulitzer Prize-winning book by Douglas Hofstadter that focuses on variations of the same theme in the creative works of logician Kurt Gödel, artist M. C. Escher, and composer Johann Sebastian Bach. At a deeper level, the book is a detailed and subtle exposition of concepts fundamental to mathematics, symmetry, and intelligence. Although mathematics, arts, and music are discussed in the book, the author's major concern is how cognition and

thinking emerge from well-hidden neurological mechanisms. He pointed out that an information-preserving transformation known as isomorphism "applies when two complex structures can be mapped onto each other, in such a way that each part of one structure is the corresponding part of the other structure, where 'corresponding' means that the two parts play similar roles in the other structures." He explained that such perceptions of isomorphism are the ones that create meanings in the minds of people. In *"Analogy as the Core of Cognition "* another stimulating masterpiece by Hofstadter that became part of The Best American Science Writing in 2000, he expounded on the importance and centrality of analogy-making in cognition.

Hofstadter is right: it is a "bolt from the blue" and a cause for joy when a correspondence between the structures of math and dance is discovered. After several years of enriching collaborative work on dances, Math Dance experts Dr. Schaffer and Mr. Stern noticed that, "math and dance both deal with codified concepts such as symmetry, spatial awareness, counting problems and patterns." They paid attention to the aesthetic similarities as well: "the need for internal consistency, the goal of striking a balance between analysis and intuition, and how either one could be abstract as well as worldly." They vigorously assert that "dance and mathematics were more than equals, they were manifestations of the same interest in aesthetics and form, thought and expression."

Oxford University mathematics education professor Anne Watson, in her paper "Dance and mathematics: power of novelty in the teaching of mathematics" for the 2008 11th International Congress on Mathematical Education Topic Study Group 14 on innovative approaches to the teaching of mathematics wrote, "Ways to engage students' minds through aesthetic and physical senses, and to relate these to symbolic modes of representation, in the learning of mathematics might become easier to find through considering contexts and tasks in which these connections arise naturally."

Pattern Recognition

In his book "The Math Gene", mathematician Keith Devlin (2000), the Executive Director of Stanford University's Center for the Study of Language and Information argues that, "mathematics is not about numbers, but about life**.** It is about the world in which we live. It is about ideas, and far from being dull and sterile, as it is often portrayed, is full of creativity**.** It is the science of patterns**.**"

Consider the patterns explored in some branches of mathematics: in logic we study patterns of reasoning; in arithmetic, we work with patterns of number operations; in algebra, we examine patterns of finding unknown quantities; in geometry, we investigate shapes and sizes; in trigonometry, we examine patterns of triangles; in calculus, we deal with patterns of change in quantities and in statistics, we are concerned with patterns of data analysis.

English mathematician G. H. Hardy (1877 - 1947) affirms: "A mathematician, like a painter or a poet, is a maker of patterns. If his patterns are more permanent than theirs, it is because they are made of ideas… The mathematician's patterns, like the

painter's or the poet's, must be beautiful. The ideas, like the colors, and the words, fit together in a harmonious way. Beauty is the first test; there is no permanent place in the world for ugly mathematics."

Dance is simply defined as movement set to music where there emerge organization, structure, and pattern. It is a composition that implies arrangement of parts into a form. Dance follows distinct logical principles.

Creative Endeavors

Math and dance share the same goal: the creative exploration of formal patterns. Mathematicians create new mathematics. Choreographers create new dances or re-create by making adaptations of previous creations.

A deep sense of the creative thinking involved in math is revealed in the statement of French mathematician Jules Henri Poincare (1854 - 1912): "Mathematics has a threefold purpose. It must provide an instrument for the study of nature. But this is not all: it has a philosophical purpose, and, I daresay, an aesthetic purpose." Karl Weierstrass (1815-1897) holds this view: "It is true that a mathematician who is not also something of a poet will never be a complete mathematician."

It has been said that dancing is the poetry of the feet. Aptly enough, the Honolulu Advertiser said of Philippine National Artist for Dance Leonor Orosa-Goquingco's *Filipinescas* dancers when they toured Hawaii in July 1966 - "They are poetry in motion."

Communicative Nature

Math and dance have a way of making the invisible visible. Equations have stories to tell and dances have messages to convey. As a visual art form, images are created in dance, and as it is a wordless language, it is a sensual one; a language of felt experience. "Dance is the hidden language of the soul," reflected Martha Graham, a pioneer and legend in contemporary dance forms, named by Time magazine in 2000 as "Dancer of the Century."

Italian astronomer and physicist Galileo Galilei (1564-1642) wrote: "Mathematics is the language in which God has written the universe." As a very symbolic language, math has its own vocabulary and grammar. It is a language of great precision. Conciseness is demanded in dance as well. Here is how Mr. Louis Horst accurately criticized dance studies in strange space design as written in Modern Dance Forms in Relation to the Other Modern Arts (1987):

A quarter of an inch makes a difference - that sort of exactitude that makes it professional. Nothing casual should happen on stage anyway.
Measured out - not free wheeling.
You only rolled over. Move like a sphere in space.
Never lose the planal concept.

If you don't feel that your foot is in the right place, you may need a mirror or someone to tell you until you do it intuitively.

Dance, like math, is a high precision language and proficiency can only be attained through practice.

Nick Joaquin, in his book *La Orosa* (1994) wrote about the memories of Carole de la Paz–Zialcita, a little lass that Philippine National Artist for Dance Leonor Orosa Guquingco turned into a star dancer: *"Mrs. Goquingco drilled us so well that, lined up as Igorot maidens, when we raised our hands, every arm was exactly at the same angle, though we were different heights. That precision had become so automatic we would have angled our arms just as uniformly even if we were all fast asleep. For our first tour abroad, in 1961, we were rehearsing the whole year. And during the tour, wherever Mrs. Goquingco noticed our movements were becoming mechanical, she would make us rehearse again and she'd give us new bits of business to do to make our numbers novel and fresh again. You do get bored doing the same thing, especially if you have to do it twice a day. Our movements were kept precise by what we call 'muscle memory' as well as by the artist eye of Mrs. Goquingco."*

Similar Terms

The elements of movement space were enumerated by Dr. Carmen T. Andin (1984) of the Philippine Normal College in *Handbook on Rhythmic Activities*:

1. Direction is the line of movement which may be forward, backward, sideward, diagonal, upward, or a combination of these.
2. Level is movement in space which may be done at a high, low or medium level.
3. Range refers to the area covered as the body moves. It may be small as when the movement is done in one's place, or large when movement covers a wide area as when getting away from one's place.
4. Floor pattern is the path or design on floor that is made while moving in space,

The terms sound familiar to a math-trained ear, conjuring images of vectors representing both magnitude and direction; the maximum and minimum points on a sine or cosine wave dictated by its amplitude; of the range determined by a function's domain; of the designs formed by a locus of points or the contour curves of an objective function for a mathematical programming model.

In 1978, C.R. Fowler, in *Dance as Education*, noted that, "the basic components of dance – patterns, lines, form, shape, time, rhythm, and energy – are pivotal concepts in many other curricular areas and can therefore be integrated with and enhance mathematics and the social sciences as well as the language arts."

MATHEMATICAL CONCEPTS USED IN DANCE

In a paper presented at the April 3-4, 2008 Science Summit held in the University of the Philippines Baguio, Dr. Christopher C. Bernido of the Research Center for

Theoretical Physics, Central Visayan Institute Foundation, referred to the circle as a rich, unifying concept. As a synthetical level example to illustrate a feature of the Dynamic Learning Program that he and his wife Dr. Marivic Carpio-Bernido are administering in Jagna, Bohol, Philippines, he enumerated the topics that can be discussed based on the circle such as Venn diagrams, circumference as a linear function, circular area as a quadratic function, coordinates of points on the unit circle, circular functions, polygon of infinite sides, nontrivial topology, wave functions and simple harmonic motion.

The simple closed curve that is the circle is fundamental to dancing. It is the dance formation that must been used for the longest time. There is a wealth of resources on circle dances, which speaks of the universality of the very ancient tradition for the celebration of special occasions, community-building and bonding. Up to this time, cultural circle dancing is alive and well in many parts of the world.

In 1970, a new power move was introduced in breakdance called *windmill*. A circular path is formed on the floor as the dancer rolls his torso, while his V-shaped legs are twirled through the air. Such twirling of the legs is very much like the movement required in using a math compass. Angular accuracy is exhibited in the entire routine.

For the March 12-18, 2008 production of Philippine nationalist playwright Aurelio Tolentino's *Bagong Cristo* at the Makiling Performance Garden of the University of the Philippines Los Baños, choreographer Jeremy de la Cruz was tasked to come up with a movement for the opening act. After he realized how a heart-shaped curve is generated using the polar equation of a cardioid, he created a dance number that symbolized love for one's nation.

On November 22, 2007, *CASayahan* was staged at the Baker Hall, University of the Philippine Los Baños in celebration of the College of Arts and Sciences 35th founding anniversary. The affair featured the fusion of the arts and sciences in a street jazz competition among the students from the different units of the college. The team from the Institute of Mathematical Sciences and Physics based its street jazz rendition on various math concepts such as the Fibonacci sequence, curves, vectors and projectile motion, among others.

On February 16, 2008, multi-awarded mathematics and psychology professor Dr. Queena Lee-Chua of the Ateneo De Manila University highlighted in her Philippine Daily Inquirer *Eureka!* column subtitled *"Math Comes Alive",* the delightful experience of her student, Ms. Cristina B. Rosales, a math teacher of Lallo National High School in Cagayan, Philippines. Ms. Rosales described a cheer dance presented by the best group in her class wherein properties of the graphs of polynomial functions were mentioned: "…they did bends to illustrate parabolas opening downward, splits showing lines with zero slope, and waves for polynomial." Concepts of linear and quadratic functions had taken concrete form in the students' bodily movements.

Physics Professor George Gollin of the University of Illinois in Urbana

Champaign, USA has done some collaborative work with dancers and Kenneth Laws, Professor Emeritus of Physics at Dickinson College and adjunct teacher at the Central Pennsylvania Youth Ballet, USA**.** Prof. Gollin gave a presentation at Hope College on the Physics of Dance on November 1, 1996 and October 24, 1997. Copies of the transparencies for the interesting lecture that links physics to dance are compiled in www.hep.uiuc.edu/home/g-gollin/dance/dance_physics.html#hope. He showed that a dancer's center of gravity moves along a parabolic trajectory. Cloaked in physics vocabulary, the mathematical concepts governing force, velocity and momentum are evident.

Assistant professor of mathematics Ann Bingham (2007) of Peace College, USA, taught transformations of functions using modern dance in an experiment that paired a modern dance class with college algebra course. The transformations of algebraic functions were scrutinized on a rectangular coordinate system established on the dance studio floor.

The Indian classical dance *Bharata Natyam* is geometry in motion – the arms, legs and torso form an array of vivacious shapes and lines, ideally depicting sculpturesque features, reflections on the ritualistic culture of Tamil Nardu. On January 1, 2003, International Journal of Humanities and Peace featured *Bharata Natyam: Classical Indian Dance: a Hindu Fractal by* Sofia Diaz. The metaphor of the self-repeating shapes within a greater identical pattern is based on the term coined by Benoit B. Mandelbrot.

The movements in contra dances, which originated from English country dance, resemble the traditional square dances. The configuration of two couples in a contra dance can be represented using matrices. Ivars Peterson analyzed contra dances using symmetries of a square in his March 10, 2003 issue of Math Trek.

The wholly intuitive performance of the Balinese candle dancers continues to impress viewers. The candle dance trick involves rotating the hand, palm-side up by 360 degrees, resulting in an arm twist. To undo this arm twist, a second 360-degree rotation in the same direction is needed. The 720-degree turn, the movement that preserves the identity, as it were, of the original hand position, is also instinctively demonstrated by Filipino dancers in their spectacular *Binasuan* (meaning "with the use of drinking glasses") dance routine. In discussions on angle measurement and direction of rotation, students can find out that they can extricate themselves from orientation entanglement by experimenting with the hand rotation as follows. A glass filled with colored liquid is held by the right hand, palm up, straight out in front. Then it is brought to the left, and in a counterclockwise direction under the underarm, it is brought around front in a circular, 360-degree rotation with the elbow straight up in the air. To get out of the awkward twisted arm position, the counterclockwise movement must be continued, but this time the arm must be swung around over the head. At 720 degrees, the hand is back to its original straight-arm- palm-up position, with no drop of the colored liquid spilled.

All the figures of the vibrant traditional Filipino bamboo dance *Tinikling* are combinations of only three basic 4/4 steps called singles, doubles, and hops. The choreography can be altered by simply changing the combinations. A new formation can be attained by rotating the poles through angles of varying degrees.

Built on the description of class activities laid out by Karl Schaffer, Erik Stern, and Scott Kim (2001) in *Math Dance with Dr. Schaffer and Mr. Stern*, Table 1 was expanded to include culturally-rich examples of math-laden dances. The activities have been tried out in a general education course on problem solving at the University of the Philippines Los Baños, and in regional seminar-workshops conducted for elementary and high school math teachers.

Table 1. Math and Dance Concepts with Corresponding Class Activities

MATH CONCEPT	DANCE CONCEPT	ACTIVITY
Counting, combinations, problem definition	Sequence, dynamics	Handshake Dances *Kumusta ka, halina't magsaya* (a getting-to-know-you Filipino action song) Clapping combinations to the tune of *"Bahay Kubo"* (a Filipino folk song) *Tinikling* bamboo dance
Probability	Chance on choreography, transitions, pattern recognition and memory	Class sequence creations (a random sequence of coin tosses is turned into a corresponding sequence of movements)
Scale, shape, estimation	Scale, shape, mechanics of how the body travels	Path Dances; Altering Patterns Video show: Irish *Riverdance* Algorithmic dances of Cebu City inmates
Geometry, polygons, polyhedra, spatial visualizations	Dance with hands, ensemble, shape, transitions	Shape Pass, Hand Shape Shifting, Hand Polyhedra, Cubes in Space
Shape, angle, area, spatial relations	Dance with props, visual story-telling shapes in space	Moving with giant tangrams
Circle, coordinates of points on the unit circle	Choreographic Elements	Ifugao *Uya-uy* wedding ritual Khmer *Ram vong* Hooky Pooky (action song) Video show: Windmill Breakdance
Matrices and groups;	Contra dancing	Experiments with square

geometric transformations and the symmetries of a square		dancing
Counting and fractions	*demi plie* (half flex) *demi-tours* (half turn) *grand plie* (deep flexing) Three-linked steps	Barre exercises Cha-cha-cha
Angles, measurements, direction, derivatives	Arm and leg positions	Video clip from Futures Channel: Dancing to the Limit Balinese candle dance Filipino *Binasuan* Honeybee waggle dance Film showing: Ice Princess Modern jazz turns and spins
Cartesian coordinate system	Stage space /Dancing area	Stage right, left, center dance experiments
Range	Movement range	Ilokano *kumintang* vs. Visayan *kumintang* (hand movements) Shoulder roll variations Full range hip rolls
Axis of symmetry, reflections	Focus, center, symmetry	Mirroring exercises Other international bamboo and fan dances
Fermat's Last Theorem	Tango	Musical drama video show: "Fermat's Last Tango"
Angles, fractals	*Bharata Natyam* elements	Lecture-performance by a professional dancer and/or video clips

BRIDGES TO UNDERSTANDING

Cultural enrichment is one of the benefits derived from math dance. Illustrative international dances that involve mathematical concepts are captivating introductions to the lifeways and belief systems of various people groups. The students get to see the world beyond the walls of the classroom. Such exposure paves the way to cross-cultural understanding and peace education.

The universality of dance gives it enduring power. It is neither time-bound nor culture-confined. As Martha Graham wisely said, "I think the reason dance has held such an ageless magic for the world is that it has been the symbol of the performance of

living." The dancing of the East is characterized by spinning dervishes that express religious zeal and self-sacrifice. The vigorous, rhythmic dancing of the Africans, the celebration dances of tribal groups from every tongue and nation, the American Indian ritual dances - these are all celebrations of the gift of life. Everyone dances with equal spirit. Mimetic and occupational dances abound in different cultural traditions; there are interesting versions of dances using indigenous materials as props, such as bamboo poles, hats, fans, scarves, candles, umbrellas, drinking glasses, sticks, coconut shells, and drums.

In the animal kingdom, the honeybee waggle dance relies on observed angular diretions to communicate location of food sources. An international research team composed of Dr Shenglu Chen and Songkun Su from Zhejiang University in China and Dr Jürgen Tautz from Würzburg University in Germany studied how the honeybee dance could break cultural barriers among Asian and European honeybees (Su, 2008). Entomologist educator Daniel Herms came up with a wonderful role-playing dance that engages the participation of grade school pupils in learning honey bee behavior. The dance pattern involves angled orientation and proportional distances. A detailed description of the simulated figure-eight formation of the waggle dance is recorded in Entomology Notes #22, Michigan Entomological Society, December 1990. Carrying out this delightful educational activity is a sticky way to heighten awareness and understanding of the wonderful world of insects.

SUMMARY

Math literacy is about fascinating learners with natural phenomena. As gleaned from the Greek root word *mathematikos* (which means "inclined to learn"), math is a "learnable knowledge" that can be made accessible to all. What better way to capture the imagination of learners than to present math in a manner they have never seen before? Capitalizing on the students' natural inclination to appreciate movements in production numbers they get to watch on stage and in television, the math dance approach is an attempt to help reduce math-indifference and math-aversion. Tackling the dances in their historical contexts broadens cultural horizons. This experimental step taken towards inter-disciplinal approach to learning is a recognition of the need to make mathematics available to all students with varied learning styles. Math dance is active learning for "mathletes" and "dancelethes", the critical and the creative thinkers, the analytic and kinesthetic.

Math dance uses the resources of seemingly different disciplines in ways that mutually reinforce. When such ways are adopted in the classroom, an increasing consciousness of the beauty, worth and relevance of math will be felt.

There is a line in the film "Strictly Ballroom" delivered in Spanish: *"Vivir con miedo es come vivir a medias."* (A life lived in fear is a life half-lived.) There is no reason for students to go on living in fear of math. Confidence can be developed through dance. Endurance can be built when students have fun in the process of learning. In the words of Martha Graham, dancing is just discovery, discovery, discovery. And that is exactly what math is all about.

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