

CALCULUS WITH CREATIVE ART – A BIDIRECTIONAL APPROACH TO CONCEPTUAL UNDERSTANDING

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ABSTRACT: Many students struggle with calculus because it requires a strong foundational understanding, deals with abstract concepts, and is often difficult to visualize or connect to real-world scenarios. This can lead to low engagement and confusion among learners. This research is directed towards the fusion of creative art and calculus in a bidirectional conceptual understanding process. Several past studies have explored the relationship between mathematics and art in creation and understanding. The key aim of this study is to integrate creative arts with mathematics to enhance conceptual understanding and engagement among learners. Two interactive learning activities were designed for Semester I students at the Institute of Technology, University of Moratuwa. Activity 1 featured creative math expressions such as mind maps, art, posters, designs, poetry, and games. Activity 2 involved students in creating visual artworks using mathematical concepts such as hyperbolas, parabolas, and the Fibonacci sequence. A paired t-test comparing performance before and after the first activity revealed a statistically significant improvement ($t = 9.08$, $p < 0.05$), indicating enhanced understanding of core calculus concepts. Analysis of the second activity demonstrated that students effectively applied mathematical principles in designing artistic pieces, fostering creativity and critical thinking. Feedback was collected afterward to evaluate engagement and perceived learning. Findings suggest that combining art and mathematics through creative expression can serve as an effective pedagogical strategy aligned with the “Calculus with Creative Art” approach to conceptual understanding. Additionally, it suggests that more similar activities could be encouraged to develop students’ cognitive and creative abilities.

Keywords: creative art with math, critical thinking, mathematical mind maps

1 INTRODUCTION

Integrating mathematics and art in teaching and learning nurtures both creativity and learning skills. Demonstrating mathematical ideas through art enhances education in both fields. The relationship between mathematics and art has been explored throughout the centuries, illustrating how the two are complementary to each other in creation as well as understanding. The majority of studies are based on the fact that mathematical principles such as geometry, symmetry, and sequences are extremely useful tools to create works of art. Simultaneously, engagement with art allows students to visualize and embed mathematical concepts intuitively and in a meaningful way (Sinclair, 2006). Mathematical tools like polar curves, hyperbolas, and the Fibonacci sequence have been used by artists and educators to produce attractive works of art (Livio, 2002). M.C. Escher is just one of the renowned artists who used geometric transformations and symmetry extensively when creating complex works of art that make mathematical patterns visually appealing (Schattschneider, 1990). The application of calculus-based mathematical concepts to visual art is not just decorative; it is a profound source of creativity and mental stimulation. Past and current research indicate how patterns like Fibonacci numbers, the golden ratio, and fractal geometry, which in the past could best be explained as purely aesthetic addenda, are really

patterns that stimulate analytical and creative imagination (Baliatti, 2020). Web-based mathematical tools like Desmos are used in several situations for designing animal, floral, and other types of patterns, helping students develop a better understanding of Polar curves (Ashley, et al., 2023). Poetry is also vital in the understanding of mathematics, for example a poem by Nina Casian addresses each verse with relation to a mathematical formula (Kalkan, et al., 2022). Most studies focus on polar curves and geometry, while the systematic integration of artistic creativity into the teaching of calculus concepts in higher education remains underexplored. Existing work is mostly one-directional, either using calculus to create artistic creations or creations to support calculus learning, rather than combining both for dual outcomes in understanding and creativity. Thus, the objectives of this study are to:

1. Examine the impact of using creative art to teach mathematical concepts.
2. Observe the impact of mathematical principles on creating artistic expressions.

Mathematical concepts and art are combined to stimulate creative thinking and mental growth. When students apply functions, curves, and geometry transformations to their artwork, they are performing higher-order thinking skills (Oner, et al, 2016).

2 METHODOLOGY

Two interactive learning activities were introduced, namely “Creative Art to Calculus” and “Calculus with Creative Art” for the Semester I students of the Institute of Technology, University of Moratuwa.

2.1 Creative Art to Calculus

The effects of creative art on demonstrating mathematical concepts were examined using mathematical mind maps, derivative art, mathematical posters, fractal and polar designs, math poetry, and educational games as a group activity with 5-10 students, with a total number of students of 650.

2.2 Calculus with Creative Art

Sixty students from the total students who completed the activity 1 participated in the second activity. These 60 students were enrolled in the Visual Art module in Semester 1. This activity created different Art projects using calculus concepts. As the first step, students were put into small groups of not more than five students to facilitate peer learning and interaction. In the second step, mathematical tasks were given, which were one or more mathematical ideas per group explored by sketching and visualization. Thirdly, in order to integrate creativity, the principles and elements of art and design were also taught to students. Students were guided to do their art on A3 paper, and coloring was done using black markers and ink pens. They were then encouraged to employ other shading methods to create the illusion of depth and three-dimensionality and thus add to the aesthetic quality and craftsmanship of their piece.

2.3 Student feedback on two activities

Finally, the students were requested to reflect on how art helped to understand mathematical concepts better. Two separate questionnaires were administered to collect students’ views.

One questionnaire focused on mathematical concepts they learned using artistic tools, while the other gathered information about the artistic creations they created using mathematical principles. Descriptive data analysis techniques were performed using Microsoft Excel from the responses of sixty students, who completed both activities.

2.4 Paired-sample t-test

Paired sample t-test (Lakens, 2021) compares means from the same group at different times (e.g., before and after treatment). The test statistic is given by equation (1).

$$T = \frac{\bar{X}_2 - \bar{X}_1}{SE} \sim t_{(n-1, \alpha)} \quad (1)$$

\bar{X}_1, \bar{X}_2 : the sample means at two different times (before and after)

SE: standard error of the difference in means

$n - 1$: degree of freedom where n is the number of pairs

α : the probability (p-value) of observing data if the null hypothesis is true.

Hypotheses: $H_0 : \mu_d = 0$; $H_1 : \mu_d > 0$, where μ_d is the difference between observations.

3 RESULTS AND DISCUSSION

This section analyzes the student engagement in two activities. Further, it highlights the key findings from student feedback analysis.

3.1 Student Engagement in Creative Art to Calculus

3.1.1 Learning Outcomes of Art-Integrated Calculus Activities

Table 1 represents a detailed summary of the activities given with the purpose of enhancing the mathematical knowledge of students using artistic tools. The key Learning Outcome (LO) associated with this activity was to identify basic concepts of Calculus. The specific LOs were: 1. Demonstrate the indeterminate forms of limits, 2. Derive definitions of hyperbolic functions, 3. Solve hyperbolic equations, 4. Solve extreme value problems, 5. Sketch curves including hyperbolic functions and polar coordinates.

3.1.2 Comparison of Students' Performance

Students' performance was evaluated using a paired t-test by comparing their marks before and after Activity 1. The test statistic is $T = 9.08$ with a p-value of $p = 0.00001$, which is less than $\alpha = 0.05$. Thus, H_0 is rejected at the 5% significance level, and H_1 is accepted. It can be concluded that students' performance has improved after the activity.

Table 1. Details of Artistic creations used to demonstrate mathematical concepts

No	Creation Name	Mathematic Topic	Description	Learning outcomes
1	Mind Maps	Applications of Differentiation and Hyperbolic Functions	Started with a main topic and branch out to related subtopics, keywords, or images with creativity.	LO1, LO2, LO5
2	The Art of Slopes	Applications of Differentiation	Use the derivative to highlight the function's behaviour across regions.	LO1, LO4
3	Recreate the first letter of your name or a given letter	Functions and Their Graphs	Created using different mathematical curves or lines	LO2, LO3, LO5
4	Design Fractals	Hyperbolic and Trigonometry Functions	Explored hyperbolic and trig functions in GeoGebra by changing equations and visualizing effects.	LO2, LO3, LO5
5	Design with polar curves	Polar Curves	Created using different polar curves	LO5
6	Poster for IDM	Hyperbolic curves, Polar curves.	Creating a poster for International Day of Mathematics.	LO2, LO3, LO5
7	Math Poetry with creative art	Any Topic	Combine mathematics with language arts by writing poetry.	LO1, LO2, LO3, LO4, LO5
8	Math Games with creative art	Any Topic	Designed a game with mathematics.	LO1, LO2, LO3, LO4, LO5

3.2 Student Engagement in Calculus with Creative Art

The LOs associated with this activity were: 1. Develop imaginative and critical thinking. 2. Apply creative and conceptual skills in the Arts. This activity was to design 10 art pieces (Figure 1). Those artworks were finished using black marker pens and black ink pens. Also used some colours to increase the beauty and add pencil shadings to add contrast and depth to their works to give life to their final piece.



Figure 1. Finished 10 Creative Art pieces

In Table 2, artworks shown in Figure 1 were broadly discussed in terms of the mathematical principles involved, the design details applied, and the hours spent in their creation. It shows that students have used numerous mathematical concepts to develop different design patterns. For this activity, different time levels were employed to create their artwork depending on the design. Ten marks were allocated for using mathematical principles.

Table 2. Details of Art Pieces created using mathematical concepts

Design No.	Used Mathematical Principle	Design Details	Time (hrs)	Score (out of 10)
1	Symmetry, Measurements, Proportions, Geometry	Geometric, grid, symmetry pattern	3	9
2	Symmetry, Measurements, Proportions, Geometry	Geometric symmetry patterns	2	6
3	Fibonacci spiral, Measurements, Proportions, Algebraic patterns	Geometric, symmetry patterns, spiral, optical illusion	4	10
4	Symmetry, Measurements, Hyperbola, Parabola, Proportion, Geometry, Algebraic patterns	Geometric, grid, symmetry pattern	5	10
5	Hyperbola, Parabola, Measurements, Proportion, Algebraic patterns	Spiral, symmetry patterns	3	6
6	Hyperbola, Parabola, Measurements, Proportion, Algebraic patterns	Geometric, grid, symmetry pattern	3	7
7	Symmetry, Measurements, Proportions, Geometry	Geometric, symmetry pattern	3	7
8	Symmetry, Measurements, Hyperbola, Parabola, Proportion, Geometry, Algebraic patterns	Mix patterns	5	10
9	Symmetry, Measurements, Geometry	Spiral, optical illusion	2	6
10	Symmetry, Measurements, Geometry, Algebraic patterns	Mix patterns	4	10

3.3 Feedback analysis

Information on students' interest in Art and Mathematics before the activities was collected through their responses. For Art, 19% of students reported being extremely interested, 36% very

interested, 30% moderately interested, and 15% slightly or not at all interested. For Mathematics, 25% indicated they were extremely interested, 39% very interested, 31% moderately interested, and 5% slightly or not at all interested. Feedback analysis further revealed that 79% of students found the integration of Mathematics and Art helpful in enhancing their artistic creations, while 97% reported that this integration improved their understanding of mathematical concepts.

4 CONCLUSION

The analysis of both activities demonstrates that integrating creative art into the teaching of calculus can significantly enhance student understanding of mathematical concepts. The paired t-test confirmed that students' performance improved after engaging in art-integrated learning, directly addressing the objective of examining the impact of creative art on mathematics learning. In parallel, the design of artistic pieces showcased the effective use of mathematical principles in creative expression, highlighting the reciprocal influence of mathematics on art. Overall, the study provides evidence that combining art and mathematics not only strengthens conceptual knowledge but also fosters creativity, thereby fulfilling both research objectives. This study will be extended to include the Semester 2 Mathematics and Visual Art modules, which will help address the limitation of a small sample size.

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