

Exploring a Computer Embroidery Swatchbook in a University Classroom

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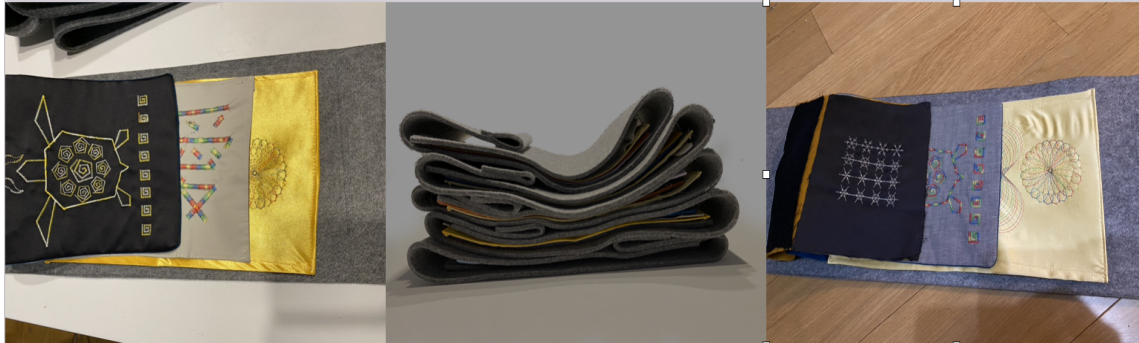


Fig. 1. “Learning with Turtles” 2020 Swatchbooks

We engaged university students in the creation of a swatchbook of computer-programmed embroidery designs, as a group project in a course, “Learning with Turtles”, about constructionist computational learning environments.

The swatchbook project is based on four framework elements: Turtle graphics (computational drawing) as a substrate for introductory programming, programmable embroidery, designing with the materiality of textile craft, and creating a group swatchbook (a soft book inspired by e-Textile Summercamp swatchbooks). While introductory programming with Turtle graphics has been widely explored in a variety of age groups and settings, and the materiality of textiles crafting, specifically programmable embroidery, has been gaining currency in learning environments, the introduction of a book adds a limited-edition craft-manufacturing component.

Based on student materials and participant-observer notes, we explore this combination as a prototype learning experience. Highlights of learning that were enabled by this tangible approach include students’ familiarization with material properties of textiles (fabrics, stabilizers, and threads) and their stitchability, approaches to debugging such as slowing the stitching processes to observe the control flow of a program, discussion and acknowledgment of the challenges of producing limited-edition multiples of swatchbook pages, and the diversity of aesthetics of “finishing” the pages in order to reveal, or conceal, the craft processes. We identify areas of promise as well as challenges for future iterations of related projects.

CCS Concepts: • **Human-centered computing** → **Interaction design**; *Interaction design theory, concepts and paradigms*; • **Applied computing** → *Media arts*; **Interactive learning environments**; • **Social and professional topics** → **Computing education**;

Additional Key Words and Phrases: computing education, programmable embroidery, design, turtle graphics

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1 INTRODUCTION

We engaged university students in the creation of a swatchbook of computer-programmed embroidery designs, as a group project in a semester course “Learning with Turtles”. The course’s overall topic was constructionist computational learning environments. We engaged the students in this project based on four framework elements: Turtle graphics as a substrate for introductory programming; programmable embroidery; designing with the materiality of textile craft; and creating a swatchbook inspired by an e-Textile Summercamp work artifact and process [13] to pose the challenge of creating a group-constructed, textile-based artifact. With this novel combination of introductory programming, design, and materiality, we collected participant-observer recollections and students’ written notes to explore this combination’s promise as an environment for computational learning, engagement with craft and materiality-based design, and engagement with a process that mirrors craft manufacturing.

This seminar-style, project-oriented class in Fall 2020 had external challenges. Because of Covid-19, some of us were on campus with the crafting machines and materials and some of us were in home spaces with only computers. The swatchbook was designed with synchronous and asynchronous communication, and crafted by the on-campus students, with individual pages designed by student pairs.

The student pairs were given the design brief of creating a page with the theme “geometry and nature”. The course participants and instructor co-created the design for the swatchbook itself, closely modeled on the e-Textile Summercamp’s swatchbook appearance[34]. We used the Turtlestitch programming environment, a variant of the Snap! programming language with turtle graphics adapted for controlling embroidery machines. Our commitment was to learn with and examine a programming environment designed to engage beginners yet provide a “high-ceiling” for computation. Each student pair had one on-campus partner (in a maker lab with a programmable embroidery machine) and a remote partner with access to Turtlestitch. The chosen theme of “nature and geometry” which allowed wide latitude for design with embroidery-related materiality, as well as the students evolving experience with turtle-geometry-based programming, to influence their page choices. The given page size was 18.5 x 33 cm, which allows use of most of the area of a large embroidery hoop.

While introductory programming with Turtle graphics has been widely explored in a variety of age groups and settings, and textiles crafting, specifically programmable embroidery, has been gaining currency in learning environments, the introduction of a brief to create a nine similar books together, which is a limited-edition craft-manufacturing component of the design process, adds a new dimension for students to consider design trade-offs involved in planning and improvisation, hand and machine work, quality, and customization. Additionally, the scope of design decisions and iterations required for a book design amplifies the opportunities to experience debugging in the physical realm and adapting crafting skills in an already hybrid programming-material project.

Highlights of learning that this highly tangible approach enabled include engagement with the close connection between material properties of textiles (fabrics, stabilizers, and threads) and their stitchability, approaches to debugging such as slowing the stitching processes to observe the control flow of a program, and acknowledgment of the diversity of individual students’ notions of what constitutes an acceptable level of textile finish in a product to share. This swatchbook received substantial short-term engagement from the broader university community at an end-of-semester exhibition.

Based on participant-observer notes on the project activities and material from student reflective reports, we highlight the experiences of design learning and computational learning enabled by this hybrid programming/material environment. We identify areas of promise for future iterations of similar projects such as scaffolding of future projects, involving students in feedback for the design of programmable embroidery environments, involvement of other textile and craft media, and constructionist embedding in multi-scale manufacturing, craft, and customization communities outside the classroom.

2 FRAMEWORK

We introduced this project based on four framework elements:

- 1. Turtle Graphics** Turtle graphics has had longstanding use in education. In this course, students engaged with Turtle graphics in two ways: “learning as beginners”, and “studying as scholars”. There is a long history of the computational learning environments and cultures surrounding Logo, Turtle graphics, and subsequent learning environments influenced by those platforms. As beginners *in* computing, students used Turtle graphics as a substrate for introductory programming – to learn the basic concepts of computational learning. As scholars *about* computing, students studied this history.
- 2. Programmable Embroidery** Programmable Embroidery involves the use of computers to control an embroidery machine. It is being actively explored as a domain for computing education, as well as in digital arts, and creative coding. It can be used to create soft circuits and e-textiles.
- 3. Materiality in Design and Craft** Materiality, as we use the term in this paper, refers to the notion that the design of an artifact, and the processes used to design it, are in part a consequence of the materials used to make it. Emphasizing materiality in design through a craft-related learning environment may expose nuanced relationships between crafting as an introductory computing and technology learning environment, and call for interpretations of maker culture. Further, our learning environment in China is embedded in a network of convenient sourcing, and a network of custom, semi-custom, and industrial manufacturing networks at all scales. In our program, creative coding and interactive arts provide a background environment within our lab facilities and for some of our students, interactive media arts is their academic major.
- 4. Swatchbook** A swatchbook is a booklet that contains samples of the raw materials, processes, or finished forms of paper, textiles, or other physical media. In our course, the group course swatchbook was a deliverable. It included student projects and it was a project in its own right, requiring design and fabrication (such as material selection and binding). The form of swatchbook we made has been explored within the e-textiles community. This project offered the students direct exposure to designing a similar artifact, exposing them to the work of an adjacent community and also giving them direct experience with craft manufacturing: the requirement to make a limited but challenging number of artisanal craft objects. For the instructor the swatchbook carries with it a legacy of “cultural knowledge transmission” that is used in both textile craft (hobby and artisanal work) and in textile industrial manufacture. Although scholarly emphasis on this latter point was not emphasized in the course studies, the direct design implications of making several, rather than one, units of a programmable embroidery project offered design challenges and tradeoffs to the students that a single, individual output might not.

2.1 Influences and Prior Work

Each of these framework elements draws from a number of prior works. The influences of each are discussed below.

2.1.1 Turtle Graphics. Turtle graphics has been a rich domain, sometimes called a “microworld”, for introductory programming since the 1960’s [31, 32, 40, 41]. Originally created as part of Logo language, the first programming language designed specifically for children, it has been used by an estimated XX million students and it forms the graphics substrate for successor languages for education Scratch, Snap!, and TurtleArt [4, 12, 28] as well as appearing as packages for many modern languages (e.g. the Python turtle library [20]) and in stand-alone drawing environments. Advanced topics and 3D Turtle graphics have been explored in [1].

2.1.2 Programmable Embroidery. Our students write programs in Turtle graphics using the Turtlestitch programming language. It has an online community site which allows remixing as well as creation of designs. It is a version of the blocks-based Snap! language adapted with embroidery-specific commands and it outputs embroidery files for a large class of consumer and professional machines. [21], Turtlestitch has been used in workshop and classroom teaching [15, 18, 23, 26, 27, 30, 45]. A combination of programming and digital embroidery conversion tools have been used in a university-level course on New Textiles [5, 7, 25]. The materiality of a controllable embroidery machine has been used in a game interface which result in textile craft results; the crafting aspect may influence game play [3, 8, 9]. Embroidery control systems allow exploration of computationally-based drawing and mathematics such as [8], or of creative development of e-textiles [2, 11, 39] Contemporary approaches to programmable embroidery made accessible to coders in Processing [17] and Python [43] have led to use in design education and creative projects (e.g. the work of Huw Messie [22]).

2.1.3 Materiality in Design and Craft. General education as well as computational and traditionally hands-on areas of inquiry, benefit from a material-rich curriculum, the availability of materiality-driven design exercises, and the materials themselves [6, 16]. In some circumstances, “the role of physical materials is not subordinate to the agency of the designer” [42]. For our students, the relative importance of the student as planner, the computational environment with its idealized drawing designs, and the agency of the sewing and embroidery materials themselves may provide conflicting or complementary constraints on what is created. We encourage students to balance design processes that stem from problem-solving, with tinkering (with computing, with hand-craft technologies, with machine technologies), and through materials and processes available within our fabrication lab and through external sourcing networks. Perspectives on these approaches may be found in [14, 19, 24, 33, 38]. In programmable embroidery, available thread colors (especially multicolor thread) was a popular element to explore and affected designs and satisfaction with the output. Available fabric materials also were very personal in appeal to students as well as affecting the ease of stitching, individualizing, and finishing pages. One student went on after this project to propose and finish another course project in which they obtained and tested a much wider range of fabrics than we supplied.

2.1.4 Swatchbooks. Contemporary swatchbooks for the exchange of technique within e-textile communities created between 2013 and 2021 [35–37] draw on the legacy of swatchbooks within textile and craft hobbyists, communities and industry. They are now being proposed as publication method for professional design researchers [37]. A relatively unexplored aspect of these swatchbooks is the limited edition artisanal manufacturing that is required. This brings challenges in both working time and design for individual creators, more broadly it echoes worldwide traditions of craft manufacturing which might be evoked, implicitly or explicitly, by this activity: “Craft manufacturing describes

the process by which skilled craftspeople produce goods in low volume, with a high degree of variety, to meet the requirements of their individual customers.” [44] While the direct forerunner to our swatchbook was for technique exchange, we also are inspired by adjacent goals such as community artifact creation and publication, and by adjacent types of soft books that resonate with textile crafts.

3 STUDENT EXPERIENCES

There were three student pairs: Fiona and Coco (figure 2a); Cole and Yuchen (figure 2b); Kyle and Jyotsna (figure 2c).

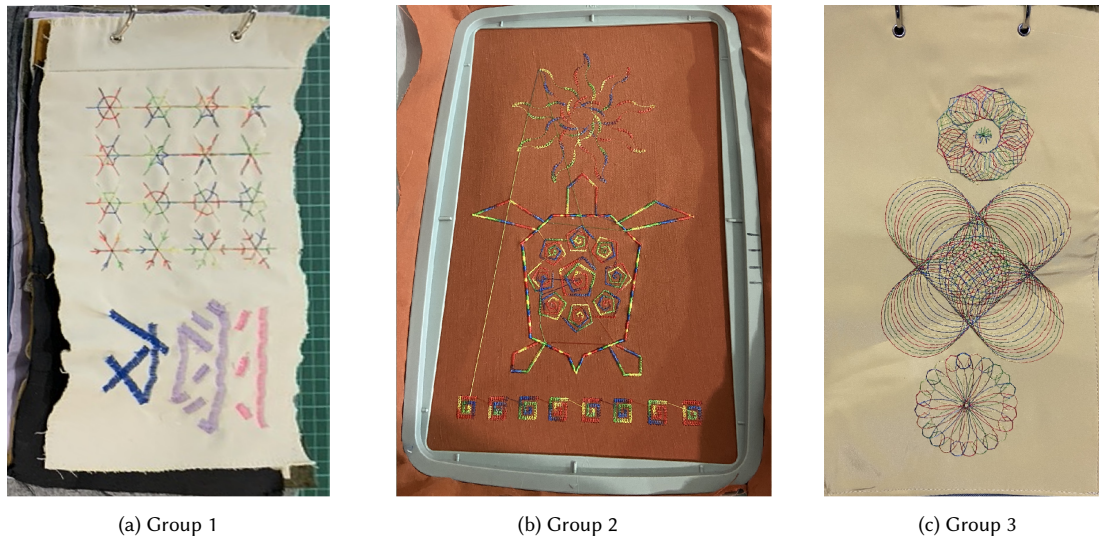


Fig. 2. The stitched page of each group

3.1 Turtle Graphics as a Substrate for Introductory Programming

Students in the course were either new to programming, or had previous introductory-only experiences with text-based languages in non-computer-science classes. The examples here from students’ project reports support the motivational and practical usefulness of the Turtlestitch environment in learning programming. The examples also illustrate use by students of metalanguage for *describing* programming choices.

Fiona learned programming from this project. She understood and articulated programming concepts, such as variables, in order to talk about her project.

Fiona wrote a program to embroider a traditional Chinese character 愛 (ai) that means “love”. She said, “I chose this project because I felt that the character would provide an interesting challenge, in terms of both the code and the geometry.” She expressed satisfaction with the experience of learning to program in this context, “This project was my first real, self-guided coding attempt, so I’m quite proud of it.” and went on to discuss progress in mastering the idea of parameterizing the size of drawing programs, by articulating the need for using variables (see Figure 3).

Kyle solidified learning about trigonometry through programming. Kyle’s experience in this project was that programming radically increased understanding of a math area previously learned in school. Working with embroidery and programming served as a motivation to understand trigonometric functions. He reported verbally that

Yuchen learned a variety of programming patterns. She also learned to program an interaction strategy. She compared several programming patterns (circular or line-segment spirals, for-loops with upward or downward iteration on the spiral side length, relative or absolute positioning of the spirals). To place the spirals, she learned a mouse-based interaction strategy.

Yuchen made modifications to her partner’s code. Yuchen and Cole faced a challenge in programming as partners to create an meshing design with parts done separately by each. Yuchen and Cole’s design process combined Cole’s sea turtle image with Yuchen’s geometric spirals. Yuchen’s comments indicate a form of code review for her partner’s work as they combined the design into a single program: “Using the jump-stitch block is the main technique to edit my partner’s code. Then, after machine stitching, the weeding process (removing unnecessary thread on a stitched pattern) is much easier.” (see Figure 5)

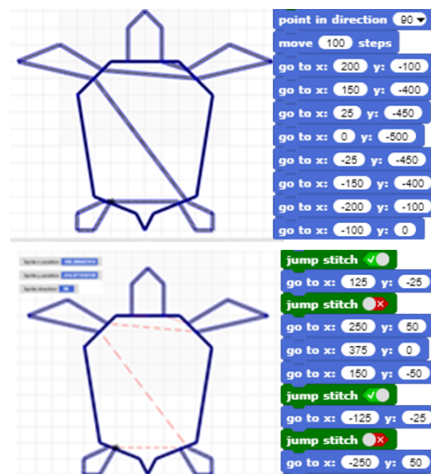


Fig. 5. Yuchen and Cole Collaborate on Coding

Debugging the program or debugging the embroidery machine? There is a choice of whether to debug problems with a stitched design at the *program* level or the *embroidery machine* that is may not be immediately apparent to students. Yuchen expresses the idea that the transfer of debugging concepts between the two domains was not obvious to her at first:

“After [embroidery machine] troubleshooting, is there nothing to do? No, you have to adjust your design. After the first draft of the turtle, I have no idea to fix [certain line thickness and size issues], because I was not thinking about editing my codes. When the instructor suggested editing the original code, I realized that editing the original code is part of iterations in the design process.”

3.2 Programmable Embroidery

Students’ reflections on having a physical embroidery machine as an output highlight relationships between this programming environment (a single turtle drawing the design on a screen) and the output machine characteristics (carrying a single thread line along a design stitched on fabric).

Here is an example of a Turtlestitch program with its screen rendering, and the corresponding stitching on a machine: (see Figure 6).

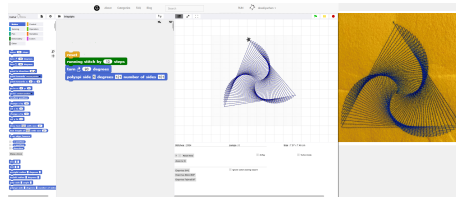


Fig. 6. Turtlestitch program layout

Students’ demonstrated a range of use of the embroidery output. Some used it at the outset of coding for short tests of partially developed designs, others stitched only after debugging almost their entire visual design. Note that the stitching time for students’ designs ranged from about 10 to 30 minutes and the number of individual stitches from a few hundred to several thousand. The machine’s speed of stitching can be slowed by a manual control.

Coco watched the machine stitching in slow-motion to understand the control flow of her program. It is striking that she used the materiality of *watching the machine itself stitch*, to trace the control flow of her program. “In the project learning process, we will meet the condition in which the commands used in a project are so complicated that we find it hard to understand. [...] I then took a single snowflake out from the original project and stitched it with the machine to see how it exactly worked.[...] I stitched it on embroidery machine with low speed to watch the trace step by step.”

Coco used stitching early in the design process. Stitching itself as the output was an early part of program debugging for Coco. “*After stitching the first whole program*, I found it difficult to distinguish among some snowflakes by eyes. So I looked closely at the program. Finally, I noticed that making the branches far from the center while increasing the length of them is probably the best alternative.” (see Figure 7)

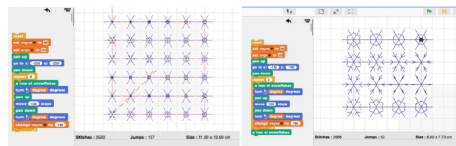


Fig. 7. Coco’s Turtlestitch embroidery debugging

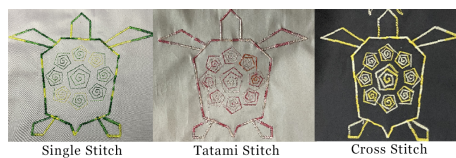


Fig. 8. Varying embroidery stitch types while debugging

Yuchen experimented with several programmable embroidery stitch styles. Yuchen tried many types of embroidery stitches for her prototype designs. She tried thickening lines of her spirals by changing their programming from running stitch to tatami stitch. However, that scaled down too much at the smaller sizes of her spirals. Moreover, it produced messy results on the reverse of the fabric, with no good adjustment possible for the thread tensions. She

tested all available stitch types and settled on cross stitch for widening the stitching lines in several of her motifs (see Figure 8).

Coco replaced randomness with orderly regulated change. Coco’s starting inspiration was a Turtlestitch community program that used randomness to produce a single, individualized snowflake on each program execution. She referred to “strengthening and personalizing” her design by changing the random drawing angles in the snowflake to regulated, iterated changes that could create a “borderless” pattern that “can be expanded forever”. By replacing randomness with regulated change, the “pattern as whole looks orderly and there could be numerous snowflakes with an overall regulation that can be traced.”

3.3 Materiality in Design and Craft

An intent for this project was for students to experience first-hand the resonances and challenges of learning a material practice along with computing. The instructor asked them to reflectively write about the experience including critically examining this combination as a learning environment. The materials they worked with included a variety of fabrics (from very thin wovens, knits, and felts to 5mm thick non-wovens), threads, stabilizers, adhesives, and tools. Techniques included machine embroidery, hand sewing, machine sewing, pressing/ironing (noting the difference between those), measuring and cutting, marking, melting, gluing, punching, pattern-making, and materials sourcing.

Fiona engaged with specific embroidery concepts: re-threading and layering. Fiona attended to *thread color change*. In computer drawing, there is no cost to changing color, whereas in embroidery, it can be important to plan a drawing order that is attentive to any thread color changes in order to minimize re-threading. “One final thing that I discovered during this project, especially towards the end, was in regards to the thread color that the character would be embroidered in. I’m definitely limited by the colors of threads available, but after trying to figure out how to use my own embroidery machine, I realized that I would have to re-thread the machine every time I wanted a color change. The benefit of this character is that each part is distinct and I could break it down into as many colors as I wanted to, and just stop the program when I wanted to change the thread color, but that certainly wasn’t a challenge I had considered when I coded the project.” Envisioning *future* programming extensions of the project, she wrote about embroidery concept of *layering*, “The first idea I had was to see about having the character be in the center of a heart, or even a filled heart, which would require coding the stitches to either go around where the character is or I would have to layer the stitches so the character is on top of the filled background.” (see Figure 9)



Fig. 9. Left: Snowflakes with silver thread Right: Snowflakes with multicolor thread; 愛 with re-threaded color changes

An experiment in aligning multicolor thread colors with design elements. A programmed drawing has predictable on-screen dimensions. Could those dimensions be matched with the lengths of colors on commercial multicolor thread to automate the colors of snowflakes? Coco instigated this investigation prompted by immersion with both media at the same time. Coco discusses trying to match the *output* properties of the thread with the

programming. Her reporting on the experiments is detailed. She measured the length of a dye run of color on the threads, and mathematically calculated the programmed stitches of her design that would fit that length. However, in real-world materiality, she discovered three different factors that prevented that abstraction from working: small and unpredictable variations in machine jump-stitches, imprecision in dyeing pattern of the threads, and very short lengths of dye placement on the threads would necessitate minuscule snowflakes (see Figure 9). Her in-depth and constructive involvement with this with this fostered a discussion in our lab of machines and materials we could invent to make this possible...perhaps a machine that dynamically colors the thread entering the embroidery machine?

A journey with thread leads to design serendipity and satisfying results. Because of Coco’s extensive and systematic experiments with multicolor threads, she was on a form of “adventure with materials”[33] that led to new and satisfying designs for her project. Although thread could not be controlled closely enough for a correspondence of *one color* with *one snowflake*, she found that the systematic beating of multicolored threads’ sequence with the regularity of the programmed design led to visually pleasing patterning. She created her own terminology for this: a *noticeable circulation*. Her experiments also led her to try many single-color threads, and she found that unusual colors such as silver could especially attract a viewer’s attention and curiosity about the design. Finally, she chose to make some of the swatchbook pages with each technique.

Students engaged with many material factors in machine embroidery practice. Yuchen’s written project report devotes several pages to systematically describing and illustrating the material elements of machine embroidery practice that she tested. She details the types of fabrics, threads, and stabilizers, and concludes “Smooth thread performs perfectly as top thread but is not so good as the bottom thread. Different styles of stitching fit different tension force.” Even after testing individual parts of a design, putting them together is yet another material practice. “Although there was already considerable testing and designing with embroidery stitches such as the *tatami* and *cross-stitch* lines, the material constraints come to the fore when stitching all the designs together.” Finally, recognizing types of bugs and debugging in the material world is a skill. A figure from her report shows top and bottom thread tensioning bugs, accompanied by a reminder to observe both the front and back of the stitched piece (see Figure 10):



Fig. 10. Variety of stitch tension problems

Acknowledging what happens. Students articulated that the combination of computed embroidery and its output was not aiming toward idealized solutions, or should always go smoothly. Yuchen notes “Some of the challenges [] fixed by redesigning and coding. However, there are many other issues that could not be fixed by design; usually these issues are caused by the mechanism of the embroidery machine, thread quality, accidental stoppage, and shortage of the threads. Every issue appears on stitched pages. After I finished all 9 copies of the stitch pages, I has broken 8 needles at least, and used up 10 bobbins of bottom thread.”

Acknowledging that solutions to problems are sometimes ad-hoc. Students acknowledges that fixing bugs in a combination environment was not always going to be fixed through programming, nor best practices in choosing materials, but by hand-work intervention as part of the final combination. For example, “After a large enough amount of stitching, I could finally tell some imperfect stitches are caused by whatever reason, and how to fix them. In one of

my works, there were several stitches that were very loose. So, I just removed these stitches and use the return button on the machine to re-stitch that part.”

Building a materials library for future students. Kyle’s relationship with the materiality of fabric and embroidery in our course extended beyond the swatchbook project. For his later individual course final project, he followed up with a related project to test many more machine embroidery/fabric combinations and create a guide for future users. The swatchbook project had engaged his interest and affinity for its the tangible craft, art, and fashion-related components. For that final course project, he visited a wholesale fabric market and obtained a wide variety of test fabrics. He then tested several embroidery designs while varying thread types, tried fabrics as stabilizers, and tried fabrics with no stabilizers. This resulted in a pictorial project aimed at helping users in later semesters choose materials and techniques. He did not choose to create a tangible swatchbook of these experiments; rather he created a “visual guidebook” slide show that showcases each experiment with material specifications and comments (see Figure 11).



Fig. 11. Visual guidebook selected slides, images c.2020 Kyle Brueggermann

3.4 Swatchbook Design and Making

Our brief was to create nine books (one for each student plus extras for the program and demonstration purposes).

The instructor made a first draft of a swatchbook based on photos from the E-Textile Summercamp site[34]. Each team’s page prototypes were placed on a ring binder in a prototype wrap-around book cover made from a thin felted wool before the detailed group design began. The swatchbook-making experience particularly engaged our group experience with the cultural and economic context in China for small-quantity sourcing.

Students learn the difference between one and many. At the outset of book design (and during most of the page design) students were yet to completely encompass the expanded effort and design criteria for producing a limited artisanal edition rather than a single artifact, we began to discuss these issues during our lab time as we experimented with the technique and time it would take to install each type of closure, as well as their appearance and feel.

They adopted the prototype’s overall “roll-it-up” shape, decided that the interior cover should hide the pages which could let readers feel a sense of mystery about what is in the book, that the closure should wrap over that page, and that the pages should still punched and be held by a binder ring.

Students consensus was that the prototype material was too soft, and sought out a thick (5mm) synthetic wool felt by sourcing from industrial textile suppliers through an online app. To obtain a reasonable tradeoff between cost and convenience, students negotiated with the supplier for a non-standard shipping quantity.

Yuchen’s documentation reported that they attended carefully to testing and placement of the snap closure. It took multiple prototype tests to all of: a sleek appearance for hiding the snap, an affordance[29] for the user’s hand to open the book, and a placement where the snap attachment was robust enough for the force required to unsnap. Other details also required testing to make a design and process viable for making nine copies: the method of attachment for the closures and binder (glue and hand-sewing were tested), the type of glue (wood glue and hot glue were tested). The amount of glue needed testing, as using too much was found to foul the mechanism of the ring binder, and to dirty and even to break the large snaps. With all the decisions tested and debugged, the book cover dimensions were finalized to a 96cm * 22cm rectangle.

The great felt anisotropy discovery. After the selection of the cover fabric, we found that the material, which as a non-woven was expected to be uniform, could be stretched easily horizontally, but is harder to stretch vertically. We made two test pieces. After several times folding pieces, the vertically cut one was stiff and developed folding marks, whereas the horizontally cut piece conformed smoothly to the book shape. Thus we decided to cut every book cover horizontally from the raw material.

The great cutting problem. It seemed as though it would be relatively simple to cut nine to twelve large rectangles from the thick fabric. We made a paper cutting pattern. Yuchen documented experimentation with cutting from the pattern: “Every time I wanted to use a tool to cut the paper, I tested the tool to understand how to use it to cut a perfect line on paper. However, the wool fabric is so different from paper; I could not cut a straight line on the wool raw material.” We tried a laser cutter (the material surprisingly produced fumes that our filtration could not handle), a rotary cutter, a utility knife, and high-precision tailor shears. In each case, the edge of the book cover was not straight at all. “I feel I was wasting materials, because the edges of the book cover are so bad. After brainstorming, we decided to ask the vendor of this wool raw material if they could cut for us. Luckily, the vendor could do this for us.” Thus we purchased a new batch of 5mm fabric, with custom pre-cuts negotiated with the vendor by the student (see Figure 12).



Fig. 12. Vendor-cut felt book covers and self-cut felt book covers

Components. The instructor went to brick-and-mortar vendors to obtain various suggested closures: buttons, snaps, and buckles. Students helped with online sourcing (on the Taobao app) to obtain options for the cover fabric, binder rings, page punching, and page reinforcements. The on-campus students and instructor together tested the closures, explicitly discussing the affordance of opening and closing, strength, “good feel”, and installation difficulty (see Figure 13).



Fig. 13. Snaps and other components of swatchbook

Uniformity versus variation. At the same time that the book design was being finalised, the partners made final page design decisions. The main factors were how to finish the page edges, and whether to have page uniformity or variation in the nine books.

Yuchen returned to designing her group’s page finish after working on the cover. She reported “In my group page, we are not willing to let the reader see the bottom bobbin threads of our work. We are using tatami stitches, and tatami causes some mess on the back of the page. So, I learned a technique to stitch two fabrics together like a pillow, so no one could see the backside of our stitch page. She documented the many measurements and steps needed to learn and repeat this technique, ending with “Finally, we iron this stitching to make the page flat and nice.”

Yuchen’s group also decided to use a variety of woven fabrics that stitched easily, and selected three different multicolor threads that made a pleasing contrast with each, so that each physical book had a unique version of their design.

In contrast, Kyle’s team made a deliberate decision to leave the appearance of the back of their piece open, including visible bobbin threads and visible stabilizer as a way of revealing the process to interested viewers of the book. To finish the edges, they opted to learn how to make a narrow machine-stitched hem, in order to keep the edges from raveling

They also decided to have a uniform appearance for the pages. Kyle stitched all pages with the same fabric (except one page from a variant prototype) which had a silky appearance but required considerable attention to keep from bubbling during stitching.

Coco and Fiona’s team opted to use a variety of mounting techniques on different pages to combine their design: one some they stitched both designs onto a single base fabric, and on others stitched onto a single base. The edge finishes for pages also varied, from melting the fabric edge, to tacking fabric edges down with hand stitches, to narrow hemming. Some of these decisions may have been pragmatic, mixing prototype pages with a more refined design in order to complete so many pages in time for the nine final books. (see Figure 14)



Fig. 14. Variety of book pages

Designing for manufacturability. In another “one to many” problem, the design for punching holes in the pages was more difficult than expected. The early prototypes used a labor-intensive book punch with hand-cut wool reinforcements glued around the holes. These were not viable for creating over a hundred instances. Yuchen also experimented with developing a machine-stitched hole reinforcement which was also not viable. After researching

online, she found metal grommets as a solution, borrowed another faculty’s leather punch, bought a grommet setter, and after several tests, had an artisanal manufacturing solution that every group could use with a reasonable investment of time.

Lo-tech project management. To make it possible for students to coordinate management of the project, the instructor led the students in a lo-tech project management activity, creating a whiteboard spreadsheet with steps for each book (including the testing steps that we had found to be needed). Students worked independently and in class sessions to produce the books, which we tracked with lo-tech paper labels pinned to them that described any distinct features (prototypes, batches of cover material) (see Figure 15, Figure 16).

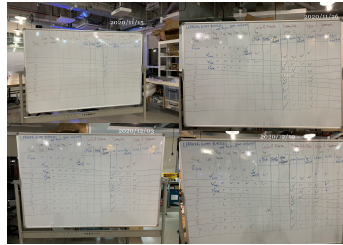


Fig. 15. Lo-tech craft manufacturing spreadsheet



Fig. 16. Craft-manufactured books under construction

4 CONCLUSIONS

The students’ engagement with computing and with craft design and practice in this project reflects the use of the computational tools for machine embroidery design available in the Turtlestitch environment, the introduction of material exploration of machine embroidery and associated textile materials, and the group design of a swatchbook artifact.

The student experiences reported above reflect their engagement with the project, instances of learning computational concepts and gaining programming skills, and use of metacognitive language about computation and about constructionist concepts of project-based learning. They also reflect learning some methodologies and practices of craft and design in the material environment of machine embroidery and in select other textile-related areas. We now consider ways in which the project and tools might be reformulated or elaborated in future group projects to probe the framework elements more deeply, and provide stronger support for learning and for critique.

The swatchbook artifact generated engagement during the making process especially from on-campus students, enthusiasm from viewers at an exhibition and informal showings, and, notably, a detailed written reflection (20 pages of written process documentation) from one student. However, the introduction of the rationales for making it, of its relationships to craft manufacturing, its relationships to current practice and scholarship in design and learning, and

reflections on its potential uses could be considerably elaborated in future versions of related projects. Some possible directions for those elaborations could be:

- (1) Making swatchbooks for the purpose of exchanging technique with each other and with ensuing users
- (2) Making swatchbooks or sampler books for the purposes of group cohesion and for display
- (3) Further exploration of other “soft book” formats in the context of programmable embroidery.

In the areas of programming, machine embroidery, and final artifact making/exchange, a future direction could include scaffolding in each area with more short-term directed exercises, examples, and design briefs to provide support for skills and exploration.

Students were encouraged to offer specific critiques of Turtlestitch as a programming and design environment. While we plan to offer those critiques to the developer and user community of that environment, we could go further in our project to encourage students to learn more about commercial, and other computational, machine embroidery design possibilities and thus further empower their practice and their critical involvement.

Finally, if craft-based techniques are to be meaningfully developed into environments that resonate with students and provide an interplay of computing and making, we must take into account the continued respect for craft work as a reservoir of knowledge, ideas and practice; and that interaction with both master practitioners and artisanal materials may continually affect our ideas of what Wood, Rust, and Horne express as “the two problems of what is to be learned and how it will be learned.” [46]. This applies to the craft of machine embroidery design, as well as the earlier crafts from which it draws inspiration and rationale, such as hand embroidery and textile surface design, construction, and embellishment. Further, our intuition was confirmed that limited-edition manufacturing resonates with the definition of craft manufacturing as “limited, high quality production by artisans in limited quantities with high variability for individual end-users” [44] as our students were indeed posed different challenges in making multiples than a single object, and also made differing choices of whether to make uniform pages or use varying materials to customize the books. This project probed “how it will be learned” while taking a rather opportunistic approach to “what is to be learned”. We recommend that ongoing work consistently probe and iterate on “what is to be learned.”

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REFERENCES

- [1] Harold Abelson and Andrea DiSessa. 1986. *Turtle Geometry: The Computer as a Medium for Exploring Mathematics*. MIT Press.
- [2] Roland Aigner, Andreas Pointner, Thomas Preindl, Patrick Parzer, and Michael Haller. 2020. Embroidered Resistive Pressure Sensors: A Novel Approach for Textile Interfaces. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. ACM, Honolulu HI USA, 1–13. <https://doi.org/10.1145/3313831.3376305>
- [3] Lea Albaugh, April Grow, Chenxi Liu, James McCann, Gillian Smith, and Jennifer Mankoff. 2016. Threadsteading: Playful Interaction for Textile Fabrication Devices. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16)*. Association for Computing Machinery, New York, NY, USA, 285–288. <https://doi.org/10.1145/2851581.2889466>
- [4] Paula Bontá and Brian Silverman. 2013. TurtleArt | Playful Invention Company. <https://www.playfulinvention.com/portfolio/turtleart/>.
- [5] Leah Buechley. 2010. Special Topics: New Textiles. <https://ocw.mit.edu/courses/media-arts-and-sciences/mas-962-special-topics-new-textiles-spring-2010/>.

- [6] Mike Eisenberg and Ann Eisenberg. 1998. Shop Class for the Next Millenium: Education through Computer-Enriched Handicrafts. *Journal of Interactive Media in Education* 1998, 2 (Oct. 1998), Art. 8. <https://doi.org/10.5334/1998-8>
- [7] gracie15. 2012. Embroidered Giraffe, Tree, Flowers, Voronoi : New Textiles 2012. <https://courses.media.mit.edu/2012spring/mas681/index.html%3Fp=2729.html>.
- [8] April Grow. 2016. Threadsteading on Crewel Tech. http://www.creweltech.com/?page_id=189.
- [9] April Marie Grow. 2019. *Computationally-Mediated Interactions with Traditional Textile Crafts*. Ph.D. Dissertation. University of California, Santa Cruz, Ann Arbor.
- [10] Mark Guzdial. 2010. Does Contextualized Computing Education Help? *ACM Inroads* 1, 4 (Dec. 2010), 4–6. <https://doi.org/10.1145/1869746.1869747>
- [11] Nur Al-huda Hamdan, Simon Voelker, and Jan Borchers. 2018. Sketch&Stitch: Interactive Embroidery for E-textiles. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 1–13.
- [12] Brian Harvey, Daniel D. Garcia, Tiffany Barnes, Nathaniel Titterton, Daniel Armendariz, Luke Segars, Eugene Lemon, Sean Morris, and Josh Paley. 2013. SNAP! (Build Your Own Blocks) Abstract. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education (SIGCSE '13)*. Association for Computing Machinery, New York, NY, USA, 759. <https://doi.org/10.1145/2445196.2445507>
- [13] Anja Hertenberger, Barbro Scholz, Beam Contrechoc, Becky Stewart, Ebru Kurbak, Hannah Perner-Wilson, Irene Posch, Isabel Cabral, Jie Qi, Katharina Childs, Kristi Kuusk, Lynsey Calder, Marina Toeters, Marta Kisand, Martijn ten Bhömer, Maurin Donneaud, Meg Grant, Melissa Coleman, Mika Satomi, Mili Tharakan, Pauline Vierne, Sara Robertson, Sarah Taylor, and Troy Robert Nachtigall. 2014. 2013 E-Textile Swatchbook Exchange: The Importance of Sharing Physical Work. In *Proceedings of the 2014 ACM International Symposium on Wearable Computers: Adjunct Program (ISWC '14 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 77–81. <https://doi.org/10.1145/2641248.2641276>
- [14] Yasmin Kafai and Gayathri Jayathirtha. 2020. Hi-Lo Tech Crafting: Tinkering with Textiles, Paper, and Everything Else. In *Designing Constructionist Futures: The Art, Theory, and Practice of Learning Designs*, Nathan Holbert, Matthew Berland, and Yasmin Kafai (Eds.). MIT Press, 301–309.
- [15] Susan Klimczak. 2021. *I Learn How to Code and Lengthen My Reach #makingliberation*. Constructing Modern Knowledge Press, 93–99.
- [16] Sarah Kuhn. 2021. *Transforming Learning Through Tangible Instruction* (1st edition ed.). Routledge, New York, NY.
- [17] Levin. 2022. PEmbroider. Frank-Ratchye STUDIO for Creative Inquiry.
- [18] Jennifer Lin. 2020. Coming Up with Designs - Garden. https://steamct.blogspot.com/2020/07/coming-up-with-designs-garden_85.html.
- [19] Silvia Lindtner, Anna Greenspan, and David Li. 2015. Designed in Shenzhen: *Shanzhai* Manufacturing and Maker Entrepreneurs. In *Proceedings of The Fifth Decennial Aarhus Conference on Critical Alternatives (CA '15)*. Aarhus University Press, Aarhus N, 85–96. <https://doi.org/10.7146/aaacc.v1i1.21265>
- [20] Gregor Lingl. 2022. Turtle — Turtle Graphics — Python 3.10.2 Documentation. <https://docs.python.org/3/library/turtle.html>.
- [21] Andrea Mayr-Stalder. 2021. Code! .. Draw! .. Stitch! TurtleStitch Coded Embroidery. <https://www.turtlestitch.org/>.
- [22] Huw Messie. 2022. HUW MESSIE. <https://huwmessie.com/>.
- [23] Richard Millwood, Mayr-Stalder Andrea, Amond Mags, John Hegarty, and Margaret Low. 2020. Turtlestitch Workshop Abstract. In *Proceedings of the Contructionism 2020 Conference*. Trinity College, Dublin, Ireland, page 59.
- [24] Marvin Minsky. 2019. The Infinite Construction Kit. In *Inventive Minds: Marvin Minsky on Education*, Cynthia Solomon and Xiao Xiao (Eds.). MIT Press, Cambridge, MA, USA.
- [25] Anonymous MIT Student. 2010. Assignment 8: "Our Home" Embroidery Project | Special Topics: New Textiles. <https://ocw.mit.edu/courses/media-arts-and-sciences/mas-962-special-topics-new-textiles-spring-2010/assignments-and-projects/knit-woven-embroidery-or-print/assignment-8-2010cour-home201d-embroidery-project/>.
- [26] Simon Mong. 2018. Different Trees. <https://medium.com/@simonmong/different-trees-85769f069ffc>.
- [27] Simon Mong. 2022. Simon Says. <https://turtlestitch.snapontop.org/>.
- [28] Jens Mönig and Brian Harvey. 2022. Snap! Build Your Own Blocks. <https://snap.berkeley.edu/>.
- [29] Don Norman. 1988. *The Psychology Of Everyday Things*. Basic Books.
- [30] Artemis Papert and Cynthia Solomon. 2021. *Spiraling*. Constructing Modern Knowledge Press, 19–25.
- [31] Seymour Papert. 1993. *Mindstorms: Children, Computers, and Powerful Ideas: 2nd (Second) Edition* (2nd edition ed.). Basic Books.
- [32] Seymour Papert and Cynthia Solomon. 1971. *Twenty Things to Do With a Computer. Artificial Intelligence Memo Number 248*. Technical Report MIT Artificial Intelligence Lab Memo Number 248.
- [33] Hannah Perner-Wilson. 2019. Adventuring with Materials.
- [34] Hannah Perner-Wilson. 2021. eTextile Swatch Exchange. <https://etextile-summercamp.org/swatch-exchange/>.
- [35] Hannah Perner-Wilson. 2021. eTextile Swatch Exchange. <https://etextile-summercamp.org/swatch-exchange/category/2020/>.
- [36] Hannah Perner-Wilson and Irene Posch. 2021. TEI2021 Swatchbook. <https://tei.acm.org/2021/swatchbook/>.
- [37] Hannah Perner-Wilson and Irene Posch. 2022. How Tangible Is TEI? Exploring Swatches as a New Academic Publication Format. (2022), 6.
- [38] Irene Posch, Ozge Subasi, Daniela K. Rosner, Raune Frankjaer, Amit Zoran, and Tania Pérez-Bustos. 2019. Troubling Innovation: Craft and Computing Across Boundaries. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–8. <https://doi.org/10.1145/3290607.3299010>
- [39] Mika Satomi and Hannah Perner-Wilson. 2022. Machine Embroidering. <https://www.kobakant.at/DIY/?p=5501>.
- [40] Cynthia Solomon, Brian Harvey, Ken Kahn, Henry Lieberman, Mark L. Miller, Margaret Minsky, Artemis Papert, and Brian Silverman. 2020. History of Logo. *Proceedings of the ACM on Programming Languages* 4, HOPL (June 2020), 79:1–79:66. <https://doi.org/10.1145/3386329>
- [41] Cynthia Solomon, Margaret Minsky, and Brian Harvey (Eds.). 1986. *LogoWorks: Challenging Programs in Logo*.

- [42] Verily Tan, Anna Keune, and Kylie Pepler. 2016. The Materiality of Design in E-Textiles. In *Taking Design Thinking to School*. Routledge.
- [43] Tatarize. 2022. Pyembroidery Library for Reading and Writing a Variety of Embroidery Formats. EmbroidePy.
- [44] The Open University. 2019. Understanding Operations Management. <https://www.open.edu/openlearn/money-business/leadership-management/understanding-operations-management/content-section-2.2.1>.
- [45] Ursula Wolz, Michael Auschauer, and Andrea Mayr-Stalder. 2019. Code Crafting with Turtlestitch. In *ACM SIGGRAPH 2019 Studio (SIGGRAPH '19)*. Association for Computing Machinery, New York, NY, USA, 1–2. <https://doi.org/10.1145/3306306.3328009>
- [46] Nicola Wood, Chris Rust, and Grace Horne. 2009. A Tacit Understanding: The Designer's Role in Capturing and Passing on the Skilled Knowledge of Master Craftsmen. *International Journal of Design* 3, 3 (2009), 14.