Goldwork Embroidery

Interviews with Practitioners on Working with Metal Threads and Opportunities for E-textile Hybrid Crafts

Lee Jones
Carleton University
Queen's University
Kingston, Ontario, Canada
Lee.Jones@queensu.ca

Sara Nabil
Queen's University
Kingston, Ontario, Canada
Sara.Nabil@queensu.ca

Figure 1: Goldwork pieces being embroidered on slate frames. Photos courtesy of (Left) Marie-Renée Otis, (Middle) Hannah Mansfield, and (Right) and Jenny Adin-Christie.

ABSTRACT

Within the emerging field of e-textiles, goldwork embroidery (also known as metalwork) which uses metal threads and materials is an underexplored area, despite being a centuries-old practice in traditional crafts of different cultures. In this paper, we explore the material culture of textile goldwork to better understand how e-textile researchers can leverage their material properties, palette, and practices. First, we provide a historical background of English goldwork to give HCI researchers context on this craft field including technological and cultural influences. Then, we interview 13 contemporary goldwork practitioners on their creative practice to better understand the tools, techniques, and skills they employ. Our study findings show how goldwork practitioners deal with the unique constraints of metal threads and materials, and how these materials need to be handled differently than regular non-metal threads and fibers. This paper contributes an analysis of goldwork practices for HCI audiences with suggestions on how we can leverage these practices for the future of e-textile hybrid crafts.

C&C '22, June 20–23, 2022, Venice, Italy

ACM ISBN 978-1-4503-9327-0/22/06.
https://doi.org/10.1145/3527927.3532809

CCS CONCEPTS

• **Human-centered computing** → **User interface toolkits**.

KEYWORDS

e-textiles, embroidery, crafting, hybrid crafts, goldwork, metal work

ACM Reference Format:
Lee Jones and Sara Nabil. 2022. Goldwork Embroidery: Interviews with Practitioners on Working with Metal Threads and Opportunities for E-textile Hybrid Crafts. In *Creativity and Cognition (C&C '22), June 20–23, 2022, Venice, Italy*. ACM, New York, NY, USA, 16 pages. https://doi.org/10.1145/3527927.3532809

1 INTRODUCTION

Tangible user interfaces (TUIs) are interactive devices that enable us to physically interact with computers not only on desktops and smartphones but within our everyday environments and objects [26, 35], and have resulted in a wide range of materials for computational devices such as paper, wood, ceramics, and textiles [31]. TUIs change not only how we might use computational devices (and what they might feel and look like), but also how individuals can make and craft them. Hybrid crafts, which incorporate technology with crafting materials and techniques (such as drawing or stitching), have led to new ways of making computational devices including new tools, materials, and practices [8, 15, 27, 29, 36, 68, 98].

Smart textiles or electronic textiles (e-textiles) is a hybrid craft that repurposes metal threads for their conductive and resistive

properties, and combines them with increasingly small computers, to make textiles that are interactive [77]. E-textiles enable new types of devices – such as those that are fuzzy, soft, and stretchy [72] – but also changes what the material culture of computing looks like. For example, with e-textiles individuals can make interactive devices with unexpected tools such as sewing needles, crochet and knitting needles, looms, sewing machines, and repurpose sewing accessories like zippers, snaps, and sewing pins for their electrical affordances [73, 75–77]. E-textiles also enable new types of projects and applications for technology [14, 38], make technology more customizable and transparent through craft-based making [72], and help to break down stereotypes of who designs technology [38].

E-textiles, as a hybrid, interdisciplinary field, incorporates insights from both textiles and physical computing. For example, microcontrollers designed with sew-able through holes [13, 14], hybrid tools such as the e-textile tester tape which measures length and electrical conductivity [75], and methods of documentation such as the e-textile swatchbook exchange which leverages the practice of swatchbooks, common in textile fields for sampling materials [34]. These blended practices demonstrate some of the benefits Human Computer Interaction (HCI) can gain from understanding textile practices for fabric-based interfaces.

The earliest e-textile projects using embroidery re-purposed metallic organza and stainless steel threads to make a variety e-textile prototypes including wearables such as a musical jacket and firefly dress, soft objects such as squishy instruments, and interior furnishings such as an electronic tablecloth [70, 78, 79]. Since then, hand and machine embroidery have been used for a wide variety of e-textile functionalities including embroidered computers [47], speakers [62, 82], colour changing textiles [63], capacitive touch sensing [5], gesture sensing [80], and pressure sensors [6] to name a few.

In this paper, we turn to the metal threads and materials that make this e-textile hybrid practice possible. We further explore the artistic affordances of these materials to uncover new opportunities for e-textiles as a hybrid craft, such as material form factors, techniques, and tools. To do so, we provide a historical background on goldwork in England (with a focus on artistic periods, cultural changes and technological influences), and then discuss findings from interviews with 13 contemporary goldwork and metalwork embroidery practitioners on how they make use of metal threads and materials in their artistic practice (see Figure 1). Ultimately, interaction designers with research interests in textile tangible interfaces, wearables, interactive everyday things, and design products or artwork can benefit from this work for new techniques and tools for creating goldwork sensors, actuators, and electronic components and connections.

Goldwork, also known as metal thread work or metalwork [53], is an embroidery medium that uses metal threads and materials and has been practiced for over 1000 years in England, and longer around the world. In comparison, e-textiles is a young field (just over 20 years old in academia [70] with some older patent concepts [74]) and has so much to learn to answer questions such as: how do we make these materials (and our prototypes) last? How can we incorporate these materials into cultural practices? How should these materials be used, handled, preserved? Metal threads are also difficult for beginners to work with (the threads "remember", get tangled, knot up, etc) [42], and understanding how practitioners work with these constraints in goldwork will help us to better understand how to work with those same material constraints in e-textiles [85].

This paper provides several contributions to e-textile hybrid craft research including:

(1) Contextualizing goldwork history for HCI researchers with a summary of terms, techniques, and materials.
(2) Analysis of interviews with contemporary goldwork practitioners to understand applications for goldwork, how they handle metal threads and materials, and how they preserve their works to last.
(3) Presenting design recommendations for e-textile practitioners on how they can leverage these historic and contemporary practices to further hybrid craft practices into fabric-based prototyping.

2 RELATED WORK

The ability to combine computation with hands-on crafting is the result of several intersecting trends. Every year computers get increasingly smaller and less expensive [52]. This decrease in size and cost has enabled ubiquitous computing, where tiny computers can be placed throughout our environment and within everyday objects [96], and tangible user interfaces (TUIs) where we can "grasp and manipulate" computers to interact with them [26, 35]. Grasping and manipulating applies to the interactions of use, but also the interactions involved with crafting computers where they can be increasingly hand-crafted and customized with DIY maker tools and supplies.

Innovations in digital fabrication have further supported the customization and redesign of components for hand crafts. Digital fabrication tools make it accessible for individuals to design their own printed circuit boards (PCBs) and microcontrollers [28], and open-hardware designs for physical computing, like the Arduino microcontroller, have led to a wide variety of microcontrollers to suit specific types of craft-based making such as the LilyPad Arduino for e-textiles [13, 14], Chibitronics microcontroller for paper crafts [83, 84], and many others to suit specific use cases or craft-based applications [17, 61]. Online maker tutorials, such as those on instructables or forums, have encouraged further remixing of projects [14, 48, 83], and hand-crafting maker communities have broadened the applications and perceptions of who makes with technology [14, 72, 83]. Educators are incorporating these craft-based computing exercises into curriculums due to their success in leveraging physical skills and creative applications for learning computational and electrical concepts [38].

These hands-on computational crafts often repurpose metallic crafting materials for their conductive properties. For example, the wire connections used with the Arduino can be replaced with hand-crafted traces such as silver threads for e-textiles [13, 14], or silver ink and copper tape for paper crafts [83, 84], or gold foil for smart tattoos [45] and the microcontrollers for these crafts are designed to suit these connections such as stitched through-holes for threads [77] and tape connections for paper crafts. Compared to wire traces, these crafted traces (made of stitches, tape, and inks) enable more aesthetic and free-hand customization [72].

Figure 2: Goldwork embroideries mirror art motifs of the time such as elongated figures and architecture styles. Chasuble (Opus Anglicanum) ca. 1330–50, British, Silver and silver-gilt thread and colored silks in underside couching, split stitch, laid-and-couched work, and raised work, with pearls on velvet. Open Access photo courtesy of the MET Museum 27.162.1.[1].

These hybrid hand crafts often involve the intersection of two skills, bringing hands-on and digital skillsets together [27], such as making physical computing systems and combining those skillsets with tacit skills such as stitching and drawing. Creativity support tools in this realm focus on physical computing – such as verifying that circuits will be functional [50, 81], but there is limited work on how to provide novices with the tacit skills to physically manage these unique materials, such as the difficulties novices experience when learning to stitch with metal threads [42].

Craft practitioners understand the constraints of working and "collaborating" with their materials [85], and human computer interaction (HCI) researchers are beginning to explore how we can provide tutorials for those tacit skillsets [24, 39, 40, 64], understand the embodied experience of crafting [27], and learn from the procedures craftspeople use to understand and document their materials [59]. In this project we focus on the insights that goldwork practitioners can provide for those working with metal threads for e-textile hybrid crafts with a focus on how practitioners physically manage their materials. Our aim is that future work can provide creativity support tools based on their recommendations and material culture to further blend e-textile crafting with the practices of those who already use these metal materials.

3 HISTORICAL BACKGROUND OF GOLDWORK IN ENGLAND

Goldwork, also known as metal thread work or metalwork [53], is an embroidery medium with a long history that uses gold, gilt, or metal threads and materials [91]. Goldwork embroidery practices in England have been influenced by art movements, cultural changes, as well as technical innovations. In this section, we provide an overview of that history and how practices have changed over time.

Unlike many other textile techniques with fibers that decay over time, conservators still have access to some goldwork examples from the 5th century onward, and using technology have been able to evaluate how they were made [37]. The earliest examples of gold threads in Europe were made of solid gold foil strips that were often braided or woven rather than embroidered [37, 51]. Around the 11th century onward, these strips were wound around a fibrous core that made them more flexible including materials such as leather or paper membranes, and then later expanding to cores of silk (13th century), gilt silver (16-19th century), pure metal (17-19th century), and various plastics (20th century) [37, 44, 51].

3.1 Medieval: Opus Anglicanum

Medieval goldwork embroidery during the 'Opus Anglicanum' (or English work) period (13th-14th century), made use of the more flexible membrane threads, as well as the stitching technique of underside couching (see Figure 2) [55, 92]. These technical changes made the embroideries more durable since the gold threads were slightly pulled through the fabric to be couched on the backside, which made them more flexible than surface couching and less likely to get caught and pulled off [46]. To manage the weight of the metal materials, embroideries were stitched through two layers – an upper layer of a finer material and a backing layer of a coarser material such as linen or calico [58]. The quality of the works, as well as images and scenes depicted which covered the fabric in gold threads, made them prized possessions throughout Europe and were often used as diplomatic gifts [55]. The motifs in the works also mirror trends in art of that period including

elongated bodies and gothic architectural motifs, and it is thought that many painters or book illustrators provided the designs for these works or perhaps made the underdrawings for embroideries [43, 54]. At the end of the Opus Anglicanum, and due to the high demand of goldwork embroideries, techniques shifted to increase production speed including more repetitive motifs (suggesting the use of stencils) and a return to surface couching [11, 88].

3.2 Tudor (1485-1603): Reformation, Renaissance

Nearing the end of the Opus Anglicanum, and during the Tudor era (15th – 16th century), innovations in imported textiles and prized materials such as velvet [32, 87, 94], made it desirable to show the ground fabric with goldwork on top [57]. Velvet, due to its pile, was difficult to embroider on directly so designs needed to be embroidered on another material, such as silk, and then transferred (see Figure 3) [33, 43]. Embroiderers began making smaller goldwork pieces as surface brocades and appliqués that could then be applied to these fabrics, as well as adding more sculptural dimensions to these surface techniques with padding [7, 55, 58]. This meant that churches could slowly build up embroideries and that a single piece could have appliqués made by many different embroiderers [33]. New wiredrawing technology (where metals were "drawn" or brought through increasingly smaller holes to make thin wires) led to a burst of new types of metal threads such as gilt threads, and the spiraled coreless purl wire [7, 44, 58, 66]. These purl wires were also cut and flattened to make spangles (or paillettes), which look like sequins made of metal [7]. We also begin to see gold and silver threads spun together to make "twists"[58]. These metal cords were easier to attach to the velvet ground fabric [43]. Imported silk threads and the Renaissance painting technique of 'chiaroscuro' influenced the goldwork embroidery technique of 'or nué' (painted gold) where rows of gold threads were couched with different colours of silk to create detailed images with shading (see Figure 4) [16]. It is believed that this technique originated in France or Burgundian Netherlands before being brought to England [58]. During the Reformation, many of the church's pieces were destroyed or repurposed for secular uses [58, 93]. Materials were also burned in order to melt and retrieve the metals [43].

3.3 Stuart (1603-1714): The Enlightenment, Stumpwork

During the Enlightenment there was increased interest in the study of the natural world and the sciences, as well as an increase of printed books with illustrations. This presents itself in the embroidery of the period with motifs including a wide variety of flora and fauna, as well as embroidery pattern books with elaborate designs for flowers, insects, birds and mammals (see Figure 5) [43, 49, 95]. The ground material shifted from the velvet used in the previous era to white silk and undyed linen [7]. During this period goldwork was incorporated with other embroidery techniques such as stumpwork or raised work, which used padding and fine wires to raise embroideries from the ground fabric [7, 49]. The metal threads or braids were frequently presented as curling stem motifs [65], with excess metal stitched in to store value in the textiles [67]. Spangles were used to fill the satin spaces between embroidered motifs

Figure 3: More repetitive motifs made separately by several artisans then then then applied as appliqués. Chasuble (Opus Anglicanum) late 15th century, British, Silk and metallic threads on linen; appliqué on silk velvet foundation with silk embroidery and silver-gilt shot. Open Access photo courtesy of the MET Museum 1982.432[3].

Figure 4: An example using the technique of 'or nué' (painted gold). Embroidery with the Annunciation, mid-15th century, Netherlandish, Silk and metal threads on linen, Open Access photo courtesy of the MET Museum 1990.330[4],

[43]. Goldwork began to be used more frequently on books, boxes, and accessories such as gloves [43, 95]. The purl coils began to be wrapped around coloured silk that was used the "shade" the wires. This technique was often used on purses and bags that though made of metal appeared to have bright colours [43].

3.4 Georgian (1714-1837): British Romanticism

During this time, fashions veered towards simplicity with more "country" styles and goldwork was used sparingly in a more restrained way with metal cords or braids embroidered on the edges of sleeves and hems [43]. In the late 18th century, aristocrats in France began deconstructing old goldwork pieces and unwinding the gold from the silver to repurpose the threads for sale [89]. These threads could then be burned and melted down for re-use. This pastime called "parfilage" in France, became known as "drizzling" when it travelled to England [43, 89].

Figure 5: An example of flora, fauna, and curling stem motifs. Close up of Jacket, ca. 1616, British, linen, silk, metal, Open Access photo courtesy of the MET Museum 23.170.1[2].

3.5 Victorian (1837-1901): Arts and Crafts Movement, Royal School of Needlework

In response to the factories of the industrial revolution, the English Arts and Crafts Movement (officially launched in 1887) advocated for the decorative arts (such as ceramics, textiles, metalwork, and furniture) [90]. Overall the movement valued craft and craftspeople, wanted crafts to receive as much attention as painting and sculpture, and pushed for the revival of craft techniques that were perceived as being at risk for being lost to industrialization [18]. Part of the movement included an idealization of the guilds of the past, working within small-scale workshops, and a revival of crafts from the medieval period [90]. This created a returned interest in goldwork and embroidery of the Opus Anglicanum period. During this time, the Victoria and Albert Museum began exhibiting embroideries as art objects [10], and the Royal School of Needlework opened in 1872 "to revive a beautiful art which had fallen into disuse" [43, 69]. This movement led to the ecosystem of materials, mentoring, and art history references that goldwork embroidery exists within today.

4 METHODOLOGY: INTERVIEWS WITH GOLDWORK PRACTITIONERS

4.1 Research Questions

Though goldwork has a long history, we wanted to explore how these traditions, developed over centuries, are used by contemporary goldwork practitioners. Our research questions for this project were as following:

- Q1: How is goldwork embroidery currently used in artistic practices (context and meaning)?
- Q2: How are goldwork embroidery pieces created (techniques, materials, and tools)?
- Q3: What are the unique constraints of goldwork compared to other embroidery techniques?

4.2 Participants

To better understand modern goldwork practices, we interviewed 13 goldwork artists (P1-P13). We recruited our participants through email followed by snowballing. All participants were goldwork practitioners, nine also taught courses and workshops on goldwork embroidery, and two had written books on the subject. Nine participants had apprenticed or taken courses from the Royal School of Needlework.

4.3 Procedure

We conducted thirteen 30-minute semi-structured interviews through video calls (Zoom) where we asked participants about their background (how they got into goldwork, how long they have been working on goldwork, and their motivations for starting), their own practice (their design process, their making process, and their applications for goldwork), their goldwork recommendations, and for educators how they teach the techniques (teaching approach, first lessons, and common mistakes). We obtained clearance from our institutions' research ethics board.

4.4 Analysis

We used orthographic verbatim transcription to transcribe 7 hours of video recording. We then performed inductive thematic analysis as described by Braun et al. [9] that aims to generate analysis from the bottom up rather than around existing theoretical frameworks. This first involved familiarization and immersion in the data with reading and notetaking, and then an initial coding of the complete dataset with line-by-line data-derived codes for each quote that aimed to mirror the language and concepts our participants discussed. With this initial list of codes, we then grouped them into central organizing concepts to create themes. These themes and subthemes were reviewed to create a thematic map. This thematic map was then used to develop the final themes on current goldwork practices.

5 FINDINGS

Our participants discussed the material cultures of goldwork and how metal materials respond differently and require different tools and techniques (Figure 6). They discussed how metals change over time, how goldwork is often used in a sculptural way, and the amount of practice the techniques require. They also discussed their work in relation to historic practices of goldwork, how they innovate upon them, and how goldwork exists within ecosystems of material production and mentorship.

5.1 Theme 1: Handling Metal

5.1.1 Working with metal threads: All of our participants described goldwork as the practice of working with metal threads, and that the unique characteristics of this embroidery medium are a response to the use of metal. Metal threads feel and respond differently, as P9 summarizes: *"It doesn't act like a fiber - it is stiffer - it kind of has a mind of its own."* Similarily P4 also stated: *"That's a big part of it, and the memory of it, the memory of the threads they all have very subtle ways of like moving differently [. . .] It takes a while to sort of build a conversation with the materials"*. The use of metal made it fundamentally different than other embroidery techniques,

Figure 6: Goldwork materials and supplies laid out for use. Photos courtesy of Hannah Mansfield and Jenny Adin-Christie.

which was often surprising to students who had previous experience with embroidery, *"it is less textile than other techniques, because of the material"* [P1]. P2: *"it's also probably one of the embroidery techniques that is totally different to anything else, and it's quite challenging to learn because of the handling and understanding of the metal threads"*.

5.1.2 Palette of materials: Our participants used a wide variety of metal and non-metal materials in their practice with the most common being passing threads, couching threads, and purls. Each material provides *"a slightly different texture"* [P2]. Though they are generally sparkly they can *"have all different types like rough and smooth, matt or shiny"* [P5] which provides different effects and *"endless variation"* [P9] (Figure 8).

- Metal threads: Passing threads have a fine metal wire wrapped around a core of cotton or synthetic material that when thin generally *"feel quite soft"* [P5]. Twists are when passing threads are spun together. 'Rococco' and 'check' are threads that are created with a core that is spun to have a wavy texture and then are wrapped with metal wire. Japanese threads are a metal paper or foil ribbon wrapped around a silk or synthetic core. Importantly, *"goldwork stitching doesn't have to be gold coloured"* [P11]. Our participants used threads made of materials such as gold, gilt, silver, copper, bronze, and tin with various percentages of metal composition.
- Purl: Purls are when wire is wrapped around a needle and then the needle is removed to make a coreless hollow spiral – *"it's like a coiled spring"* [P4]. Check purl is when the needle has a triangle shape to make angular rather than circular spirals. Pearl purl is a thicker wire around a needle to give it a wider profile that when couched *"looks like pearls"* [P6].
- Metals (Other): Plate is a *"flatted strip of wire"* [P7] that looks like a metal ribbon. Spangles are individual short wires shaped into a circle and then stamped flat and look *"like metal sequins"* [P9]. Foil leather is when leather has a metal foil so that it is shiny.
- Couching threads: Our participants used a wide variety of non-metal threads to couch their metal threads and purl wires. The couching threads such as regular embroidery floss or silk needed to be flexible and go through the base fabric.
- Base fabric: Our participants used two layers of base fabric, with the lower being a sturdy muslin, calico, cotton or linen (creating a *"thick layer at the bottom"* [P1]), and a surface fabric (*"the good one"* [P8]), which is the visible fabric that can be made of finer materials like silk. These two layers help to support the weight of the metal materials.

5.1.3 Techniques: Goldwork is a *"form of surface embroidery"* [P6] that does not *"go through the fabric"* [P9]. Here we discuss the techniques that make this possible (Figure 7).

- Padding: Padding is a preparation technique done to raise the surface of the fabric to create 3 dimensional surfaces. Padding is done in layers either with felt or thick string (see Figure 9).
- Couching: The main technique our participants used was surface couching where an embroidery thread would be threaded up from the bottom side of the fabric, looped around the metal thread or purl, and then brought down again through the fabric. P6: *"It's the very basics of goldwork – just couching a piece of passing"*. These are done in *"brick wall rows"* [P3] with *"typically two threads at a time"* [P4] to make it *"sturdy"* [P6]. Underside couching *"used in English medieval embroidery"* [P1] uses the same technique but the couching thread pulls the metal thread through the fabric a little bit at each stitch so you do not see the couching thread. Or nué (shaded gold) was where metal thread was laid down in horizontal lines and coloured threads are surface couched to create an image out of the couching threads (like a *"grid"* [P12]). Italian shading is a type of or nué done on curves rather than straight lines.
- Cut work: Cut work is a fill technique generally used on top of padding. Rows of purls are cut to a specific length and then an embroidery thread goes through the spiral core to stitch the purl to the fabric. P7: *"It's a little coil you can actually run your thread through the middle [...] and it's quite a process to learn to do it properly to cut them just the right size."*
- Chip work: Chip work is similar to cut work where the embroidery thread goes through the spiral core but instead uses *"tiny, tiny little pieces"* [P6] of purl that are stitched down in different directions to add texture. P3: *"You cut them to size and then you thread them through like a bead"*.
- Building with parts: Our participants tended to build up their goldwork, with more complicated pieces being made separately and then brought together at the end. For example, for works with perspective participants made *"the background work separately [from the foreground] and you can have more than one person working on them"* [P1].

5.1.4 Equipment: Our participants used a variety of tools for transfering and creating their goldwork designs. (see Figure 11)

- Design transfer tools: There are several methods that our participants used to transfer their designs including coloured pencils, chalk, and the traditional 'prick and pounce' method where a powder enables participants to 'prick' their design with a needle through paper and then rub powder through the holes and onto the fabric (see Figure 10).

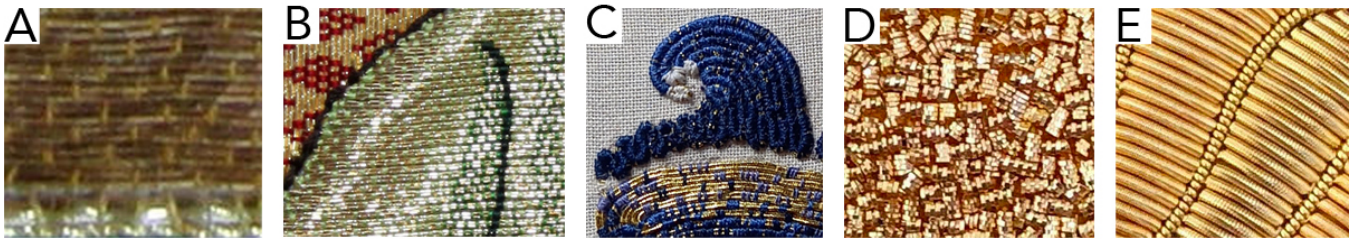

Figure 7: Stitching techniques (A) Surface couching (B) Or nué (C) Italian Shading (D) Chip work (E) Cut work. Photos courtesy of Dr Jessica Grimm (A,B), Karen F Bainbridge (C), and Hannah Mansfield (D,E).

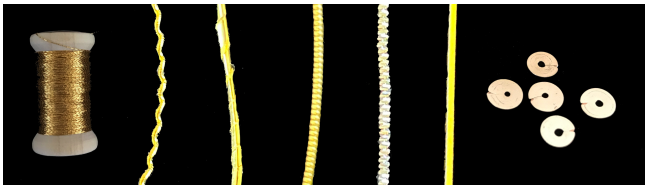

Figure 8: Common goldwork materials (from left to right): passing thread, rococco thread, Japan thread, purl, check purl, plate, spangles.

- Embroidery needles: Our participants used sewing needles with varying sizes of eye depending on the thickness of the threads.
- Handling tools: There are several tools that aim to help individuals avoid touching their materials. A mellor is a tool with a paddle side and a stiletto side to help *"guide the threads"* [P11] into place. Tweezers with a fine point *"are essential for pinching and manipulating the threads into position"* [P2]. A 'koma' is a thread spool with a square formfactor to ensure that it does not roll to hold threads in place and avoid touching the spool. A velvet or fabric board helps to prevent the threads and purls from rolling or getting damaged since the velvet pile *"keeps them on the board"* [P6], and is helpful especially with chip work.
- Goldwork scissors: Goldwork scissors have a *"fine, serrated"* [P11] to hold purls and metal threads in place while they are being cut. Since metal will blunt scissors, our participants said it was important to have a separate set for goldwork. P2: *"reserve scissors just for metal thread work"*.
- Beeswax: Using beeswax helps make the threads smooth so *"it is stronger and less likely to catch"* [P3], get attached to other materials, or fray while threading or embroidering with.
- Slate frame: A slate frame (which is *"four bars that slot into each other"* [P5]) keeps the base fabric *"drum taut"* [P1]. Moreover, P2 elaborated that *"The tension of the ground fabric is really essential to producing excellent metal thread work and then when it comes off the frame it remains beautifully smooth"*.

Figure 9: The process of creating layers of padding to give volume to a piece of goldwork embroidery. Photos courtesy of Hannah Mansfield.

Figure 10: The preparation process of prick and pounce where a pricking tool is used to outline a drawn design on paper and then pounce powder is rubbed on the holes with felt to create a stitching guide on the fabric underneath. Photos courtesy of Jenny Adin-Christie.

Figure 11: Common goldwork tools (from left to right): tweezers, mellor, embroidery scissors, goldwork scissors with serrated blade, beeswax.

Figure 12: Examples of sculptural goldwork embroideries created by Cynthia Jackson (left and middle) and Hannah Mansfield with a vase made by ceramicist Alex McCarthy (right). Photos courtesy of the artists.

5.2 Theme 2: Metals Change Over Time

5.2.1 Tarnishing: One of the unique constraints of metal materials is that many of them tarnish over time. P1: *"It really depends on where you're living and the materials you have used. The higher the gold content you're going to be fine."* Many materials our participants were a combination of gilt materials (mixed with silver) and as a result would tarnish. Our participants discussed how they manage their materials based on this constraint. The first approach is methods to minimize or prevent tarnishing. This included avoiding unnecessary touching of the materials to avoid tarnishing from *"skin oils"* [P2], keeping works dry and out of the sun, storing materials in *"acid free bags"* [P3] and *"wearing gloves"* [P5] when handling them, *"clean hands"* [P7] when stitching, applying protective sprays to seal the work from air using (which *"adds a protective layer to the thread"* [P4]), and putting works in frames behind glass.

The second approach is embracing the inevitability of tarnishing. Four of our participants mentioned that they valued the tarnishing or *"patina"* [P9] for how it captured the passing of time. P4: *"It will happen, but that makes it a living thing."* Works could also be designed with the expectation of tarnishing as it *"can actually produce really beautiful colours"* [P2]. One important thing to note was that because of tarnishing it is important to date materials – so that they will tarnish at the same rate and avoid unintended differences. As P10 summarizes: *"I usually date [mark down] when I received it. Just so that I know that if I have bought my threads for a project that I have all the threads from the same lot."*

Due to the constraints of metal materials, our practitioners discussed how goldwork tended to have applications such as artwork, soft furnishing and decorations, structured ceremonial clothing or object surfaces – items that are not washed or handled. P9: *"I think gold work is beautiful for something you hang on the wall. It's beautiful for like a book cover."*

5.2.2 Avoid items that need washing: As mentioned in the previous section, goldwork materials tend to tarnish, and as a result our practitioners recommended that it should not be used for items that need laundering, ironing, or in areas where the materials could get wet or damp. P5: *"Because, especially with the precious metals they will just get ruined."* As a result, items like everyday clothing were not recommended, but could be incorporated if they were thoughtfully designed. P11: *"Thought has to go into how it's going to be used before you actually make your final choices, and so maybe it's something that can be removed before it goes through the laundering process."* P6: *"It's just something that you have to be aware of if you're going to put it on a garment."* Our practitioners, though recognizing that goldwork tends to be used for certain areas, did not want to limit possible applications, and instead encouraged being creative with design choices while working with the constraints.

5.2.3 Avoid items that are handled: Their second recommendation was less negotiable due to goldwork only being used for surface embroidery. Though surface embroidery is the best way to ensure that the metal materials are not ruined during the stitching process (i.e., the metals are not worn away), surface embroidery is at risk for *"getting caught on things"* [P7]. This makes goldwork unsuitable for applications where it is handled a lot, *"leaned against"* [P5], or *"thrown off, thrown on"* [P7]. For example, *"if it catches onto something you can just unravel it"*. To deal with this, in conservation when they reattach a piece but it's still really *"frail it needs to be netted with conservation net over the top"* [P3]. To navigate this, practitioners recommend considering *"the placement of the article"* [P9] so the design is not in a location that will rub against other surfaces.

5.3 Theme 3: Sculptural Embroidery

Though surface embroidery might provide goldwork application constraints, the focus on surface techniques makes it one of the more sculptural forms of embroidery (see Figure 12). The materials themselves have a wide variety of textures that are highlighted by their shine creating *"movement and vibration"* [P8]. The "memory" of the more wire materials enables them to hold shapes in ways that would not be possible with other techniques – P9: *"you can manipulate it in more three-dimensional ways"*. Practitioners also add to these *"sculptural qualities"* [P4] by adding padding underneath materials with felt and thick string to create *"raised embroideries"* [P2] – or combining it with techniques such as 'stumpwork'. Though the materials should be embroidered flat, they can then be sewn

Figure 13: Incorporating found materials. Photo courtesy of Marie-Renée Otis.

afterwards into different shapes. As P7 summarizes: *"[You] stitch them flat, [and then] make pleats where you want three dimensions. It's very technical and architectural."* Our participants also discussed the culture within goldwork of incorporating non-textile materials such as pearls, spangles, and other found materials (see Figure 13). P1: *"Yeah that's very fun - so whenever I find an object, I think, 'we can use that'"*. Our participants incorporated found materials into their works such as *"bone"* [P1], *"fish skin"* [P8], *"raw flax"* [P9], *"leaves"* [P10], and *"jewelry"* [P12]. Upon seeing some of the e-textile components, participants reflected on this culture of incorporating materials: *"I noticed when you were showing me [the e-textile components]. You can adapt, and I have done that before, where I used a lot of findings like earrings. Maybe microchips, and boards, and things like that, you can use them in a goldwork pattern. They look very similar"* [P6].

5.4 Theme 4: Preciousness Require Practice

5.4.1 Goldwork is luxurious: Our participants often discussed the shine of goldwork giving the medium a unique impact compared to other embroidery forms. As P3 summarizes: *"It has a more decadent feeling than a lot of other techniques"*. Our participants described it with words such as *"bold"* [P1], *"fabulous"* [P2], *"precious"* [P4], *"magnificent"* [P8], *"powerful"* [P9], *"jaw dropping"* [P10], *"stunning"* [P11], and *"sophisticated"* [P12]. This both had to do with its history as *"the reserve of royalty, the church, and the military"* [P4], but still applies today as goldwork has expanded *"to fashion, interiors, and grown in popularity"* [P5]. Goldwork materials are also more expensive than regular embroidery thread adding to the perceived and real value of the material.

5.4.2 High visibility: Our participants highlighted how the shine of the material made every stitch more visible than other embroidery techniques. The interaction between the materials and light makes goldwork embroidery *"like a shining mirror"* [P1] that *"catches the light"* [P9]. The way it works with light adds dimension since it *"play[s] with the light, you never fully know a piece of goldwork because it's going to change"* [P4], but also makes errors more obvious. For example, *"if you don't stitch the rows closely together you get [more obvious] gaps where the fabric underneath shows through"* [P3]. Purls *"need to have the exact right length and it's just a coil more or less"* [P1]. P10: *"You have to make sure that you've got your stitch in the right place."* Overall our participants emphasized that goldwork requires precision.

5.4.3 Time investment: Our participants all said that goldwork was a slow process and that it took a lot of time to create their pieces. Most pieces our participants showed were smaller than an 8.5"×11" but required approximately 40-75 hours to create, with two participants spending over 100 hours on their pieces. Padding and planning took up a large portion of that time. P2 spent *"as much time on the padding as the gold on top"*. Teaching students goldwork requires educators to *"stress to students to be gentle [...] and to take their time and not rush because it is a slow technique and even if you have been doing it for a long time it takes you a while"* [P5]. As a result, embroiderers who work professionally learn where they can cut corners, *"but you need to know when you can, and when you can't"* [P1].

5.4.4 Importance of iteration and experimentation: As a result of the value of the material, and the visibility of errors, and the time invested, our participants emphasized the importance of practice, and practitioners do *"lots of samplers"* [P10] before adding a stitching technique into their projects (see Figure 14). P9: *"It's not debilitatingly expensive but you don't want to screw it up and waste it. It's better to test it out first"*. Our participants' samplers were ways of trying things out so if they did not achieve the desired result they could *"rip it out again"* [P1]. Samplers were ways of experimenting and iteration; having *"a conversation with one little element [...] and compare how it changes the feel of the outcome"* [P4]. P6: *"There are lots of repeats [but] if you look at it more closely you can see that I've done the same thing again and again but with a different thread or in a different way"*. Not sampling and not correcting small mistakes when they happen are the most common errors that beginners make. P5: *"A lot of students when they don't cut the wire to the right length, they will sew it down anyway rather than taking the time to undo it."*

5.5 Theme 5: Recreating and Expanding Historic Practices

Our participants discussed how goldwork was used professionally either for conservation, teaching, or in art practice.

5.5.1 Conservation and restoration: Our participants highlighted that the practice of goldwork is embedded in how these materials

Figure 14: Practice samplers developed by: (left) Tracy A Franklin, (middle) Hanny Newton, and (right) Ginette Marcoux. Photos courtesy of the artists.

have been used historically, and that keeping these practices alive is a key motivator for how and why they are taught. P3 worked in conservation as well as teaching: *"On the whole, goldwork today isn't so much about new projects because of the expense. It's more to do with repairing what's already out there and [...] making it good for the next hundred years, and also teaching people [how to do so]."* Our participants who worked in conservation would receive commissions to repair a portion of a piece (often before it was fully worn out in anticipation of repairs), or to recreate pieces. Their understanding of goldwork was valued for how it would enable them to repair works, which often led to different motifs being used in their artistic practice when compared to their commissions. P2: *"I don't think in my own personal practice I'm terribly influenced by motifs and traditional designs from the past. I'm much more interested in in moving it forward a bit and using the techniques to kind of convey my own ideas. Often in terms of commissioned work, I suppose the pieces are more traditional, they tend to be often heraldic or ecclesiastical and often, of course, there might be motifs that are required by the client to be included in there."*

5.5.2 Emulating period techniques: This focus on recreation is emulated in how goldwork is taught where apprenticeships focus on recreating historic works (see Figure 15). Students are also often drawn initially to goldwork in order to study these techniques. As P13 describes their initial interest in goldwork: *"I wanted to learn those techniques and so very, very early on, it was about how can I learn to do what they were doing in the 14th and 15th century, I want to know how to do that."* The focus on historic periods in teaching goldwork was also important to our participants because there was a lack of information through other means. As P1 summarizes: *"There's a lot of discussion on how these medieval embroideries were being made because nobody left a manual. There's no writing about how they were made because these fields are very little studied."* After completing courses participants often would begin to do their own research to better understand specific techniques. P7: *"I am getting to know fashions in the 16th century because what I'm working on now is reproducing some of the embroidery."*

5.5.3 Moving the craft forward: For individuals who used goldwork in their art practice there was a tension between feeling connected to these practices but also limited by their constraints. As P4 summarizes: *"I love that I'm like connected to methods of stitching and materials and processes that are like centuries old, but I still feel like there's a lot of challenges there, I still feel like there's a lot of 'this is the way we do it'"*. Learning how these materials were used historically gives participants a better understanding of *"the techniques, and the abilities, and restrictions of the materials"* [P10], and our educators highlighted that this was an important first step. P10: *"Regardless of what they're planning to make they need to learn the principles"*.

After receiving initial training and apprenticeships practitioners then began to experiment more: *"We learned all the different aspects of embroidery and goldwork was one of them, and I've just maybe experimented with it a little bit more and made it a little bit more contemporary"* [P6]. After learning the techniques, students and educators valued courses that taught them to approach the materials differently. P9: *"I was really pushed to do some pretty wacky things and that's where I started to free up my thinking and find my artistic voice."* This influence also came from taking courses outside of goldwork. P4: *"I loved it so much, but kind of felt a bit that in order to find out who I was as a stitcher I needed to not be around stitchers. I really enjoy questioning and challenging and getting other stitches to challenge that too, because I don't think there's many people teaching goldwork in a sort of creative free way that encourages everybody to find their own way, rather than being like '[there are] a specific number of techniques that go with goldwork, and this is how it's done'"*.

Practitioners were also inspired by how their materials and tools have changed since historic times. P8: *"The tradition has been continued even though [it is] not same material."* Our participants discussed how metal content, core threads, the use of synthetic materials, and the regular and symmetric nature of purls have all changed since medieval times. Two participants also started incorporating technology into their goldwork practice. P7 used machine embroidery: *"I did a combination of machine and hand embroidery. I loved it. It was very interesting, and I had to be very creative, and solving problems with making the threads go where I want[ed] them to go."* They

also used their computer to make their designs and then printed them on fabric for students rather than using traditional prick and pounce: *"I've been doing a lot of printing. My printer just outlines for like for classes and things I print the outlines for the students, so they don't have to do that"*. P11 used an iPad during the design process to create more modern and abstract motifs, as well as enable experimentation – *"There are different apps that you can play with and pixelate your pictures and do a whole lot of like fun stuff with it, so I took mine and I decided I would swirl it."* Though only two participants used these techniques, they had very positive feelings about them and enjoyed the experimentation they provided.

5.6 Theme 6: Goldwork Ecosystems

Goldwork, because it uses such specific materials, is a craft that is taught around geographical hubs where the materials are available and there is demand for commissions. Practitioners in the UK discussed how, because the materials are made locally, they can experiment with the materials: *"I love the fact that I can talk to the person who makes them for me, and I can work with them to create threads that as far as I know, no one has created or played with. Or like small changes to the process of making can really change the whole thread - I was like 'what else can you make?'"* [P4]. There is also more immediate exposure to goldwork as a career: *"When I was in university, we had the opportunity to go and do a tour of this studio in London, which is an embroidery studio. They are very traditional embroidery studio and one of their specialisms is gold work and they do a lot of it for the military. I just thought it was so intriguing."* [P5] Having a school that could provide the training was also important, P3 started her embroidery apprenticeship at 18, but many of our participants discovered training opportunities after receiving another degree. Notably, many of our participants learned goldwork embroidery after discovering the Royal School of Needlework which provides specialized training.

5.6.1 Online expansion: Our participants discussed how the move to online courses (in many cases catalyzed by the COVID-19 pandemic) helped to bring goldwork to broader audiences and make goldwork instruction more accessible, as well as provide specialization in different types of goldwork embroidery. P4: *"I'm having now more people who are coming to the workshops because they know my work and because they're excited by what I'm doing rather than [a general interest in goldwork]."* Five practitioners continued to take courses to expand their practice and online learning made that more accessible; *"I love the whole online learning thing. I'm unable to take courses from people in the UK - I couldn't have afforded to be able to go over and stay"* [P11]. The benefit of online learning included more detail from videos *"a few people have said to me they've actually benefited more from learning online because they can see things in much more magnified detail"* [P6], as well as more time to practice *"I can structure the workshop so people have like a week in between to do stuff in their own time"* [P4].

5.6.2 Lack of touch: As mentioned in section 5.4, fixing mistakes immediately is an important part of avoiding waste with goldwork, and unfortunately this is harder to catch online. As P2 summarizes: *"It is definitely a good way of conveying basic technique, but it has been frustrating as a teacher that you can't go in and adjust somebody's hands or see exactly how they're working to allow them to improve their work."* There is also a gap in terms of the social parts of learning: P4: *"I think it can be a bit harder to get a feeling of connection with people but I'm always trying to work on that, and I've actually been thinking about my next classes and running like a very optional kind of morning Zoom coffee"*.

6 DISCUSSION

From our review of the history of English goldwork, and analysis of participant interviews, we provide several recommendations and opportunities for e-textile hybrid craft practice.

6.1 Practice and Plan

Compared to regular non-conductive threads, metal materials feel different and cost more. Due to how these material shine, their texture, and how they interact with light, errors are also more visible on goldwork pieces. As a result, our practitioners recommended making samplers, and small experiments, to practice a technique before applying it to their project. They emphasized that experienced practitioners often make many samplers before they work on their final project, and that not taking this important first step is one of the most common errors that beginners make. Learning how to stitch, learning how to maneuver new tools, and handling new materials all takes practice. This aligns with work done within the e-textile practitioners' community on swatch exchange [34], but is yet to be widely adopted within the wider research community. As a result, we recommend that e-textile educators include this practice when teaching students, rather than jumping right into circuit exercises and applications.

Our study highlights how much time practitioners spend planning out their pieces before they even make their first stitch. Most participants used prick and pounce with powder, but others also included techniques such as chalking out their design, developing stencils, underpainting, or printing out digital design on fabric. Teaching students to map out their design before they begin stitching it also provides an opportunity for teachers to review the design to make sure it will function (i.e. as a circuit or system) before students stitch it in place.

6.2 Handle with Care

Goldwork practitioners have specific techniques, tools, and handling guidelines that are used to manage and preserve their metal materials. This includes goldwork-specific tools to mold pieces into place and to keep individuals from touching the materials (such as the mellor, tweezers, koma spools, serrated scissors, and velvet board), storage techniques (such as dating materials, handling with gloves, acid free bags), and applications (where the goldwork embroideries will be kept dry and avoid abrasion). Based on the constraints of our materials, we might need to re-think what applications e-textiles are most suitable for in terms of wearability and launderability[56]. For instance, our study findings show how goldwork was mostly used for artistic pieces and decorative items such as furnishings that are not physically handled. Goldwork practitioners also get creative around these same constraints, such as designing decorative garments with parts that are removable for

Figure 15: Two different design styles with the technique of or nué. Left: Reproducing the or nué of an early 16th-century orphrey by referencing a printed picture of the original (photo courtesy of Dr Jessica Grimm). Right: Showing the design process of using coloured pencils to map out the design and then the finished piece (photo courtesy of Ginette Marcoux).

laundering. E-textiles practitioners, when faced with similar constraints, can look to the vast body of goldwork pieces and museum collections for inspiration.

Although limited recent prior work has looked into making use of –both interactive and aesthetic– wear over time [71] and reuse [42, 97], it is an underexplored research area that requires in-depth work. E-textile practitioners can further explore and reflect on how they could design for tarnishing and sustainability, and plan for it in their designs. For example, are there sections that can be removed after an extended period of time and replaced? Goldwork conservators demonstrate how these historic pieces are repaired to stay in their best condition. When we think about sustainability, it is crucial to explore how using goldwork practice with e-textiles can enable us to develop computational devices that can be repaired, upcycled, and updated over time.

6.3 Expand Materials

Our goldwork practitioners used many of the same materials that we used in our own e-textile practices, such as sequins [12] and silver or copper threads [47]. However, they also included many other materials that we – as a research community– are yet to explore such as paper foil threads, purls, checks, rococo, and foil leathers, all with metal content. They also used non-metal materials such as silk, pearls, padding, and a wide variety of found materials. The findings of this study can help us expand the material palette of e-textiles for applications in the areas of self-expression [22, 41], self-care and well-being [71], healthcare[60], and digital living. We look forward to exploring these materials with our multimeters, experimenting with their potential applications, and evaluating how people interact, cherish and live with them in-the-wild. Our goldwork practitioners, in their use of found materials, also demonstrated a willingness to incorporate new materials into their practice, and to continually push and expand the practice of goldwork. This makes goldwork a promising area for further collaborations.

6.4 Think Long Term

When not actively destroyed and taken apart, metal embroideries (with thoughtful applications to avoid wear) have lasted since the medieval times. This has important sustainability implications as we think of the impact of our own work in e-textiles. Though our materials might have slightly different compositions than those of medieval times, with more blended and synthetic threads, the prototypes we develop will not break down like other textile objects. We must consider how the items we produce will exist in the future. Goldwork practice also provides some hints for us. The use of surface embroidery, where the metal materials do not go through the fabric, has enabled continuous re-use of the materials. For example, during the reformation when many works were vandalized for their metal contents, and again during the Georgian period when it fell out of fashion and individuals "drizzled" the metal cords and threads. For e-textiles, surface embroidery enables individuals to easily cut out couching threads without damaging the metal threads, and would also enable easier re-use of circuit board components.

6.5 Collaborate with Technical Craftspeople

Though goldwork is a practice embedded in conservation and restoration, our participants were excited by opportunities to move the craft forward with experimentation and exploration. Collaborating with goldwork practitioners and conservators could help e-textile researchers design for material constraints and solutions that can last long term. Learning goldwork through courses and workshops could also give e-textile researchers a better understanding of how to work with their materials, as well as new applications and locations for computing. As discussed by HCI researchers who have run artist residencies [21], craft practitioners do not need to understand physical computing concepts to be of value through their material and technical expertise.

6.6 Integrating Circuits and Crafts

Our participants discussed their use of found materials and non-metal materials in their goldwork embroidery designs. Their use of items such as beads, stones, and jewelry, and how they incorporate them into their work, provides opportunities for the many sewing accessories common in e-textile work such as metal snaps, buttons, and zippers to be incorporated into these designs. Simple changes to the colours of e-textile PCB boards (for example to match the gold, silver, or copper threads - similar to the metal Chibitronic stickers [83]) would enable goldwork practitioners to easily work e-textile components into the colour pallette of these shiny and shimmering embroideries. Goldwork also uses creativity support tools such as stencils, and prick and pounce to mark out designs, which could be further augmented with digital tools such as aesthetic electronics [50] and sketch & stitch [30], which enable individuals to draw out their circuits for planning and verification. Goldwork practice has a specific and unique set of tools such as mellors and tweezers, that could be augmented to make hybrid tools that both help individuals to manage the materials and verify that circuits are working [76].

6.7 Use of Metal Threads Among Cultures

This paper does not aim to be the definitive work on goldwork embroidery, but we hope it can foster discussion on incorporating cultural practices in hybrid crafts. Embroidering with metal materials is a practice that has appeared throughout art history and around the world with different techniques such as the practices of mukaish in India, tally in Egypt [23], tel kirma in Turkey [25], and kelingkan in Malaysia [86], among many others. This is one of the benefits of hybrid crafts compared to traditional computing, in that it enables researchers to create contextual computational devices incorporating their own cultural heritages [20]. English goldwork is also a medley of innovations learned through trade and travel, and merchants and pilgrims travelled widely even during medieval times and the Opus Anglicanum [19]. This is demonstrated in imported materials, such as silk, velvet, and Japan thread, and techniques such as or nué. There are also likely techniques that are currently attributed to English embroidery in the literature that will change overtime as research continues into the provenance of different techniques.

7 CONCLUSION

Hybrid crafts blend craft techniques with physical computing to create new ways of making and interacting with computers. Hybrid crafts also enable computing to gain insights from different fabrication fields and expand what computers are capable of. In this paper, we look to goldwork embroidery, the practice of working with metal threads and materials, to better understand the constraints and opportunities of these materials and how we can incorporate them in e-textile research. To do so, we provide an overview of the history of goldwork embroidery in England, and interview 13 contemporary goldwork practitioners. Our findings include recommendations and guidelines on how goldwork practitioners handle materials, the tools they use to do so, the practices they employ, and the applications they use these materials for. Insights from our study are not generalizable, but transferable as intermediate knowledge meant for researchers working with e-textiles and fabric-based tangible interfaces. Articulating the historical background of English eras (from medieval to Victorian) as an overarching theme allowed us to add a second layer of reflection, acting as the broad strokes of what occurred throughout this cultural practice and how it evolved. We see that this approach could be of benefit to other topical areas for Creativity and Cognition (C&C). Overall, this paper covers a research gap on promising conductive materials for physical prototyping, presents an in-depth analysis of that palette of materials and how they can be used, and contributes design opportunities for future e-textile research projects so researchers can leverage these cultural practices.

ACKNOWLEDGMENTS

We would like to thank our study participants who each generously contributed their time to share and discuss their goldwork practice with us.

REFERENCES

[1] ca. 1330-50. Chasuble (Opus Anglicanum) ca. 1330-50, British. *The MET Museum Image Library* (ca. 1330-50). https://www.metmuseum.org/art/collection/search/466660

[2] ca. 1616. Jacket, ca. 1616, British. *The MET Museum Image Library* (ca. 1616). https://www.metmuseum.org/art/collection/search/81132

[3] late 15th century. Chasuble (Opus Anglicanum) late 15th century, British. *The MET Museum Image Library* (late 15th century). https://www.metmuseum.org/art/collection/search/466096

[4] mid-15th century. Embroidery with the Annunciation, mid-15th century, Netherlandish. *The MET Museum Image Library* (mid-15th century). https://www.metmuseum.org/art/collection/search/466182

[5] Roland Aigner, Andreas Pointner, Thomas Preindl, Rainer Danner, and Michael Haller. 2021. TexYZ: Embroidering Enameled Wires for Three Degree-of-Freedom Mutual Capacitive Sensing. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 499, 12 pages. https://doi.org/10.1145/3411764.3445479

[6] Roland Aigner, Andreas Pointner, Thomas Preindl, Patrick Parzer, and Michael Haller. 2020. *Embroidered Resistive Pressure Sensors: A Novel Approach for Textile Interfaces.* Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376305

[7] Cristina Balloffet Carr. 2010. The Materials and Techniques of English Embroidery of the Late Tudor and Stuart Eras. *Heilbrunn Timeline of Art History:The Metropolitan Museum of Art* (2010). https://www.metmuseum.org/toah/hd/mtee/hd_mtee.htm

[8] Glenn Blauvelt, Tom Wrensch, and Michael Eisenberg. 1999. Integrating Craft Materials and Computation. In *Proceedings of the 3rd Conference on Creativity &Cognition* (Loughborough, United Kingdom) *(C&C '99)*. Association for Computing Machinery, New York, NY, USA, 50–56. https://doi.org/10.1145/317561.317572

[9] Virginia Braun and Victoria Clarke. 2013. *Successful qualitative research: A practical guide for beginners.* sage.

[10] Clare Browne. 2021. Afterward. In *English Medieval Embroidery: Opus Anglicanum*, Clare Woodthorpe Browne, Glyn Davies, Michael A Michael, and Michaela Zöschg (Eds.). Yale University Press.

[11] Kirstie Buckland. 1983. The Skenfrith Cope and Its Companions. *Textile History* 14, 2 (1983), 125–139. https://doi.org/10.1179/004049683793690543 arXiv:https://doi.org/10.1179/004049683793690543

[12] Leah Buechley and Michael Eisenberg. 2009. Fabric PCBs, electronic sequins, and socket buttons: techniques for e-textile craft. *Personal and Ubiquitous Computing* 13, 2 (2009), 133–150. https://doi.org/10.1007/s00779-007-0181-0

[13] Leah Buechley, Mike Eisenberg, Jaime Catchen, and Ali Crockett. 2008. The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Florence, Italy) *(CHI '08)*. Association for Computing Machinery, New York, NY, USA, 423–432. https://doi.org/10.1145/1357054.1357123

[14] Leah Buechley and Benjamin Mako Hill. 2010. LilyPad in the Wild: How Hardware's Long Tail is Supporting New Engineering and Design Communities. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems* (Aarhus, Denmark) *(DIS '10)*. Association for Computing Machinery, New York, NY, USA, 199–207. https://doi.org/10.1145/1858171.1858206

[15] Leah Buechley and Hannah Perner-Wilson. 2012. Crafting Technology: Reimagining the Processes, Materials, and Cultures of Electronics. *ACM Trans. Comput.-Hum. Interact.* 19, 3, Article 21 (oct 2012), 21 pages. https://doi.org/10.1145/2362364.2362369

[16] Giulia Chiostrini. 2015. Conserving the Saint Martin Series: Technical Analysis of Fifteenth-Century Embroideries. *The Metropolitan Museum of Art: Blog* (2015). https://www.metmuseum.org/blogs/now-at-the-met/2015/saint-martin-conservation

[17] Beginner's Mind Collective and David Shaw. 2012. Makey Makey: Improvising Tangible and Nature-Based User Interfaces. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction* (Kingston, Ontario, Canada) *(TEI '12)*. Association for Computing Machinery, New York, NY, USA, 367–370. https://doi.org/10.1145/2148131.2148219

[18] Tom Crook. 2009. Craft and the Dialogics of Modernity: The Arts and Crafts Movement in Late-Victorian and Edwardian England. *The Journal of Modern Craft* 2, 1 (2009), 17–32. https://doi.org/10.2752/174967809X416242 arXiv:https://doi.org/10.2752/174967809X416242

[19] Glyn Davies and M.A. Michael. 2021. Introduction. In *English Medieval Embroidery: Opus Anglicanum*, Clare Woodthorpe Browne, Glyn Davies, Michael A Michael, and Michaela Zöschg (Eds.). Yale University Press.

[20] Deepshikha and Pradeep Yammiyavar. 2018. Traditionally Crafted Digital Interfaces. In *Proceedings of the 2018 ACM International Conference on Interactive Surfaces and Spaces* (Tokyo, Japan) *(ISS '18)*. Association for Computing Machinery, New York, NY, USA, 387–392. https://doi.org/10.1145/3279778.3281462

[21] Laura Devendorf, Katya Arquilla, Sandra Wirtanen, Allison Anderson, and Steven Frost. 2020. *Craftspeople as Technical Collaborators: Lessons Learned through an Experimental Weaving Residency*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376820

[22] Laura Devendorf, Joanne Lo, Noura Howell, Jung Lin Lee, Nan-Wei Gong, M. Emre Karagozler, Shiho Fukuhara, Ivan Poupyrev, Eric Paulos, and Kimiko Ryokai. 2016. "I Don't Want to Wear a Screen": Probing Perceptions of and Possibilities for Dynamic Displays on Clothing. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 6028–6039. https://doi.org/10.1145/2858036.2858192

[23] Rania Elsayed and Sahar Ahmed. 2015. Tally Motifs as a contemporary fashion in designing upholstery fabrics. *International Journal of Innovation and Applied Studies* 11, 1 (2015), 167.

[24] Shreyosi Endow and Cesar Torres. 2021. "I'm Better Off on My Own": Understanding How a Tutorial's Medium Affects Physical Skill Development. In *Designing Interactive Systems Conference 2021* (Virtual Event, USA) *(DIS '21)*. Association for Computing Machinery, New York, NY, USA, 1313–1323. https://doi.org/10.1145/3461778.3462066

[25] Harun Er and Davut Gürel. 2020. Metallic Embroidery and Masters of Thread-Breaking as an Example of Cultural Heritage in Turkish Handicrafts. *Journal of History Culture and Art Research* 9, 2 (2020), 451–466. https://doi.org/10.7596/taksad.v9i2.2493

[26] George W. Fitzmaurice, Hiroshi Ishii, and William A. S. Buxton. 1995. Bricks: Laying the Foundations for Graspable User Interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '95)*. ACM Press/Addison-Wesley Publishing Co., USA, 442–449. https://doi.org/10.1145/223904.223964

[27] Raune Frankjær and Peter Dalsgaard. 2018. Understanding Craft-Based Inquiry in HCI. In *Proceedings of the 2018 Designing Interactive Systems Conference* (Hong Kong, China) *(DIS '18)*. Association for Computing Machinery, New York, NY, USA, 473–484. https://doi.org/10.1145/3196709.3196750

[28] Neil Gershenfeld. 2012. How to make almost anything: The digital fabrication revolution. *Foreign Aff.* 91 (2012), 43.

[29] Connie Golsteijn, Elise Van Den Hoven, David Frohlich, and Abigail Sellen. 2014. Hybrid crafting: towards an integrated practice of crafting with physical and digital components. *Personal and ubiquitous computing* 18, 3 (2014), 593–611. https://doi.org/10.1007/s00779-013-0684-9

[30] 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* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3173574.3173656

[31] Sarah Hayes and Trevor Hogan. 2020. Towards a Material Landscape of TUIs, Through the Lens of the TEI Proceedings 2008-2019. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Sydney NSW, Australia) *(TEI '20)*. Association for Computing Machinery, New York, NY, USA, 95–110. https://doi.org/10.1145/3374920.3374944

[32] Maria Hayward. 2007. Crimson, Scarlet, Murrey and Carnation: Red at the Court of Henry VIII. *Textile History* 38, 2 (2007), 135–150. https://doi.org/10.1179/004049607x229142 arXiv:https://doi.org/10.1179/004049607x229142

[33] Kate Heard. 2021. Ecclesiastical Embroidery in England from 1350 to the Reformation. In *English Medieval Embroidery: Opus Anglicanum*, Clare Woodthorpe Browne, Glyn Davies, Michael A Michael, and Michaela Zöschg (Eds.). Yale University Press.

[34] 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* (Seattle, Washington) *(ISWC '14 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 77–81. https://doi.org/10.1145/2641248.2641276

[35] Hiroshi Ishii and Brygg Ullmer. 1997. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA) *(CHI '97)*. Association for Computing Machinery, New York, NY, USA, 234–241. https://doi.org/10.1145/258549.258715

[36] Jennifer Jacobs, David Mellis, Amit Zoran, Cesar Torres, Joel Brandt, and Theresa Jean Tanenbaum. 2016. Digital Craftsmanship: HCI Takes on Technology as an Expressive Medium. In *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems* (Brisbane, QLD, Australia) *(DIS '16 Companion)*. Association for Computing Machinery, New York, NY, USA, 57–60. https://doi.org/10.1145/2908805.2913018

[37] Márta Járó. 1990. Gold embroidery and fabrics in europe: XI–XIV centuries. *Gold Bulletin* 23, 2 (1990), 40–57. https://doi.org/10.1007/BF03214711

[38] Gayithri Jayathirtha and Yasmin B. Kafai. 2020. Interactive Stitch Sampler: A Synthesis of a Decade of Research on Using Electronic Textiles to Answer the Who, Where, How, and What for K–12 Computer Science Education. *ACM Trans. Comput. Educ.* 20, 4, Article 28 (oct 2020), 29 pages. https://doi.org/10.1145/3418299

[39] Lee Jones and Audrey Girouard. 2021. Patching Textiles: Insights from Visible Mending Educators on Wearability, Extending the Life of Our Clothes, and Teaching Tangible Crafts. In *Creativity and Cognition* (Virtual Event, Italy) *(C&C '21)*. Association for Computing Machinery, New York, NY, USA, Article 36, 11 pages. https://doi.org/10.1145/3450741.3465265

[40] Lee Jones and Audrey Girouard. 2022. Learning with Stitch Samplers: Exploring Stitch Samplers as Contextual Instructions for E-textile Tutorials. In *Designing Interactive Systems Conference* (Virtual Event, Australia) *(DIS '22)*. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3532106.3533488

[41] Lee Jones, Sara Nabil, Amanda McLeod, and Audrey Girouard. 2020. Wearable Bits: Scaffolding Creativity with a Prototyping Toolkit for Wearable E-Textiles. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Sydney NSW, Australia) *(TEI '20)*. Association for Computing Machinery, New York, NY, USA, 165–177. https://doi.org/10.1145/3374920.3374954

[42] Lee Jones, Miriam Sturdee, Sara Nabil, and Audrey Girouard. 2021. Punch-Sketching E-Textiles: Exploring Punch Needle as a Technique for Sustainable, Accessible, and Iterative Physical Prototyping with E-Textiles. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 21, 12 pages. https://doi.org/10.1145/3430524.3440640

[43] Margaret Jourdain. 1912. *The history of English secular embroidery*. Dutton and Company.

[44] Márta Járó and Attila Tóth. 1991. Scientific identification of European metal thread manufacturing techniques of the 17–19th centuries. *Endeavour* 15, 4 (1991), 175–184. https://doi.org/10.1016/0160-9327(91)90124-T

[45] Hsin-Liu (Cindy) Kao, Christian Holz, Asta Roseway, Andres Calvo, and Chris Schmandt. 2016. DuoSkin: Rapidly Prototyping on-Skin User Interfaces Using Skin-Friendly Materials. In *Proceedings of the 2016 ACM International Symposium on Wearable Computers* (Heidelberg, Germany) *(ISWC '16)*. Association for Computing Machinery, New York, NY, USA, 16–23. https://doi.org/10.1145/2971763.2971777

[46] Marion Kite. 1989. The Conservation of the Jesse Cope. *Textile History* 20, 2 (1989), 235–243. https://doi.org/10.1179/004049689793700220 arXiv:https://doi.org/10.1179/004049689793700220

[47] Ebru Kurbak. 2018. *Stitching worlds: exploring textiles and electronics*. Revolver Publishing.

[48] Stacey Kuznetsov and Eric Paulos. 2010. Rise of the Expert Amateur: DIY Projects, Communities, and Cultures. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries* (Reykjavik, Iceland) *(NordiCHI '10)*. Association for Computing Machinery, New York, NY, USA, 295–304. https://doi.org/10.1145/1868914.1868950

[49] Frances Little. 1939. English Embroideries of the Stuart Period. *The Metropolitan Museum of Art Bulletin* 34, 7 (1939), 177–182. http://www.jstor.org/stable/3256544

[50] Joanne Lo, Cesar Torres, Isabel Yang, Jasper O'Leary, Danny Kaufman, Wilmot Li, Mira Dontcheva, and Eric Paulos. 2016. Aesthetic Electronics: Designing, Sketching, and Fabricating Circuits through Digital Exploration. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (Tokyo,

Japan) *(UIST '16)*. Association for Computing Machinery, New York, NY, USA, 665–676. https://doi.org/10.1145/2984511.2984579

[51] Márta Láró, Tamás Gál, and Attila Tóth. 2000. The Characterization and Deterioration of Modern Metallic Threads. *Studies in Conservation* 45, 2 (2000), 95–105. https://doi.org/10.1179/sic.2000.45.2.95 arXiv:https://doi.org/10.1179/sic.2000.45.2.95

[52] Chris A. Mack. 2011. Fifty Years of Moore's Law. *IEEE Transactions on Semiconductor Manufacturing* 24, 2 (2011), 202–207. https://doi.org/10.1109/TSM.2010.2096437

[53] Helen McCook. 2018. Goldwork. In *The Royal School of Needlework Book of Embroidery: A Guide to Essential Stitches, Techniques, and Projects*. Search Press.

[54] M.A. Michael. 2021. The Artistic Context of Opus Anglicanum. In *English Medieval Embroidery: Opus Anglicanum*, Clare Woodthorpe Browne, Glyn Davies, Michael A Michael, and Michaela Zöschg (Eds.). Yale University Press.

[55] M. A. Michael. 2017. Creating Cultural Identity: Opus anglicanum and its Place in the History of English Medieval Art. *Journal of the British Archaeological Association* 170, 1 (2017), 30–60. https://doi.org/10.1080/00681288.2017.1366714 arXiv:https://doi.org/10.1080/00681288.2017.1366714

[56] Md. Tahmidul Islam Molla, Crystal Compton, and Lucy E. Dunne. 2018. Launderability of Surface-Insulated Cut and Sew E-Textiles. In *Proceedings of the 2018 ACM International Symposium on Wearable Computers* (Singapore, Singapore) *(ISWC '18)*. Association for Computing Machinery, New York, NY, USA, 104–111. https://doi.org/10.1145/3267242.3267255

[57] Lisa Monnas. 1994. Opus Anglicanum and Renaissance Velvet: the Whalley Abbey Vestments. *Textile History* 25, 1 (1994), 3–27. https://doi.org/10.1179/004049694793712078 arXiv:https://doi.org/10.1179/004049694793712078

[58] Lisa Monnas. 2021. The Making of Medieval Embroidery. In *English Medieval Embroidery: Opus Anglicanum*, Clare Woodthorpe Browne, Glyn Davies, Michael A Michael, and Michaela Zöschg (Eds.). Yale University Press.

[59] Hedieh Moradi, Long N Nguyen, Quyen-Anh Valentina Nguyen, and Cesar Torres. 2022. Glaze Epochs: Understanding Lifelong Material Relationships within Ceramics Studios. In *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Daejeon, Republic of Korea) *(TEI '22)*. Association for Computing Machinery, New York, NY, USA, Article 4, 13 pages. https://doi.org/10.1145/3490149.3501310

[60] Argyro Moraiti, Vero Vanden Abeele, Erwin Vanroye, and Luc Geurts. 2015. Empowering Occupational Therapists with a DIY-Toolkit for Smart Soft Objects. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (Stanford, California, USA) *(TEI '15)*. Association for Computing Machinery, New York, NY, USA, 387–394. https://doi.org/10.1145/2677199.2680598

[61] Fabio Morreale, Giulio Moro, Alan Chamberlain, Steve Benford, and Andrew P. McPherson. 2017. Building a Maker Community Around an Open Hardware Platform. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 6948–6959. https://doi.org/10.1145/3025453.3026056

[62] Sara Nabil, Lee Jones, and Audrey Girouard. 2021. Soft Speakers: Digital Embroidering of DIY Customizable Fabric Actuators. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 11, 12 pages. https://doi.org/10.1145/3430524.3440630

[63] Sara Nabil, Jan Kučera, Nikoletta Karastathi, David S. Kirk, and Peter Wright. 2019. Seamless Seams: Crafting Techniques for Embedding Fabrics with Interactive Actuation. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 987–999. https://doi.org/10.1145/3322276.3322369

[64] Ken Nakagaki and Yasuaki Kakehi. 2012. Needle User Interface: A Sewing Interface Using Layered Conductive Fabrics. In *Adjunct Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology* (Cambridge, Massachusetts, USA) *(UIST Adjunct Proceedings '12)*. Association for Computing Machinery, New York, NY, USA, 1–2. https://doi.org/10.1145/2380296.2380298

[65] J. L. NEVINSON. 1939. ENGLISH DOMESTIC EMBROIDERY PATTERNS OF THE SIXTEENTH AND SEVENTEENTH CENTURIES. *The Volume of the Walpole Society* 28 (1939), 1–13. http://www.jstor.org/stable/41830878

[66] Brian D Newbury and Michael R Notis. 2004. The history and evolution of wiredrawing techniques. *Jom* 56, 2 (2004), 33–37. https://doi.org/10.1007/s11837-004-0142-2

[67] Tricia Wilson Nguyen. 2020. Scandal and Imprisonment: Gold Spinners of 17th Century England. *Hidden Stories/Human Lives: Proceedings of the Textile Society of America 17th Biennial Symposium, October 15-17, 2020* (2020). https://doi.org/10.32873/unl.dc.tsasp.0095

[68] Michael Nitsche, Andrew Quitmeyer, Kate Farina, Samuel Zwaan, and Hye Yeon Nam. 2014. Teaching Digital Craft. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI EA '14)*. Association for Computing Machinery, New York, NY, USA, 719–730. https://doi.org/10.1145/2559206.2578872

[69] The Royal School of Needlework. [n.d.]. Our History. https://royal-needlework.org.uk/our-history/

[70] Maggie Orth, Rehmi Post, and Emily Cooper. 1998. Fabric Computing Interfaces. In *CHI 98 Conference Summary on Human Factors in Computing Systems* (Los Angeles, California, USA) *(CHI '98)*. Association for Computing Machinery, New York, NY, USA, 331–332. https://doi.org/10.1145/286498.286800

[71] Minna Pakanen, Kasper Heiselberg, Troy Robert Nachtigall, Marie Broe, and Peter Gall Krogh. 2021. Crafting a Leather Self-Tracking Device for Pollen Allergies. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 96, 15 pages. https://doi.org/10.1145/3430524.3446072

[72] Hannah Perner-Wilson, Leah Buechley, and Mika Satomi. 2010. Handcrafting Textile Interfaces from a Kit-of-No-Parts. In *Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction* (Funchal, Portugal) *(TEI '11)*. Association for Computing Machinery, New York, NY, USA, 61–68. https://doi.org/10.1145/1935701.1935715

[73] Irene Posch. 2017. Crafting Tools for Textile Electronic Making. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI EA '17)*. Association for Computing Machinery, New York, NY, USA, 409–412. https://doi.org/10.1145/3027063.3052972

[74] Irene Posch. 2020. Burglar Alarm: More Than 100 Years of Smart Textiles. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS' 20 Companion)*. Association for Computing Machinery, New York, NY, USA, 473–476. https://doi.org/10.1145/3393914.3395847

[75] Irene Posch and Geraldine Fitzpatrick. 2018. Integrating Textile Materials with Electronic Making: Creating New Tools and Practices. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction* (Stockholm, Sweden) *(TEI '18)*. Association for Computing Machinery, New York, NY, USA, 158–165. https://doi.org/10.1145/3173225.3173255

[76] Irene Posch and Geraldine Fitzpatrick. 2021. The Matter of Tools: Designing, Using and Reflecting on New Tools for Emerging ETextile Craft Practices. *ACM Trans. Comput.-Hum. Interact.* 28, 1, Article 4 (feb 2021), 38 pages. https://doi.org/10.1145/3426776

[77] Irene Posch, Liza Stark, and Geraldine Fitzpatrick. 2019. ETextiles: Reviewing a Practice through Its Tool/Kits. In *Proceedings of the 23rd International Symposium on Wearable Computers* (London, United Kingdom) *(ISWC '19)*. Association for Computing Machinery, New York, NY, USA, 195–205. https://doi.org/10.1145/3341163.3347738

[78] E.R. Post and M. Orth. 1997. Smart fabric, or "wearable clothing". In *Digest of Papers. First International Symposium on Wearable Computers*. 167–168. https://doi.org/10.1109/ISWC.1997.629937

[79] Ernest Rehmatulla Post, Maggie Orth, Peter R Russo, and Neil Gershenfeld. 2000. E-broidery: Design and fabrication of textile-based computing. *IBM Systems journal* 39, 3.4 (2000), 840–860. https://doi.org/10.1147/sj.393.0840

[80] Ivan Poupyrev, Nan-Wei Gong, Shiho Fukuhara, Mustafa Emre Karagozler, Carsten Schwesig, and Karen E. Robinson. 2016. Project Jacquard: Interactive Digital Textiles at Scale. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 4216–4227. https://doi.org/10.1145/2858036.2858176

[81] Narjes Pourjafarian, Marion Koelle, Bruno Fruchard, Sahar Mavali, Konstantin Klamka, Daniel Groeger, Paul Strohmeier, and Jürgen Steimle. 2021. BodyStylus: Freehand On-Body Design and Fabrication of Epidermal Interfaces. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 504, 15 pages. https://doi.org/10.1145/3411764.3445475

[82] Thomas Preindl, Cedric Honnet, Andreas Pointner, Roland Aigner, Joseph A. Paradiso, and Michael Haller. 2020. *Sonoflex: Embroidered Speakers Without Permanent Magnets*. Association for Computing Machinery, New York, NY, USA, 675–685. https://doi.org/10.1145/3379337.3415888

[83] Jie Qi, Leah Buechley, Andrew "bunnie" Huang, Patricia Ng, Sean Cross, and Joseph A. Paradiso. 2018. Chibitronics in the Wild: Engaging New Communities in Creating Technology with Paper Electronics. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–11. https://doi.org/10.1145/3173574.3173826

[84] Jie Qi, Andrew "bunnie" Huang, and Joseph Paradiso. 2015. Crafting Technology with Circuit Stickers. In *Proceedings of the 14th International Conference on Interaction Design and Children* (Boston, Massachusetts) *(IDC '15)*. Association for Computing Machinery, New York, NY, USA, 438–441. https://doi.org/10.1145/2771839.2771873

[85] Daniela K. Rosner. 2012. The Material Practices of Collaboration. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work* (Seattle, Washington, USA) *(CSCW '12)*. Association for Computing Machinery, New York, NY, USA, 1155–1164. https://doi.org/10.1145/2145204.2145375

[86] Rose Dahlina Rusli and Norwani Md Nawawi. 2016. Uniqueness of Malay Traditional Embroidery: Kelingkan. In *Proceedings of the 2nd International Colloquium of Art and Design Education Research (i-CADER 2015)*. Springer, 625–635. https://doi.org/10.1007/978-981-10-0237-3_63

[87] Kay Staniland. 1989. The Great Wardrobe Accounts as a Source for Historians of Fourteenth-Century Clothing and Textiles. *Textile History* 20, 2 (1989), 275–281. https://doi.org/10.1179/004049689793700329 arXiv:https://doi.org/10.1179/004049689793700329

[88] Leanne C Tonkin. 2012. Insights into the Production of Opus Anglicanum: An Object Analysis of Two Panels from the Pillar Orphreys on the Whalley Abbey Altar Frontal. *Textile History* 43, 1 (2012), 83–89. https://doi.org/10.1179/174329512X13284471321280 arXiv:https://doi.org/10.1179/174329512X13284471321280

[89] Gertrude Townsend. 1956. Notes on Embroideries Worked with Gold and Silver Thread. *Bulletin of the Museum of Fine Arts* 54, 297 (1956), 67–75. http://www.jstor.org/stable/4171245

[90] Victoria and Albert Museum. [n.d.]. Arts and Crafts: an introduction. https://www.vam.ac.uk/articles/arts-and-crafts-an-introduction

[91] Victoria and Albert Museum. [n.d.]. Embroidery styles: An illustrated guide. https://www.vam.ac.uk/articles/embroidery-styles-an-illustrated-guide

[92] Victoria and Albert Museum. [n.d.]. Opus Anglicanum: Masterpieces of English Medieval Embroidery. https://www.vam.ac.uk/exhibitions/opus-anglicanum-masterpieces-of-english-medieval-embroidery

[93] Alexandra Walsham. 2017. Recycling the Sacred: Material Culture and Cultural Memory after the English Reformation. *Church History* 86, 4 (2017), 1121–1154. https://doi.org/10.1017/S0009640717002074

[94] Patricia Wardle. 2006. A Rare Survival: The Barge Cloth of the Worshipful Company of Pewterers and the Embroiderer John Best. *Textile History* 37, 1 (2006), 1–16. https://doi.org/10.1179/004049606x94440 arXiv:https://doi.org/10.1179/004049606x94440

[95] Melinda Watt. 2010. English Embroidery of the Late Tudor and Stuart Eras. *Heilbrunn Timeline of Art History:The Metropolitan Museum of Art* (2010). https://www.metmuseum.org/toah/hd/broi/hd_broi.htm

[96] Mark Weiser. 1999. The Computer for the 21st Century. *SIGMOBILE Mob. Comput. Commun. Rev.* 3, 3 (jul 1999), 3–11. https://doi.org/10.1145/329124.329126

[97] Shanel Wu and Laura Devendorf. 2020. *Unfabricate: Designing Smart Textiles for Disassembly*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376227

[98] Clement Zheng and Michael Nitsche. 2017. Combining Practices in Craft and Design. In *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction* (Yokohama, Japan) *(TEI '17)*. Association for Computing Machinery, New York, NY, USA, 331–340. https://doi.org/10.1145/3024969.3024973