MATH DANCE: A STUDY OF EFFECTIVENESS

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Pattern Play is an interdisciplinary college course exploring pattern recognition, creation, and analysis through simultaneous study of mathematics and dance. The effectiveness of this method was evaluated through the use of pre/post mathematics tests, attitudinal surveys, and drawing prompts. These data were compared to those of students in a traditional general education mathematics course covering the same mathematics topics. The results show that the students in Pattern Play outperformed the control group students in the areas of mathematical content knowledge, attitudes towards mathematics, and persistence in problem solving.

Despite the fact that about 70% of students enrolled in mathematics and statistics university classes are non-majors fulfilling general education requirements (Blair, Kirkman, & Maxwell, 2013), traditional mathematics courses are "primarily serving the needs of potential science majors" (Laws,1999, p. 217). For students not majoring in the sciences, fulfilling general education requirements for mathematics sometimes becomes a seemingly insurmountable hurdle preventing graduation. The resulting attrition 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 (Laws, 1999; Steen, 2000). The pilot section of Pattern Play: Mathematics and Creative Arts taught at Weber State University provides an intriguing model for delivering mathematics content to non-majors using an integrated study of mathematics and dance. This quasi-experimental study investigated the effectiveness of the Pattern Play course.

Related Literature

For decades, calls have been made to change the teaching of general education mathematics classes (Laws, 1999; Steen, 2000). These calls suggested giving students more opportunities to collaborate with instructors and peers, encouraging multiple solution strategies, exploring fewer topics in more depth, reasoning critically and conceptually, relating science and math topics to everyday life, and developing communication skills (Laws, 1999). Arts integration methods provide one model for deepening the learning of mathematics through stimulating self-thinking, self-expression, and problem solving (Hanna, 2000; Rinne, Gregory, Yarmolinskaya, & Hardiman, 2011; Schaffer, Stern, & Kim, 2001). In the article "Learning Through Dance," Hanna (2000) refers to 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 a regular study of the arts improved the youths' academic performance and increased their abilities in self-assessment. Yakimanskaya (1991) documented the important relationship between spatial thinking and mathematics education.

A progression from the palpable to the abstract served as a foothold to understanding the mathematical topics in the Pattern Play course. This progression aligns with the principles of cultural-historical activity theory that emphasize educational tasks that cause students to first investigate a concept through the study of real objects and activities and then to follow up on these experiences by carefully scaffolding understanding to a more abstracted, symbolic representation of a given concept (Davydov, 2008; Kozulin, 1990).

Instructional Methodology

The pilot section of Pattern Play: Mathematics and Creative Arts provided an innovative approach to diversifying the delivery of general education mathematics course content. Co-taught by professors from mathematics and performing arts, Pattern Play satisfied university general education requirements for mathematics and creative arts. The course was open to all students at the university and was advertised widely across campus.

The mathematics content aligned with the university liberal arts mathematics course and included the topics of algebraic functions, geometry, and basic probability and statistics. The accessible dance activities focused on choreographic, collaborative problems that students "solved" by creating short movement studies within given parameters. Students were encouraged to push themselves physically and conceptually, but there was no pre-requisite dance experience or standard of dance ability. The movement activities were based on the performances, writings and workshops of Schaffer, Stern and Kim (2001) and adapted by the second and third authors to suit the required topics and level of this university level mathematics for liberal arts course. In addition to the study of pattern in arts and traditional mathematics contexts, students were introduced to movement forms and breath regulation as a method for dealing with anxiety often associated with learning mathematics.

Significant class time was devoted to the transition from the exploration of patterns in dance to the symbolic representation of these patterns on paper. Instructors devised extensive worksheets designed to develop student understanding and to trace in a rung-by-rung manner the overlapping critical and creative thinking important to both the arts and mathematical problem solving. Multiple pathways to a solution in both creative arts and mathematics were encouraged in an effort to build persistence in problem solving.

The topic of permutations will serve as an example of the method employed in Pattern Play. Students begin with a warm up activity moving in and out of various positions with their bodies. Then students are led through approaches to inventing a succinct and clear dance “move” that is repeatable with a beginning and ending. Placed into trios and quartets, each student teaches her dance move to the rest of the group. Each group decides on a new order for the moves and are tasked with developing transitions between the moves, rehearsing and performing their combined group dance for the rest of the class. After the performance, the class reflects on the activity in terms of aesthetics; they also list the orders of the moves on the board, leading to a discussion of how many total four-move dances could be made. Following a class discussion of permutations, students collaboratively or individually begin worksheets that connect movement problem-solving skills to permutation problems of increasing complexity.

It must be emphasized that the kinesthetic mode of instruction used in the course creates an entirely different environment for learning. Student explorations were informed by the collaborative, close association inherent in dance classes. Moreover, being in large open spaces without desks encouraged students to work in small groups or individually, to find comfortable spaces and positions, and to follow their own learning needs when solving problems and completing worksheets. This allowed for focus on breath control, awareness of returning anxiety, and development of ways to cope with that anxiety via discussion, yoga, changing problem solving approaches, walking around, and talking to others. Instructors de-emphasized lecture, and students were encouraged to focus on gathering what they knew before considering what the answer might be. Sometimes the instructors even instructed students to *avoid the answer* in order to focus on the process of problem solving.

Research Methodology

The purpose of this study was to assess the effectiveness of this interdisciplinary general education mathematics and dance course. There were 12 general education students in the Pattern Play course. The mathematics professor from Pattern Play also taught a traditional section of liberal arts mathematics in the spring following the pilot of Pattern Play. This section served as the control group for the study, and there were 34 students that completed this course. Several assessment tools were used to analyze the effectiveness of Pattern Play in an attempt to capture the full influence of the multimodal approach to learning featured in this course. These assessments included pre and post mathematics tests, pre and post drawing prompts, and pre and post attitudinal surveys. Students were not given any extra credit for completing any of the assessments and these assessment were not included in the grades for the course. Also the course instructors were never in the room at the time of assessment.

Mathematical Content Knowledge

The mathematical pretest/posttest was composed of twelve questions. The students were given 30 minutes to complete the exam and were allowed to use a scientific calculator. The questions were either taken from the course textbook or from a past exam used in another section of mathematics for the liberal arts. The questions included analysis of a linear function, a counting problem, a Venn diagram probability question, an applied Pythagorean Theorem problem, a proportionality arc length question, and a scaling problem. The exams were graded according to a rubric. For example, for a five point question involving multi-step calculations, students received all five points for correct responses with clearly communicated work, four points for mostly correct work involving an arithmetic error, three points for mostly correct work with multiple arithmetic or algebraic errors, two points for citing relevant formulas or trying valid methods but failing to arrive at a complete solution, one point for any work with some correct component, and zero points for blank or fully incorrect work. The solutions on this exam were also analyzed qualitatively to discern any patterns in the type of solutions produced.

Drawing Prompt

The drawing prompt asked students to “Draw yourself doing mathematics.” The students in both the treatment and control sections were given the drawing prompt on the first and last day of their respective classes. The students had about ten minutes to complete the drawing. The researchers explained that the quality of the drawing was not important and instructed the students to draw what came to mind when they thought of themselves doing mathematics.

This drawing prompt was adapted from previous work with the Draw-Yourself-Learning/Teaching-Mathematics test (Mcdermott, & Tchoshanov, 2014) and the Draw a Mathematics Teacher test (Utley, Reeder, & Redmond-Sanago, 2015). Instead of focusing on developing teachers' view of mathematics, this adaptation focuses on the student view of learning mathematics. A rubric was developed based on prior work by Farland-Smith (2012) and Utley et al. (2015). The rubric categorized drawings as extremely negative (1), negative (2), unpleasant (3), neutral (4), pleasant (5), positive (6), and extremely positive (7). The coding process is fully described in Bachman, Berezay, and Tripp (2016).

Attitudinal Survey

The attitudinal survey featured seven statements about mathematics: "Math is confusing," "Math involves a lot of experimentation," "I fantasized of a world without math," "Math involves a lot of memorization," "If I get stuck on a math problem on my first try, I try a different approach," "Math is a social activity," and "I get anxious when I have to do math." Students were asked to select a choice that best fit their response to each statement from the following options: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, and Strongly Agree. All the students in the study answered the attitudinal survey on the first and last days of their respective classes. They were given about five minutes to complete the survey.

Findings

Table 1: Quantitative Results

	Treatment			Control				
	n	Mean Change	Median Change	n	Mean Change	Median Change	Conan's *d*	Mann-Whitney *U*
Math Content	10	26	19.5	23	9	2	0.831	1.000**
Drawing Prompt	11	2.25	2	17	0.22	0	1.106	45.500*
Attitudinal Survey	12	6.33	6.5	19	1.82	0	0.9471	58.500*

*$p < 0.05$. **$p < 0.01$

Table 1 summarizes the pre and post measures used to assess treatment and control groups. The Mann-Whitney *U* test was chosen due to the small sample sizes in this study. All three assessments showed a statistically significant difference between the pre/post gains made by the treatment group compared to the control group. Also, the effect size for each measure (Conan's *d*) was determined to be large according to Conan's classification of effect sizes.

Mathematical Content Knowledge

On average, the treatment group score 26 points higher on the posttest than the pretest while the control group only improved by 9 points on average. Eighty-three percent of the treatment group students scored higher on the posttest than the pretest; only 71% of the control group scored higher on the posttest. Throughout the assessment, the treatment group displayed more persistence in problem solving than the control as evidenced by fewer blank problems. For example, when determining arc length, 54% of the control either left the problem blank or wrote "Can't remember the formula" compared to only 25% of students responding this way in the treatment group.

Drawing Prompt

On average, Pattern Play students increased their rubric score on the drawing prompt by 2.25 points (out of a maximum positive score of 7). Students in the control group increased their score by 0.22 points. 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. Furthermore, none of the posttest treatment drawings were considered "strongly negative" while five students (28%) from the control group received this score on the posttest. Also, students from Pattern Play were more likely than the control group students to include other people in their pictures, draw a nontraditional setting for learning, and not focus their drawings on panic or confusion on the posttest drawings.

Attitudinal Survey

The responses from the attitudinal survey were combined to give each student a mathematics attitudinal score. The maximum score was 35 and signaled a perfectly positive attitude toward mathematics. On average, the treatment group improved their attitudinal survey score by 6.33 points while the control group improved only an average of 1.82 points.

Implications

Students in Pattern Play outperformed the traditional control group students in the areas of mathematical content knowledge, attitudes toward mathematics, and persistence in problem solving. Also, every student that took Pattern Play successfully completed the course. In the control group, three students (9%) failed to successfully complete the course for general education mathematics credit. Furthermore, Pattern Play offers an exciting, innovative option for learning mathematics in an understandable, interesting, and relevant setting. This method has the potential of reaching students who struggle with traditional textbook mathematics. While this pilot section was offered in a college level liberal arts mathematics course, the methods in this class are pertinent to K-12 and developmental mathematics classrooms as well to foster understanding and use of effective mathematical practices of teaching and learning.

Every Pattern Play class was videotaped to allow for a case study of the methods used in the course. Key lessons were also videotaped from the control group to provide a contrast of the Pattern Play lessons to approaches used in more traditional mathematics classrooms. Initial analysis of the Pattern Play classroom videos has piqued interest in the research team about the methods used in that course to reduce math anxiety, foster class participation, elicit persistence and perseverance in problem solving, and foster a collaborative class environment. Future study of this course includes a detailed analysis of these videotaped classes. Furthermore, the research team plans to offer the course again in the future to refine the instructional methods used in the course and to design materials to be shared with others desiring to implement such techniques in their own classrooms.

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