The Pattern Project: Designing Educational Material Combining Fashion and Mathematics

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Abstract

In this paper, I introduce The Pattern Project, a creative STEM project that applies mathematical theory to shirt pattern design. I investigate the integration of high school mathematics theory into sewing pattern drawing and examine how this can be turned into an educational project.

Introduction

Conrad Wolfram describes his perspective on mathematics education in his TED talk, emphasizing the four essential steps: posing real-world problems, translating them into mathematical formulations, performing calculations, and interpreting results [9]. However, current mathematics education primarily focuses on calculations, a domain where computers excel, leaving students feeling disconnected due to the lack of real-world significance.

While real-world applications are emphasized in STEM education, mathematics often plays a supporting role rather than being the focal point [5]. To address this, I propose an educational project that focuses on a real-life application of mathematics, facilitating students in undertaking all steps around calculating by combining mathematics with creativity and hands-on making students gain a contextual understanding, fostering a sense of ownership over their work.

This design concept was developed as a Final Bachelor Project in Industrial Design. This paper delves into the incorporation of high school mathematics into sewing pattern making, presents exercises for pattern drawing, and the outcomes of two user tests. The final design introduces the Pattern Project, proposed as an educational initiative for a Dutch STEM course called NLT (Nature, Life, Technology) [8].

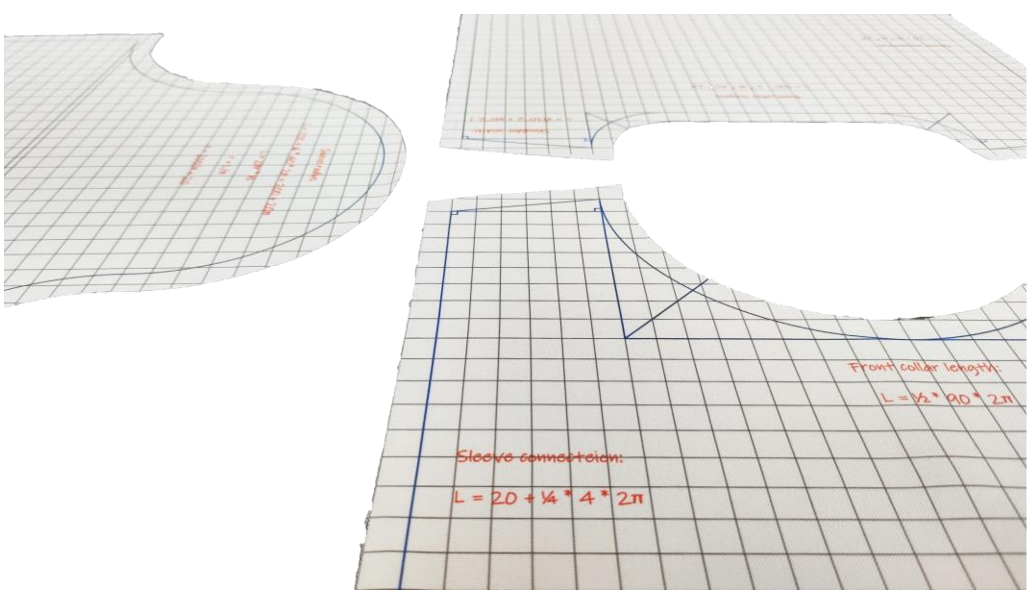


Figure 1: *Geometry in the sewing pattern of a shirt*

Related Work

Other research on mathematics in sewing patterns has been conducted. For example, in [2], the authors describe explorations of more complex and curved sewing patterns to create interesting sewing curves. This paper is inspired by [3], which focuses on developing spheres with curved edges within the context of garment making. Subsequently, the authors expanded on this concept with digital models to create more close-fitting garments [1]. Additionally, in [4], Feijs and Toeters describe how a Mandelbrot fraction is utilized to design a garment, where the sewing pattern shape is also influenced by this algorithm.

A common thread among all these papers is the use of mathematics to ensure that two pattern sides have different shapes but the same length. However, their explorations primarily aim at making patterns more complex. Given that the focus of my work is more on educational purposes rather than aesthetics, my goal was to simplify the sewing pattern.

A similar educational project conducted at an open school in Denmark involves a skirt-making project for girls. They acknowledge the importance of mathematics in sewing, but the mathematical focus mainly revolves around transitioning shapes from a 2D to a 3D perspective [6]. Unlike this paper, they derive shapes from instructional patterns rather than drawing geometric shapes.

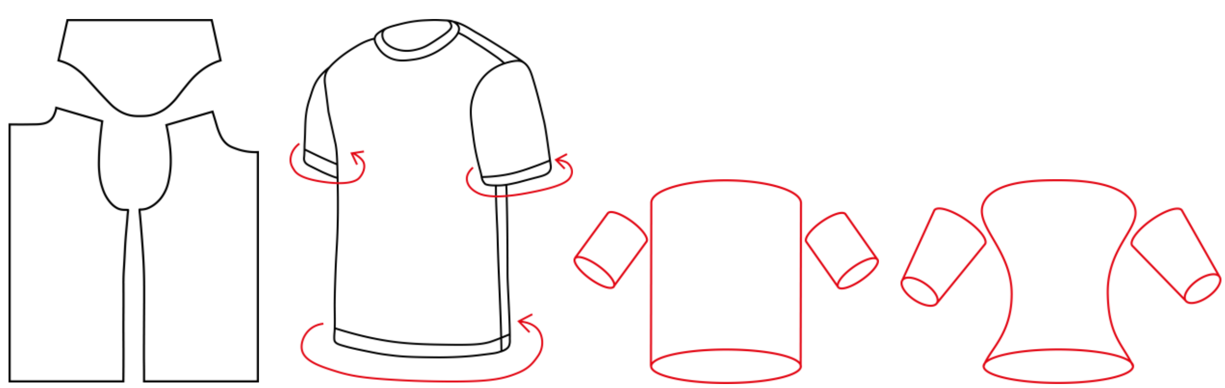
Design

I started with an exploration to identify a high school mathematical theory applicable to shirt patterns. After summarizing the content from the first three years of a Dutch high school mathematics book, I categorized the topics into four groups: Algebra, Geometry, Powers and Fractions, and Statistics.

Recognizing the visual aspects of Algebra (graphs) and Geometry (shapes), I specifically focused on these two categories. My goal was to explore whether it was possible to create a shirt solely utilizing elements derived from these mathematical theories at the level of the first three years of high school.

Shirt pattern

An example of a basic pattern of a shirt is given in Figure 2(a), which I analyzed abstractly. A shirt needs to cover three cylindrical shapes; two arms and a torso. To make rectangular pattern pieces that cover those parts, it is necessary to know the circumference of those parts to determine the width of that pattern piece, as shown in Figure 2(b). On top of that, the desired length of the sleeves and the shirt influences the height of those pieces. Instead of creating rectangular pattern pieces that turn into cylinders like Figure 2(c), those parts can also be (partly) cone-shaped or rounded, as shown in Figure 2(d).



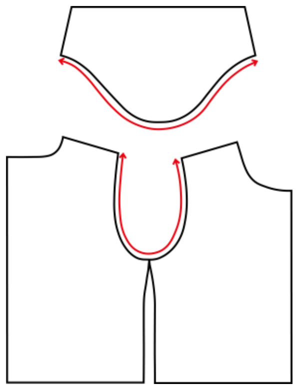
(a) (b) (c) (d)

Figure 2: *Analysis of a shirt sewing pattern: (a) a basic shirt pattern, (b) 3 cylinders found in a shirt, (c) schematic representation of cylinders, (d) schematic cylinders cone-shaped or with curves.*

A very mathematically interesting part of the pattern of a shirt is the attachment of the sleeve and the body. For the top side of the sleeve, French curves are often used. The higher the curve on top, the more angular the sleeve. French curves are not part of high school mathematics theory, but in many t-shirt patterns, this curve looks very similar to a parabola. Circle shapes can also be used to make this part of the pattern.

The part where the sleeve is attached to has a different shape than the top of the sleeve but needs to have the same length to make the pieces fit together, as seen in Figure 3(a). There are a lot of possibilities here for interesting mathematics questions.

The neckline can be any shape, but it should fit around the head, and it cannot be broader than the width of the shoulders. The circumference of this shape should be determined for adding a collar to this hole. Options for collars where the length can be calculated are presented in Figure 3(b).


(a)

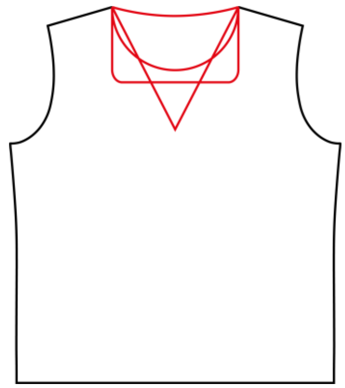

(b)

Figure 3: *Opportunities for mathematics exercises: (a) Fitting the sleeve, (b) Designing a neckline*

Algebra

To make a shirt using only algebra, I turned all shapes of the shirt pattern into linear graphs, or parabolas. The linear graphs are made by filling in two coordinates in $y = ax + b$. For the curved parabola edges, the width and the height of the parabola were determined. This can be turned into the coordinates of the top and one intersection point with the x-axis. These 3 values can be put into the following formula to get the formula of the parabola. This formula may appear somewhat intimidating to students, and its usage would depend on their proficiency in mathematics. However, if the y-axis is positioned at the center of the parabola, the formula becomes much simpler.

$$f(x) = ax^2 - 2aT_x x + T_y + a\,{T_x}^2$$

with $a = -T_y/(S_x - T_x)^2$, T_x= x coordinate of the top of the parabola, T_y= y coordinate of the top of the parabola, S_x= x coordinate of one intersection point with the x-axis.

It is possible to also make sleeves with a different parabola shape, with the same length and the arm hole of the body. To determine the length of a graph, integration calculations are needed and this is not part of the theory of the first 3 years of high school mathematics. Because I wanted to stay in this scope, the final algebra design is sleeveless.

For the fabric prototype, centimeter squares are sublimation printed on the fabric, and the parabolas are drawn onto the fabric by hand. For clarification on the mathematics used, the formulas are attached, which can be seen in Figure 4.

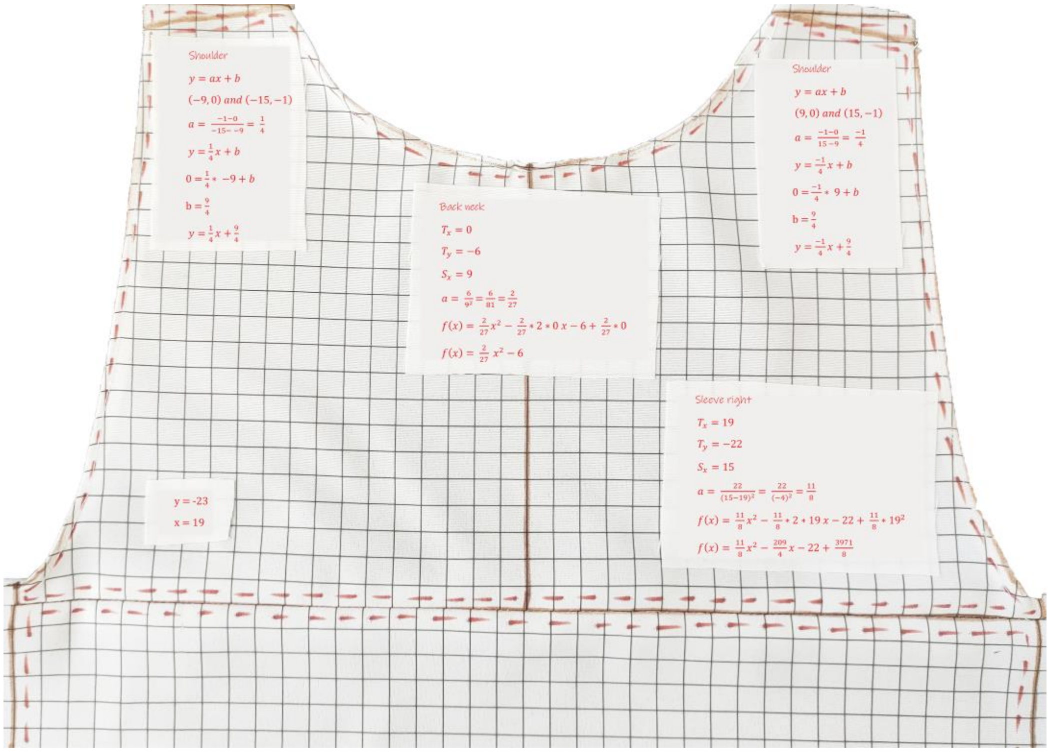
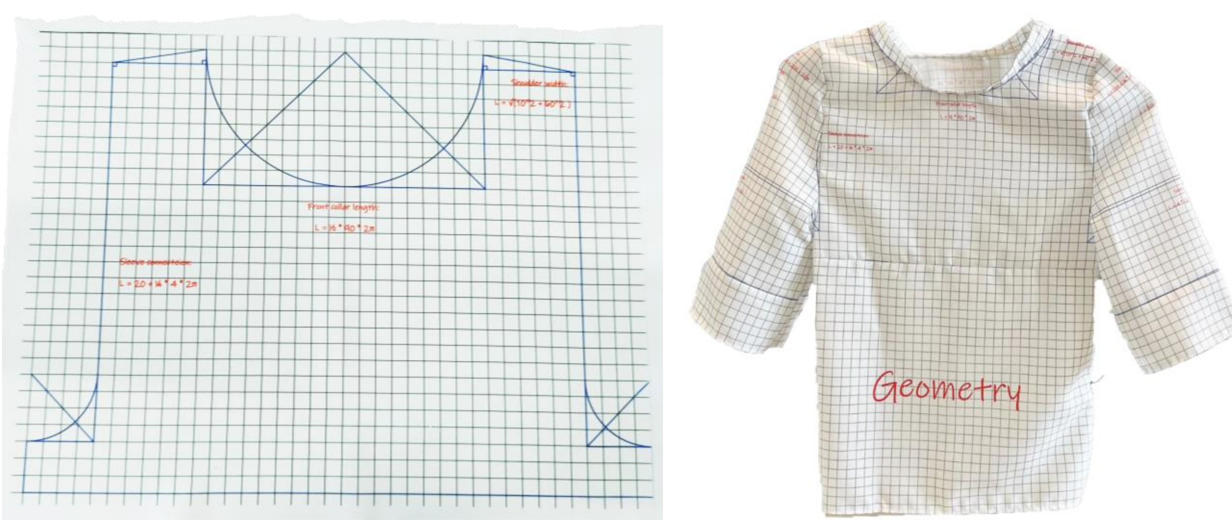


Figure 4: *Algebra shirt: Final prototype with formulas added*

Geometry

For a geometry shirt, I turned the pattern of a shirt solely into straight lines and (parts of) circles. Many calculations can be performed to determine areas and circumferences for the parts and necklines can have different geometric shapes. Unlike the algebra shirt, the geometry shirt sleeves can be drawn with the known mathematical theory. The armhole has the shape of a straight line with a quarter of a circle. The top of the shirt got the shape of 4 quarters of a circle shaped like a curve. The radius of this circle is determined by equalizing those lengths. For this prototype, the full pattern with the formulas is sublimation printed on the fabric, like in Figure 5(a). The final shirt is presented in Figure 5(b).



(a) (b)

Figure 5: *Geometry shirt: (a) Sublimation printed pattern, (b) Final geometry shirt*

Conclusions of the Design Exploration

Algebra versus Geometry: Geometry provides the means to calculate lengths and circumferences, which are crucial for aligning patterns and ensuring consistent edge lengths. I couldn't make sleeves using algebra only, because calculating the length of a parabola, falls outside the current mathematical capabilities of my target group. On the other hand, algebra is often perceived as more abstract and theoretical. Geometry is often already visually explained, which creates a bigger need for algebra to be taught practically. I decided to proceed with geometry. Because this project is relatively new, I wanted to start creating this project with the mathematics branch that allows the most creativity and flexibility.

Sublimation Printing: Printing pattern paper directly on the fabric turned out to be an interesting technique (Figure 6). It allowed the patterns to be directly drawn on the fabric, instead of tracing real pattern paper. However, drawing on fabric is not so precise because of the material's flexibility. A possible solution for this could be to stiffen the fabric temporarily. Drawing patterns digitally and printing them on the fabric is also an option, but this takes away the hands-on tangible exploration of the shapes. In the user tests, different material usage is tested to explore this further.

A3 pieces were utilized for drawing patterns due to the limitation of the common type of sublimation heat press, which could only accommodate this size. However, it resulted in the shirt being slightly too small. It is better to use A2 pieces and thus achieve a standard-sized shirt.

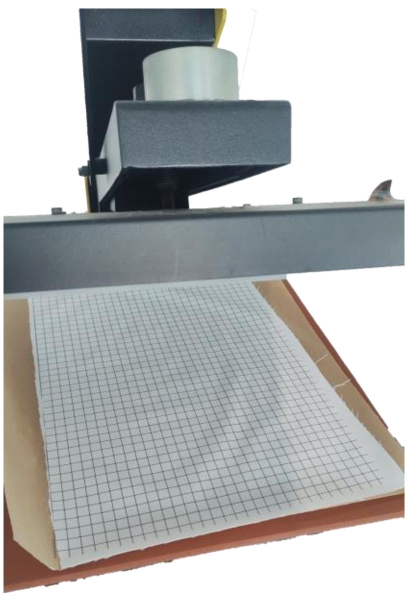


Figure 6: *Sublimation printing centimeter squares on A3-sized fabric*

Education Material

The next step in this project is turning my explorations into an exercise booklet for students. My vision for this booklet is inspired by Dan Meyer, who is a mathematics education creator at Desmos. In his words, 'What problem have you solved, ever, that was worth solving where you knew all given information in advance? Or you didn't have a surplus of information and you had to filter it out or you didn't have insufficient information and you had to find some' [7]. Many present-day exercises give only exactly the right amount of information and even show example questions that students can copy. He worries that students don't learn to deal with real-life problems this way.

One of my goals in this project is to create a connection with real life and his suggestions create more realistic problems that could occur in real life. Meyer suggests using multimedia, encouraging student intuition, asking the shortest question you can, letting students build the problem, and being less helpful.

I think guidance is necessary for starting questions to get familiar with the possibilities and expectations, but every topic should end in a structure more based on Meyer's suggestions, where students are encouraged to gather the right information and methods themselves. The booklet, created with this vision, consists of 4 parts: Introduction to patterns and exploring existing clothing, measuring shirt sizes, calculating and drawing patterns, and suggestions for further creation and exploration. The exercises are gradually getting more open-ended and the questions are getting shorter.

The booklet is improved twice based on test results described in the next chapter. Two versions of the final booklet are presented in the supplement. The Dutch version is used to conduct the user tests and the final version is translated to English.

Tests

This project underwent testing twice at various stages of the design process. Initially, the test was conducted with a group of Industrial Design students. Apart from gathering feedback from the students, I also tested different materials and construction possibilities. Subsequently, based on the test results, the assignment booklet was refined. With these adjustments, another test was carried out with high school students. After this session, I also interviewed the teacher. The table below describes both tests, and pictures of the tests can be found in Figure 7.

Table 1: *Overview of user tests.*

	Test 1	**Test 2**
Number of participants	N=9	N=10
Age range	21 –24	14 –17
Educational background	3rd or 4th year Industrial Design students	VWO 4 class with NLT course in their course package
Length of the session	2 hours	2 hours
Evaluation methods	Observations by the researchers and a second observer Different materials and construction techniques were given to different people Open-ended questionnaire	Observations by the researcher and the teacher Interview with the NLT teacher User experience questionnaire Open-ended questionnaire

(a) (b) (c)

Figure 7: *User test: (a) Measuring, (b) Drawing, (c) An unfinished shirt design.*

Test Results and Conclusions

Booklet improvement

The assignment booklet underwent two rounds of improvements based on participant feedback, focusing on enhancing language consistency and providing more detailed illustrations aligned with the descriptions. Two versions of the final booklet (Dutch and English) are presented in the supplement.

Motivation and engagement

In both tests, participants demonstrated high engagement, often exceeding the designated time slots or returning during lunch breaks to complete their shirt designs. The high school teacher confirmed a positive and vibrant atmosphere, highlighting student motivation and active participation. He explained this by highlighting the significance of real-life applications in mathematics exercises, emphasizing the value of practical lessons that empower students to explore and discover on their own. In his words, ‘It's not the teacher demanding the circumference of the circle; it's the sleeve that asks for it.’

Fashion show

Participants were visibly proud of their creations once the shirts started to look realistic. Most groups showed their design to others. These observations suggest that it is worthwhile to organize a fashion show at the end of this module, to present all the designs.

Real-life material usage

Participants preferred the most realistic sewing process and materials. In this case, drawing on pattern paper, tracing on fabric, and sewing with a sewing machine. While the NLT teacher acknowledged potential challenges, such as schools lacking sewing machines or technical skills for teaching sewing, he considered these issues solvable.

Options for Future Work

NLT module

Clothing, as a topic, goes beyond the realm of mathematics. The life cycle of a garment, from raw material to disposal, is inherently interdisciplinary. The NLT association requested that I create an interdisciplinary module about textiles and fashion, integrating mathematics with biology, and chemistry, and addressing societal and environmental challenges. This association currently oversees 229 schools that offer the NLT course and have the option to select modules from the collection of NLT [8]. The textile module will be designed for the 'onderbouw,' encompassing the first 3 years of Dutch high school with students aged between 11 and 15 years old.

Scaling up

This module could also be an opportunity for a scaled-up study. Following more participants over a longer period could give us more information on the long-term impact of the curriculum. Will this practice improve the mathematics skills and knowledge? Will the student's attitude towards mathematics change? Furthermore, The NLT course is currently in The Netherlands but another possibility for future work could be to discover different contexts. For example, it could be interesting to do this project with students in different countries.

Integration of other technologies

Throughout the project, various technological integrations have been explored and discussed, including sublimation printing, projecting patterns onto fabric, laser cutting fabric, and 3D printing of fabric. Although most schools currently lack access to these technologies, the exploration of these advancements is viewed positively as they offer expanded possibilities for creative exploration.

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Finally, I want to offer a very special thank you to my study coach, Loe Feijs, for the coaching sessions, the valuable feedback provided throughout the entire process and to encourage me to submit this paper to the Bridges conference.

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