# Re-Crafting Mathematics:
## Early Lessons Learned at the Intersection of Textile Crafts and Math

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## ABSTRACT
This paper describes Re-Crafting Mathematics, an investigation of the intersection of traditionally feminine crafting practices and mathematics. This project is an extension of our previous work in learning and education through design, craft, and computation. One key goal of this work is to explore the meaningful implications of traditionally feminine crafting practices in Science, Technology, Engineering, and Mathematics (STEM) learning environments so that we may address the underrepresentation of women and girls in lifelong STEM learning.

## Categories and Subject Descriptors
K.3.0 [**Computers and Education**]: General

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Design, Theory

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Creativity, Community, Computation, Diversity, Education, Inclusion, Females, Learning Environments, Making, Mathematics, Participation, Patterns, Spatial Reasoning

## 1. INTRODUCTION
Greater awareness of the female minority in STEM fields [2] has led to a variety of inclusion initiatives in formal education. Such initiatives aim to create learning spaces in which women and girls are comfortable to engage in computational practices. However, the importance of hands-on, interest-driven learning and the value of community and sense-of-belonging are often overlooked in the creation of new learning environments. In addition, many of the teaching tools used in STEM instruction are often implicitly male-gendered (e.g., traditional circuitry learning kits with wires, bulbs, and bulky batteries [6]). In particular, math instruction suffers from an over-reliance on abstract and hypothetical problem-solving that does not connect the mathematical concepts to meaningful, real-world relevance.


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Rooted in the theoretical tradition of Papert's constructionism, which posits that learning occurs best when learners can create personally meaningful, shareable artifacts [1], [4], we turn to the domain of traditionally feminine crafting practices - such as knitting, crocheting, sewing, weaving, and quilting - as an underexplored avenue for concretizing mathematical instruction. These crafts require a range of mathematical thought processes. For example, a successful purchase of materials needed for a textile piece hinges on accurate estimation by the maker. In addition, the deviations from pattern measurements may require the ability to manipulate fractions and proportions. Here, we narrow our focus to ongoing ethnographic studies in the areas of sewing and knitting. We present a synthesis of observed and hands-on learning experiences. We highlight compelling observations in formal and informal learning spaces, and communicate the potential for future development of teaching tools based on the emergence of mathematical concepts in sewing and knitting crafting practices.

Descriptions of our learning experiences underscore the importance of hands-on instruction in crafting. Further, our observations suggest that the sense-of belonging in crafting communities aids in the teaching and development of new skills, helping to motivate makers to continue to engage in crafting activities.

In conclusion, we issue a call for hands-on, interest-driven, inclusive, design-based teaching methods, which are rooted in our experiences, and which allow mathematicians, makers, and educators to better theorize the intersection of craft and computation in formal education institutions.

## 2. EMBEDDED ETHNOGRAPHY
The first phase of this research comprises a series of detailed cognitive ethnographies of local crafting communities [7]. We began by embedding ourselves in local craft communities. Through detailed field notes, interviews, and involvement in the communities' everyday activities, we have become part of the communities in which knitting and sewing exist as artful practices. Our embedded knitter spent time in a local yarn shop that, besides selling all the implements needed for knitting, crochet, weaving, and spinning, also offered classes in these crafts. The embedded sewer investigated a community that specializes in upcycling and mending of clothing in the local public library, as well as a new teen space in that same library where sewing is just one of the many crafts that teens engage in.

Our field notes on these spaces include details of crafter skill level and personality, language used in the crafting instruction, inferences of the use of gesture in teaching, and notes of the space in which the learning takes place. These observations focus on individual crafters as well as collaborative groups of crafters. The ethnographers are careful to note details of the space that facilitate the learning experience and lead to the development of a relationship between individuals in the space, such as the location of instructor and student in relation to each other.

An important component of the embedded ethnographies is to actually engage in the craft. Both ethnographers started as novices in their chosen craft, so we could observe firsthand how the learning curve works in these spaces, and what kinds of valued disciplinary content—especially with respect to mathematics—were necessary to successfully produce products of increasing complexity. The ethnographers were careful to document the value of mistake-making in skill acquisition as their own crafting skills developed.

The knitter began with a series of scarf projects that allowed for the development of technical skills. She has progressed to more-complex hat and garment projects, which include color work. Learning to knit projects of higher complexity enables her to combine her curiosity in code-like patterns with her interest in design and soft, fiber materials. Meanwhile, the sewer chose to sew cosplays—costumes of characters from media properties. She has created clothing items like a sailor collar, skirt, high-collared robe, hooded cloak, and shorts. Sewing cosplays is her way of exploring her interests in geek media and connecting sewing to youth culture, since the vast majority of cosplayers are teens and young adults.

# 3. EXPLORATION OF MATH IN CRAFT

In our study of sewing and knitting, we encountered many ways in which we had to apply math in a concrete manner in order to accomplish our project goals.

## 3.1 Estimation

Textile craftwork involves estimation at many stages in the crafting process. Prior to the initialization of a project, the maker must approximate the amount of material that must be obtained. In order to complete the project successfully, this material should be obtained at one time, as dye lots often change over time, and slight variations in color could disrupt the crafter's design for the piece. Many crafters develop a personalized style or trademark in their work, which can lead to variations in estimation. Such variations are often rooted in aesthetic preference.

Sewing: Because characters' outfits often do not look like ordinary clothing, cosplayers usually cannot simply buy patterns for them at a craft store and instead must use fan-created guides and patterns found online. For the cosplay involving a hooded cloak and shorts all made out of the same color fabric, the online patterns did not provide an estimation of amount of fabric needed. The embedded sewer had to measure her own body according to the measurements provided in the patterns, and then use that to calculate her own estimations, including seam allowance, of how many yards of fabric the pieces would require. This also showcases how important the mathematical skill of measuring is to sewing.

Knitting: The most accurate measure with which to measure yarn is in yards. The knitter must consider the weight of the yarn when making estimations about the yardage. For example, fine yarn is much lighter than bulky yarn and yields a greater number of stitches per inch. This means that a project made with fine yarn will require a greater number of yards of yarn. The embedded knitter chose to make pieces of slightly larger or smaller size than the size noted on the patterns she worked with. This design preference required the embedded knitter to use a different amount of yarn from the amount specified on the pattern. The embedded knitter learned to make accurate approximations based on yarn weight and project size.

## 3.2 Counting, Addition, & Subtraction

Knitting: Arithmetic operations are required in knitted craft, for the knitter must count the number of stitches in each row to ensure consistency and accuracy with respect to the pattern. 3-Dimensional patterns, such as hat projects, required the embedded knitter to use increase and decrease techniques in order to add or subtract the number of stitches in a given row. These techniques required the embedded knitter to call on arithmetic skills learned early in education.

## 3.3 Ratio and Proportion

Sewing: Sewers sometimes encounter patterns that do not fit their body size, and must use ratios and proportions to increase or decrease the pattern's size. For instance, when making the robe, the embedded sewer and her more experienced helper started with a shirt pattern the latter had made years ago. They had to enlarge it and add to it in order to create the effect of looseness that the robe required.

Knitting: To custom-fit knitted pieces to the individual, the knitter must be able to transform the pattern through the manipulations of ratios and proportions. For example, the embedded knitter chose a scarf pattern that called for lightweight wool, but she chose to make a larger scarf from chunkier wool. Knitters must manipulate ratios and proportions in order to determine the amount of yarn needed for the pattern so that the piece will be created with the desired fit or look.

## 3.4 Spatial Visualization

Sewing: Every sewing project that involves creating a piece of clothing involves envisioning what 2-dimensional fabric will look like when worn by a person in 3 dimensions. Sewing patterns are also on flat, 2-dimensional paper, and require 3-D visualization in order to understand them. An example from the sewer's experience is the first time she was instructed to sew something—in this case, a sailor collar—inside-out: she had to mentally envision what the collar would look like when it was turned right-side-out, so she could figure out which sides of the fabric would be outwardly visible.

Knitting: Like a sewing pattern, a knitting pattern is printed and shared on 2-dimensional paper spaces. However, knitted projects are often 3-dimensional. One example from the embedded knitter's experience is the hat project she began earlier in her knitting ethnography. She learned to view the hat pattern in 2 dimensions and then visualize the object in 3-dimsensional space.

Further, the embedded knitter engaged in spatial rotation of the knitted object when she imagined the knitted piece from different angles before completion.

### 3.5 Symmetry

Sewing: Most outfits are meant to be bilaterally symmetrical, so sewers want both the left and right halves of an outfit to be identical mirror images of each other. This often means folding fabric at the midpoint and drawing half of a pattern on the fabric, then cutting through both layers of the folded fabric so both sides will turn out identical. The embedded sewer had to do this numerous times in both the robe and hooded cloak cosplay.

## 4. OTHER VALUED DISCIPLINARY CONTENT

The embedded sewer incorporated content from disciplinary areas other than math when creating her cosplays. For instance, she included *science* and *technology* by sewing lights into her costumes with conductive thread, which our lab's previous work has shown to be effective for learning about circuits [5]. She was motivated to use new *high-tech maker tools* like 3D printers and laser cutters for the first time in order to create accessories and details for the costumes. Like any sewer, she had to keep in mind aspects of *aesthetics* and *artistry* in order to ensure her costumes looked pleasing to the eye. And because she had to interpret characters from media in order to create their costumes, she was also engaging in *literacy* practices. This shows the broad educational applications that are possible when other spheres are incorporated into textile crafts.

## 5. HANDS-ON LEARNING & MAKING

There is no way to learn how to sew or knit without actually engaging in sewing or knitting. It is an inherently hands-on process. It often involves the creation of something specific, so the crafter sets a goal to create a concrete product that can then be worn and shared with others, fitting in exactly with constructionist ideals [1], [4]. To properly create sewn and knitted projects, crafters must attend to and accurately complete the math and other required disciplinary content. It provides motivation to learn this content that an abstract, school-bound lesson might not do.

Another aspect of constructionist learning that Papert [4] emphasized was the personal meaningfulness inherent in a product that a learner has constructed for herself. From our experiences and from others' experiences that we have observed, we know that crafters attach special meaning to the products they have made, even if they did not turn out exactly as initially planned. There is a sense of ownership and pride that cannot be derived from a mass-produced object or from an abstract math problem worked out on paper only.

## 6. INTEREST-DRIVEN LEARNING

Another goal of the Re-Crafting Mathematics project is to tap into youths' interests so that they become intrinsically motivated to pursue the craft and thus, learn the math involved. For instance, the embedded sewer pursued cosplay because otherwise, she would not have found sewing to be very exciting. Her observations of the library's teen space have revealed some burgeoning interest in crochet, knitting, and sewing. One fruitful avenue appears to be engaging the teens' existing interests in pop culture media. For instance, at a puppet-making workshop, most of the teens chose to create puppets based off of their favorite books, movies, and video games. There is also a significant group there that has either shown interest in or already engages in cosplay.

The potential of this is that while many youth, especially girls, feel alienated from the math they learn in math class [3], if they are intrinsically motivated to pursue textile crafts and come to see the math involved in them, then they may come to identify more personally with math. Since textile crafts are a domain traditionally associated with women and femininity in our culture, girls may feel more invited into a math class that involves textile crafts. In this way, we hope this project will help to lead to more gender parity in STEM fields, as well as greater innovation in those fields as more diverse perspectives bring in unexpected ideas from textile crafts.

## 7. ROLE OF COMMUNITY IN LEARNING

In schools, where an overreliance on grades can sometimes lead to an overemphasis on individual performance and competition, the communal aspects of learning can often be overlooked. In textile crafting communities, however, the apprenticeship models of artisanal craftsmanship are alive and well. As the embedded ethnographers observed in their field sites, this type of learning often involves a more expert crafter working one-on-one with a novice to show them the ropes and help them debug mistakes.

Our observations in formal and informal learning environments show that hands-on learning scenarios, in which more experienced crafters pass crafting practices to novice crafters through spoken and gestured instruction, are beneficial for the creation of community in education and interactive learning spaces. The instructor can speak to the student directly while she *shows* the complexity of the crafting technique. The instructor can also observe the mistakes of the student in real-time, which encourages communication between the instructor and the student. Such observations point to the importance of community to effective communication practices between student and instructor in learning environments.

In addition, the modern era allows the expansion of crafting communities onto the internet. Knitting has social networks, like Ravelry, which allow crafters to post, share, and borrow patterns for garments and other projects. Similarly, cosplay would be much more difficult without the online guides and tutorials of those who have made the same costume before.

Community also provides a meaningful context, and thus, motivation to engage in textile crafts. If a teen's friends are making cosplay costumes and are going to have fun pretending to be their favorite characters at a fan convention, then that teen will likely be motivated to participate as well. In addition, handmade gifts given to family and friends are often viewed as more special, and thus generosity toward loved ones can be the community aspect motivating textile craftwork.

## 8. IMPLICATIONS FOR EDUCATIONAL PRACTICE

One goal of this line of research is to develop novel prototypes for teaching tools in STEM learning environments. So far, our experiences in the field have shown us the importance of hands-on, interest-driven, concrete learning, pursued in a context that values and is inseparable from the community. It has given us personal encounters with the math and other disciplinary content involved in textile crafts. To bring these lessons into the classroom, we will have to ensure that interest-driven, concrete making remains a priority. To retain the community aspect, perhaps expert crafters from crafting communities can be brought into the classroom, crafting circles can be established during after-school time for those who want to pursue it further, and social networking and internet resources can be utilized. As for the math-related content, some of it is inherent, but other parts may need to be scaffolded, such as by teaching students to fold fabric before cutting to ensure bilateral symmetry.

Ultimately, we see great potential in the use of textile crafts for the learning of math and other subjects, in order to make math learning more concrete and relevant than it usually is, to tap into students' preexisting interests, and to make math more inviting to girls.

## 9. ACKNOWLEDGMENTS

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Textile craft is used here These examples present mathematics research exploring connections as a means of making mathematics explicit. It transforms a mathematical between mathematics and textiles conducted by mathematicians who, idea into a material object in order to demonstrate proof of concept and within their research, may act as non-professional designers or crafters to facilitate the understanding of the textile craft, and simultaneously and perform their research through craft. As the connections between the gives insight into the underlying mathematics for textile practitioners. two 6. Anthony M., Reader in Mathematics, LSE, University of London; Math-ematics for Economists, Study Guide, University of London. 7. Robert Gibbons. A Primer in Game Theory.Â  The union and the intersection of subspaces. A transformation of coordinates under a change of a basis. 1, 27.3 â€“ 27.5, p. 757â€“770; 4, page 21 â€“ 30. Spark an interest in math with these hands-on math lesson plans! A subject that can be difficult to master, math is made fun with these lesson plans.Â  In this hands-on science lesson, your students will create their own plants to help them identify and remember the parts of a plant. 1st grade. Math.Â  In this interactive lesson, your students will learn to identify four elements of a fictional story: characters, setting, problem, and solution. 3rd grade. Math. The language of mathematics is the system used by a mathematician to communicate mathematical ideas among themselves. This language consists of a substrate of some natural language (for example English) using technical terms and grammatical conventions that are peculiar to mathematical discourse, supplemented by a highly specialized symbolic notation for mathematical formulas.Â  How to Say and Write Numbers in English. â€œAnglesâ€ Vocabulary. An angle equal to 1/4 turn (90Â° or Ï€/2 radians) is called a right angle. Two lines that form a right angle are said to be normal, orthogonal, or perpendicular. A pair of angles opposite each other, formed by two intersecting straight lines that form an â€œXâ€-like shape, are called vertical angles or opposite angles or vertically opposite angles. This article highlights lessons learned from the design and study of the visual computer programming environment, Scratch (Peppler, 2013a(Peppler, , 2013b, where youth came to see computer programming "like paper" because it allowed them to create whatever they wanted.Â  Drawing on over a decade of research at the intersection of the arts, creativity, and new technologies fromÂ  ReCrafting Mathematics Education: Designing Tangible Manipulatives Rooted in Traditional Female Crafts. Kylie A. Peppler. Melissa Gresalfi.Â  Our primary focus is on traditional crafts like textile, fiber, and needlework as we believe this research will lead to crucial advancements needed in math education. [more]. View project. Project.

Picture books about mathematics are the perfect cross-curricular tool to introduce your kids and students to complicated concepts and mathematical thinking. I made a list of my favorite math books to add to your library and inspire your childrenâ€™s mathematical minds. Now, you can make learning math fun with these 54 unique math books for children! Pete the Cat and His Four Groovy Buttons. Are you an instructor who wants to maximize your teaching and learning time with cross-curricular activities? Pete, the Cat, and His Four Groovy Buttons is an excellent book for students just learning about s See more ideas about Montessori crafts, Math, Montessori classroom.Â LEGOs are a perfect tool to use for math lessons! If you have not yet used them in your math activities, you definitely need to give them a shot! Then, take it a step further.Â  Montessori Basics: How Math Progresses Through the Levels | Hollis Montessori School, NH. You know your four year old loves their classroom and their work. You know their teachers are guiding them to learn early math skills. But what, exactly, does that look like? And how does it change as they get older? Textile craft is used here These examples present mathematics research exploring connections as a means of making mathematics explicit. It transforms a mathematical between mathematics and textiles conducted by mathematicians who, idea into a material object in order to demonstrate proof of concept and within their research, may act as non-professional designers or crafters to facilitate the understanding of the textile craft, and simultaneously and perform their research through craft. As the connections between the gives insight into the underlying mathematics for textile practitioners. two Collect and store your craft supplies so that you don't waste time searching for bits of string at the last minute. Tidy the classroom as you go rather than waiting until the end of the lesson. The children are bound to lose vital parts of what they're making if they have to contend with lots of bits of cut up paper on their desks. Integrate the tidying up as part of the language learning process with bin monitors saying â€˜Put your rubbish in the bin.' or â€˜Any rubbish?' When they've finished using the glue have the glue monitor say â€˜Put the glue in your pencil case.&apo...Â  Don't let the craft itself be the end of the learning cycle. Give the learners something meaningful to do with their object. This could be acting out a few phrases in English with a finger puppet or telling a story using a book they've made. See more ideas about Math activities, Math classroom, Kindergarten math.Â  Make a fun geometric shapes activity for hands on math. Explore geometry with simple materials for an early learning STEM activity kids will love. Math For Kids Fun Math Math Activities Maths Games Ks1 Math Art 1st Grade Learning Games Vocational Activities Activities For 6 Year Olds Easy Math. Learning with Cupcake Liners!