

Putting Your Best Foot Forward: Movement & Mathematics in College

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Abstract

This 90-minute workshop shares several aspects of an innovative interdisciplinary college course, Pattern Play, that links mathematics and dance to meet creative arts and quantitative literacy requirements. Participants will: 1) Engage in two open-ended movement activities – Giant Tangrams and Hustling Graph – that introduce geometry, algebra, and dance concepts as well as the broader theme of kinesthetic and arts-based learning, 2) Learn how the creative discovery process can be used to form an atmosphere of experimentation and play that can positively affect student attitudes about mathematics, dance and learning, and 3) Learn how strategies such as movement, breath control, and reframing/redesigning assignments help students identify and cope with learning anxiety.

Rationale and Overview

For college students in the United States not majoring in the sciences, there are limited appealing options for liberal arts mathematics classes. As a result, fulfilling mathematics general education requirements can become a barrier to graduating. The resulting discomfort with and avoidance of quantitative literacy requirements, particularly for students majoring in arts and humanities, is causing educators to look for more effective ways to engage and inspire students in their study of mathematics in order to communicate the beauty and relevance of the subject. While a fresh look at non-lecture based teaching practices is useful for all postsecondary mathematics classrooms, liberal arts majors who often do not identify as strong traditional mathematics learners stand to gain the most from such innovations. See [5] and [8].

In the article "Learning Through Dance," Hanna [4] discusses a study of dance that encouraged the explorations of various mathematical concepts such as space, time, and phrasing. The article also cites a ten-year study of low-income youth in which regular study of the arts improved the youths' academic performance and increased their abilities in self-assessment. Yakimanskaya [9] documented the important relationship between spatial thinking and mathematics education.

Many instructors of general education college mathematics courses are adept at recognizing when a student is discouraged, reluctant, afraid, disengaged, or anxious. Unfortunately, the focus and format of the majority of these courses do not include the means and rationale to pursue strategies to alleviate these negative feelings. Pattern Play draws on research connecting kinesthetic and mathematical thinking, in particular that of Schaffer, Stern and Kim [6], to change the dynamic and focus of learning. A Pattern Play class session looks, sounds and feels very different from a traditional college mathematics or dance class. While learning about a particular topic or unit, students and teachers shift fluidly from extended creative movement problems to specialized worksheets begun in class to working out questions on a

white board to 15-minute Yoga sessions. Students also shift from working alone, in groups, and with instructors. Much time and effort is devoted to physical exploration and the transition between physical and symbolic representations. These intentional applications of different but related ways of grasping the material not only offer more access points; they foster a sense of educational agency. This agency is an outgrowth of exposure to a range of approaches to learning; students reflect regularly on how each approach influences their understanding and competency (in both dance and mathematics).



Figure 1: *Pattern Play students learn multiple ways to solve problems. In addition, they develop the ability to choose methods that suit their evolving learning needs.*

Accordingly, students are encouraged throughout to find solutions in ways that are rigorous but that also suit them. This choice lays the groundwork for persistence in problem-solving and for a non-rigid approach to problem solving. It also provides students with methods to 1) analyze personal learning patterns and tendencies, and employ methods to consciously alter negative mindsets that impede progress, and 2) regulate anxiety about learning through breath control, mindful physical exertion, and reframing how to approach assignments and tests. These strategies are designed to give student tools to recognize and alter negative attitudes about certain subjects in higher education, most notably mathematics (particularly in those U.S. colleges that have more open entrance requirements). Creativity and attention to process are staples of this approach, are integral to the syllabus and learning outcomes for Pattern Play, and are discussed further in the “Workshop Activities” and “Learning Outcomes” sections below.

In this workshop, participants experience how carefully designed kinesthetic activities can lay the foundation for mathematical understanding and can alter the environment for learning by engendering the sort of close, collaborative associations inherent in some dance classes. These associations serve as a new model for mathematics learning, and speak more directly to students studying the arts and humanities by showing how creative discovery can positively influence the learning process. This educational model aligns well with the Bridges 2016 workshop theme of “Creativity and Learning.” Stated simply, Pattern Play seeks to empower students to take control of their own progress by helping them learn how they learn.

Workshop Activities

The workshop consists of two participatory movement activities – Giant Tangrams and Hustling Graph – and requires an open space with enough room for participants to move. A rule of thumb for evaluating the size of the venue is that all participants can extend their arms and turn slowly without touching another person. A smooth even surface on the floor is needed (no carpet); a sprung dance floor is ideal. Chairs on the perimeter allow for discussion and reflection, and the ability to amplify sound from a computer is preferable.

Giant Tangrams is an activity that draws on the inventive ways dancers use props. From mock battles with swords to fan dances to choreographer Alwin Nikolais’ use of elastic, choreography with objects is a global thread in dance. For beginners, an accessible prop that doesn’t require a high degree of skill can ease discomfort with performing by placing the focus on the object, as opposed to the person manipulating it. Giant Tangrams expands on the rich history of props by using oversized large foam versions of the Chinese seven-piece geometric puzzle (Figure 2). Participants begin with an accessible warm-up with the prop that gradually develops spatial awareness and appreciation for the relationships of shapes and sizes of Tangram pieces. After a class discussion about the warm-up challenges (for example, “it’s hard to coordinate the prop with my body”) and discoveries (“I found if I used my legs more I could move more smoothly with the prop”), the class is given this assignment: each group works cooperatively to create a sequence of four to seven group shapes that incorporate props and bodies. Groups are asked to pay attention to the transitions between the shapes; each transition in a group’s movement study should be intentional and distinct. After a brief question and answer (typical questions include “what counts as a different transition?” “do we all have to do the same thing?” and “do the puzzle pieces have to touch edges”), there is a 10 to 30-minute work period.

This choreographic assignment leaves plenty of room for exploration, and students are encouraged to devise a movement study that feels complete to them. This process introduces students to the act of cooperating in pursuit of a unique solution, and to aesthetics. Fostering a relaxed yet engaged environment in which students push their comfort zones is the heart of the course. Interaction with others, moving to music, and sharing the resulting phrases of movement in an engaging but non-judgmental way to underscore class themes of investigation, repetition, cooperation, and agency. Comfort with and enjoyment of this process is emphasized and used as a paradigm for creative problem-solving in general, but particularly for mathematics. Leading students through an activity like Giant Tangrams can catch them unaware, and break down assumptions and expectations about learning. This allows for the creative mindset, with its particular type of rigor, to emerge and sets the tone for the course.

The informal performances that result from the choreographic assignment are a basis for discussions about aesthetics of choreography, and about similarities and differences of puzzle pieces. As follow up to each movement activity, students in the course complete specialized interdisciplinary worksheets that help them retrace the progression from the physical to the symbolic. Worksheets are typically begun in class and completed at home. The worksheet for Giant Tangrams (samples of which are available at the workshop) begins with questions about the movement activity and progress to relationships of lengths of edges, and problems on perimeter, area and decomposing triangles, squares and parallelograms (Table 1).



Figure 2: *Through open-ended choreographic activities, students develop creative, cooperative problem solving skills, and apply them to mathematic thinking. In this activity, structured play with giant foam Tangrams forms a basis for artistic and geometric investigation.*

Hustling Graph draws on folk and ethnic dance traditions of travelling through the space in fixed repeated patterns, and offers a new look at the traditional study of linear equations and related topics (Table 2). From the Hora to the Hustle, group repetitive dances take place in circles, lines, and other formations. Learning these patterns presents a spatial and rhythmic thinking challenge, and an opportunity to learn how to “locomote,” or move through space.

Participants learn a repeating movement pattern that covers space in an L-shape (one step over and two steps up). Through movement, discussion and graph paper, participants explore the question: How far will a dancing group travel after three, four or ten repetitions of the L-shaped dance?

Next, each group is tasked with devising a new group travel dance with a different spatial progression (for example, two up and three over). After performing their variations, groups share how they created their spatial progressions, and discuss the relative merits of the approaches. The spatial regularity of these dances serves as a sort of giant “dancing graph” that presents a clear analog to the traditional paper version. It reframes graph paper as a way to notate a spatial path that is now familiar.

The discussion and activity moves from the cultural contexts to the steepness of the lines, or, put another way, the slopes of linear equations.

Learning Outcomes

The two above activities exemplify Pattern Play's methodology and give insight to two of the course outcomes: 1) Students will discover, understand and put to use connections between creative movement investigations and mathematic/symbolic concepts, and 2) Students will reflect on the roles creative discovery, multiple solutions and related thinking strategies have on their own experience and study of dance and mathematics.

Table 1

Learning Outcomes: Giant Tangrams

<i>Math</i>	<i>Dance</i>
Analyze relationships between area, perimeter, and geometric shapes	Articulate effects of and demonstrate transitions in dance and choreography
Investigate area, perimeter and geometric properties of non-standard shapes	Analyze use of props across cultures
Devise various geometrical proofs	Demonstrate understanding of effects of choreographic strategies

Table 2

Learning Outcomes: Hustling Graph

<i>Math</i>	<i>Dance</i>
Solve linear equations	Demonstrate/articulate dance technique methods
Demonstrate understanding of graphs and linear equations	Perceive and analyze relationships between dances across cultures
Identify and represent scale	Analyze aesthetics of social dance forms

It should be noted these outcomes are met through a combination of movement activities and follow-through assignments (worksheets with integrated learning outcomes, extensions of original choreographic activity, written assignments, and more). The initial movement activities, therefore, serve as reference point for an entire unit. While the activities are harnessed in a way that meets university learning outcomes in creative arts and quantitative literacy, Pattern Play's deeper value lies in the shared understanding articulated in learning outcome 3: Students develop and use critical and creative thinking skills to perceive and articulate the relationship between mathematics and creative arts. The presence of pattern recognition, investigation, expression and definition in mathematics and dance is the central subject of the course.

The final outcome requires more explanation: 4) Students will be able to intentionally apply strategies from class to their own learning process in order to improve attitude, understanding, and performance. In connection with movement activities and homework, Pattern Play students read, discuss, and write about learning tendencies in the context of the multiple learning approaches that are mainstays

of the course. Part of this process involves identifying personal hurdles, learning about the role of negative attitudes and emotions on brain function, and practicing when to apply these various techniques.

The performative aspect of the choreographic assignments plays a central role in this process. Instructors apply to mathematics methods that dancers use to prepare for performance. These methods help students deal with in-class anxiety and prepare for tests: warming up physically and mentally, utilizing breathing techniques when stress levels rise, noticing the effect working closely with others has on learning and attitudes. In other words, this question runs through the semester: if performers have established warm-ups to prepare them to do their best, how should mathematicians prepare?

Hence, the various modes of learning (intra- and interpersonal, physical, creative, collaborative, etc.) provide examples of a range of approaches that afford students insight into their own learning patterns and tendencies. The course includes several readings and assignments to foster student self-reflection that form a foundation for choosing methods to move away from negative approaches toward positive ones.

Pattern Play led to the creation of related strategies that proved valuable in redirecting student anxiety. One strategy began as a playful way to emphasize process over product when students worked problems on the board in front of the class. The method consists of one rule: simply say and write down what you know about the question. Embedded in this approach is de-emphasis of the answer. Related knowledge, be it a formula, class activity, reference to movement problems, discussions, is acceptable. This approach came to be called Share What You Know, and grew into a game of seeing how much one can call to mind, and encouraged perseverance in problem solving, particularly with unfamiliar problems.

A related strategy for addressing student anxiety is classroom environment. During the semester it became apparent that giving students the freedom to refashion the arrangement of chairs and tables would reinforce other methods, such as Share What You Know. This refashioning included avoiding traditional desks and table arrangements, playing music softly during tests and preparing for tests with breathing exercises.



Figure 3: *Pattern Play focuses on a flexible learning environment that supports the transition from movement to symbolic thinking.*

Initial Assessment of Pattern Play and Related Approaches

The course Pattern Play and a control group in a course that covered comparable mathematics topics (but not dance/creative arts topics) were assessed for traditional mathematic learning and for attitudes toward the subject. Two presentations at the Research Council of Mathematics Learning 2016 conference [1] [2] focus on kinesthetic methodology, traditional pre- and post-course assessments of content knowledge, and a draw-yourself-doing-math prompt.

A summary of the RCML assessments show statistically significant improvement in treatment group quantitative literacy and attitudes towards mathematics. The draw-yourself-doing math prompt revealed the intensity of feelings students have about mathematics learning in general, and a difference between the treatment and control groups. Overall, 75% of the treatment group drew more positive pictures about themselves doing mathematics on the posttest; only 39% of student drawings from the control group were more positive on the posttest. In terms of mathematical content knowledge, on average the treatment group scored 26% higher on the posttest than the pretest while the control group only improved by 9%. Throughout the assessment, the treatment group displayed more persistence in problem solving than the control as evidenced by fewer blank problems.

Though Pattern Play is geared to higher education, K-12 instructional approaches emphasized in *Breaking Barriers* [3] offer a framework for understanding the course. In Chapter 4 of *Breaking Barriers*, “Improving Academic Performance,” two instructional approaches outlined are “activity-based instruction,” such as promoting knowledge and skill acquisition through actions, and “cooperative learning,” such as idea exchange, support, feedback, etc.

Structured choreographic problem solving is action-based and lays the groundwork for mathematical thinking and learning skills. On its most basic level, the act of pushing oneself physically within clear guidelines and in a relaxed and safe classroom environment introduces patterns in a way that forms memorable social, kinesthetic, creative and critical thinking experiences on which to base mathematical thinking. It also sets up comfortable, flexible yet rigorous expectations for persistence in problem solving. The group problem solving inherent in the choreographic assignments establishes the mindset of cooperative learning. Once a rapport is established, students are given opportunities to consciously apply movement and creative cooperative learning to the cooperative study of symbolic math.

Future Plans

If time allows, at the end of the workshop presenters will share next steps in the project: preliminary analysis of video assessment, the next iteration of Pattern Play, summer writing on worksheets as part of a planned book, and the implications for this work on other interdisciplinary courses. The assessment component focuses on videotaped interviews during which students from the treatment and control groups were posed non-standard mathematics questions. These interviews are currently being coded for affect by project team member Rachel Bachman, with particular attention to persistence in problem solving. Initial results indicate the treatment group persisted longer and showed more success with non-standard problems than the control group. Presenters feel the broader theme of incorporating culture and creativity to foster an attitude that embraces open-ended problem solving could serve as a paradigm for other interdisciplinary courses and settings. The presenters also look forward to learning more about this theme

from other conference presentations.



Figure 4: Students use breath and movement techniques to ease tension and address learning anxiety.

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