Use of Mathematics in Costume Design and Construction

A Senior Honors Thesis

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for Graduation in the Honors College

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Introduction:

My journey at Brockport did not follow the typical mathematics major's path; as a student in the adolescent education program, I focused on topics of mathematical literacy, including conceptual understanding, procedural fluency, and mathematical reasoning. As an Honors student, I supplemented my learning experience by contracting courses in stage makeup and costume construction. This thesis combines what I've learned across the disciplines, and demonstrates the importance of teaching for mathematical literacy, and the benefits of recognizing underlying mathematical concepts and making informed decisions based on them.

Thesis:

Following my own creative process, I will observe and recognize the mathematics used during the project and explain how they are connected to the mechanics of sewing. By "creative process", I am referring to pattern drafting, draping, sewing, and tailoring. My "observation" will include a full video documentation of the process, accompanied by the following written component; math and sewing are both highly visual fields, and this work cannot be clearly communicated by either film or text alone.

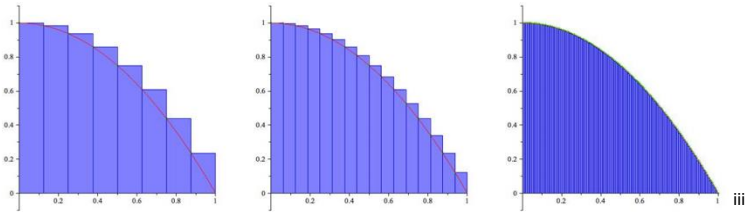
For each section of the creative process, the mathematics observed will be categorized as "explicit" to denote clearly observable math-specific concepts and terminology, and "implicit" to denote general concepts which may not initially be recognized as having mathematical properties. The techniques used will be categorized as "conventional" if learned from a professor or fashion literature, and common use in the industry, and "unconventional" if original or otherwise. Any new relationships discovered, in sewing or mathematics, will be recorded.

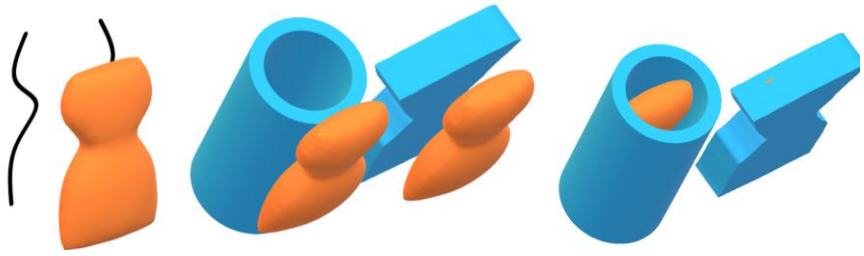
Below, the video is partitioned by timestamps, and sections are labelled to describe mathematics observed during that segment of the video. They are organized in chronological order of execution to preserve the progression of thought. I recommend watching the video in its entirety before continuing, and again while reading each section below.

Process:

Riemann Sums: 0:00 – 0:15

In calculus, Riemann sums are used in order to approximate the area underneath a curve using rectangles. As the width of rectangles used decreases, and the number of rectangles used increases, the sum of the area of the rectangles becomes increasingly closer to the actual area underneath the curve.[i] In sewing, seams create separations in fabric that allow for pivoting and precise placement of fabric in three-dimensional space, providing rigidity and angular control.[ii] The images below suggest that adding seams and creating paneling mimics the use of rectangles to approximate areas in two-dimensional space, but instead to approximate volumes in three-dimensional space. I used this information when constructing my paneled body shaping garment, in order to create a desired volume and shape to wear the costume over. The connection is implicit, and the technique is conventional.


[iii]



Projection: 0:15 – 0:29

In projective geometry, points and lines are transferred from one plane to another, by connecting corresponding points on each plane with parallel lines.[iv] The points and lines may be transformed, but when the lines between corresponding points are perpendicular to each plane, the resulting projection is an exact copy of the original shape. I used this information when creating a pattern based off a garment that already fit me well, to create an almost identical abstraction I could work from to make a new garment. The connection is implicit, and the technique is unconventional.

Symmetry: 0:29 – 0:48

In the coordinate plane, an axis of symmetry is a line such that the shape on one side of it reflects the shape of the other side, like a mirror.[v] I used this information when creating the main garment pattern and placed an axis of symmetry down the middle of the shape, in order to correct any mistakes made when tracing, and to produce an aesthetically pleasing, symmetrical garment. The connection is explicit, and the technique is conventional.

Triangle Inequality: 1:00 – 1:38

In geometry, the triangle inequality theorem states that the length of each side of a triangle is less than the sum of the lengths of the other two sides.[vi] I noticed a similar relationship while making patterns; when covering the same square footage with multiple pieces sewn together, instead of cutting one piece, the amount of fabric necessary is increased, due to the need for seam allowances. Also, the amount of thread used, and time spent cutting and sewing all increase with the number of sections pieced together. Shown in the image below, this is because the seam (red) bends the fabric, resulting in an angle being formed, pushing the joined pieces (black) off the plane that they would have created if they were not separated (orange). Therefore, reducing the number of pieces used to cover an area will reduce the cost of production, like how the shortest route is the most direct. The connection is explicit, and the technique conventional.

Surface Area, Volume, and Scaling: 1:38 – 1:58

The relationship between surface area and volume is positive, meaning that as the surface area of an object increases, so does the volume contained by that surface area.[vii] I used this information while creating my initial prototypes of my patterns, when I realized the prototypes were too tight. To increase the volume contained in the garment, while maintaining the shape, I traced a new pattern at a fixed distance outside of the original pattern. I noticed the similarities between increasing the size of my pattern and the geometric transformation of dilation, changing the size of a line on a graph.[viii] Though it

may seem common sense, that bigger patterns make bigger garments, there is specific mathematics involved in the process. The connection is implicit, and the technique is conventional.

Tessellation: 2:12 – 2:53, 5:52 – 6:03

In plane geometry, tessellation is the use of polygons to entirely cover a plane uniformly.[ix] In sewing, when using a patterned fabric, the goal is to align the cuts and seams of the fabric so that when the garment is completed, the pattern is undisturbed across the garment. Not only for maintaining pattern, but for consistent directional stretch quality of the fabric, and consistent reflective properties of the fabric. Having the shared properties in mind affects how patterns are shaped, and how fabric is oriented and cut. The connection is implicit, and the technique is conventional.

Units of Measurement: 3:18 – 3:43

Perhaps the most obvious use of math in sewing, and by far the most often applied is the concept of units and measurement; they are necessary to describe real-life distances, ratios, and every aspect of pattern making.[x] The connection is explicit, and the technique is conventional.

Algebraic Equations: 3:44 – 3:48

In algebra, an equation contains an expression of variables and constants set equal to another expression of variables and constants, with a ‘root’ value existing for each variable, such that the expressions are truly equal.[xi] In sewing, when trying to determine a

measurement of a certain aspect of a pattern, one can set up an equation with variables and constants, applying the same skills one would use when given a word problem in a middle school mathematics course; the ability to identify what is known and unknown in a situation, to identify relationships between them, to describe such relationships in mathematical terms, and then work through the abstracted form to solve for the unknown. The connection is explicit, and the technique is conventional.

Polar Coordinates: 3:48 – 4:05

In coordinate geometry, the expression of a point is given by the radial distance from the origin and the counterclockwise angular distance from the x axis.[xii] These coordinates are helpful when describing circular objects, and I used them while creating a circle skirt, which is to say, quite literally a circular piece of fabric with a circular hole in the middle. I used the reflection of one quarter circle three different times, on a folded square of fabric, to increase efficiency, and traced the curve using fixed radii. The connection is explicit, and the technique is unconventional.

Period and Amplitude: 4:06 – 4:56

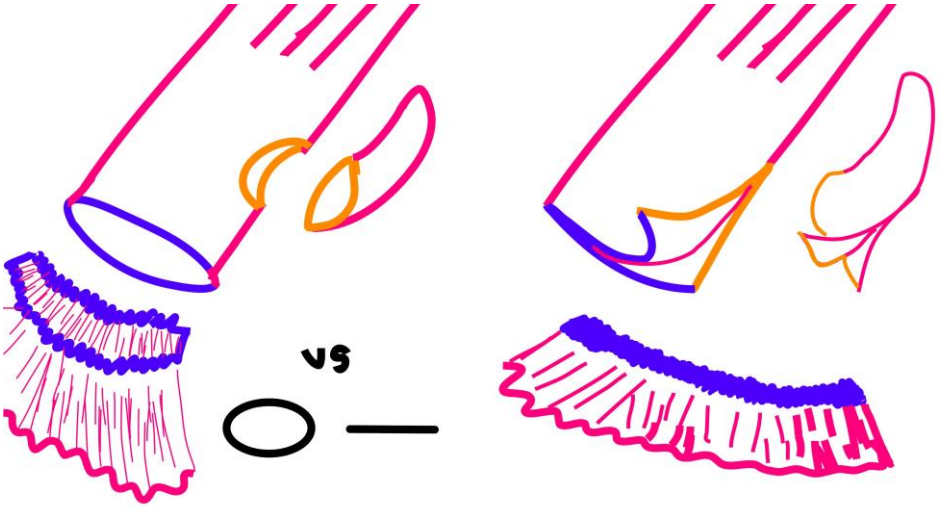
When considering a sinusoidal graph, the period is the distance between consecutive maximums/minimums, and the amplitude is the distance between a maximum/minimum and the midline. In sewing, threads pass over and under through fabric, causing the fabric to act as a midline for the sinusoidal path of the thread. Through this comparison, I realized the mechanics behind the width and length of a zig-zag stitch. These stitches are used to create seams that stretch with the fabric; pulling fabric around a straight stitch

would cause the thread to snap, since you are increasing the distance the stretchy fabric covers, but not adding enough of the rigid thread to cover the same distance. Sewing in a zig-zag fashion increases the amount of thread present per length of fabric stitched, providing a stretch factor to the seam. Therefore, decreasing the length of a stitch, and increasing the width of stitch increases seam elasticity. I used this in order to create a skirt that would cinch tight around my waist but would still be able to stretch wide enough to accommodate passing over the shoulders and hips while taking the garment on and off. This connection is implicit, and the technique is conventional.

Vertices and Pathways: 6:50 –

Equivalent paths between vertices, and how that is related to creating different strategies of arranging, pinning, sewing, and what order in which they happen, in order to reduce difficulty, time, and thread spent, and to produce more consistent results.

In graph theory, graphs consist of vertices which are connected by edges.[xiii] Two pathways are considered equivalent if there is a one-to-one correlation between all vertices and edges, and I used this when reordering the seams while creating gloves. When sewing the first glove, I ran seams along the thumb and closed the wrist, creating two circular seams (purple and orange, left) that needed to be attached.



This proved to be very difficult to sew, due to their size and circular nature. When making the second glove, I left the individual parts unsewn (purple and orange, right), and attached them to each other as straight seams only, which provided a much less difficult sewing experience. Changing the order of the seams reduced sewing over the same seam multiple times and allowed me to save time, effort, and thread. There are parallels between rearranging seams to increase efficiency and finding the path of least resistance in graph theory. The connection is implicit, and the technique is unconventional.

Findings:

Sewing	**Math**	**Explicit/ Implicit**	**Conventional/ Unconventional**
Darting and Seams	Riemann Sums	I	C
Garment Tracing	Projection	I	U
Pattern Making	Symmetry	E	C
Pattern Making	Triangle Inequalities	E	C
Pattern Sizing	Surface Area and Volume, Scaling	I	C

Fabric and Pattern Alignment	Tessellation	I	C
Measurements	Units and Measurements	E	C
Measurements	Algebraic Equations	E	C
Pattern Making	Polar Coordinates	E	U
Stretch Seams	Period and Amplitude	I	C
Seam Arrangement	Graph Theory	I	U

Conclusion:

No significant correlations were found between an implicit/explicit correlation and a conventional/unconventional method. Connections between mathematics and sewing technique were categorized almost evenly between explicit and implicit.

The purpose of this project was to show that many mathematical components are incorporated into creative and applied fields like sewing, and to demonstrate how much of my costume's success depended on what I've learned in my math major. I doubt my costume would be as well fitted, consistently patterned, symmetrical, voluminous, or durable without the mathematical understanding I had. In conclusion, I would not have seen the connections between sewing and mathematics had I not learned about the process of teaching and understanding mathematics through my time in the education department. I also would not have had the opportunity to explore the connection between arts and sciences without being able to incorporate costume construction classes into my Honors learning experience.

Endnotes

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