Demonstrating Fabric-Based Breadboards as Women-Centered Prototyping Tools for E-Textile LED Circuits

Salma Ibrahim
School of Computing, iStudio Lab
Queen's University
Kingston, Ontario, Canada
salma.ibrahim@queensu.ca

Pouya M Khorsandi
Queen's University
Kingston, Ontario, Canada
20pmk2@queensu.ca

Janevra Pier
School of Computing
Queen's University
Kingston, Ontario, Canada
janevra.pier@queensu.ca

Jannah Sultan
iStudio Lab
Queens University
Kingston, Ontario, Canada
jannah.sultan@queensu.ca

Sara Nabil
iStudio Lab
Queen's University
Kingston, Ontario, Canada
sara.nabil@queensu.ca

Figure 1: We explore the design of 'FabricBoards' for prototyping and testing wearable components using various textile crafts for creating FabricBoards through sewing, quilting, layering, weaving, knitting, felting, and embroidering.

Abstract

E-textile circuit prototyping presents unique challenges, as current electronic prototyping tools are often rigid and incompatible with the flexible nature of fabric. In this demo, we present FabricBoards, a set of fabric-based breadboards designed for e-textile LED circuits, by women, for women. FabricBoards reimagine the solderless breadboard in a textile-based form, using tools and materials native to textile crafting, making them inviting and accessible to historically underrepresented makers. We explore various textile crafts, including machine sewing, felting, knitting, crocheting, digital embroidery, and weaving, culminating in a set of design artifacts that demonstrate a bridging gap between craft and electronics practices while offering an accessible entry point for diverse makers.

CHI EA '26, Barcelona, Spain

ACM ISBN 979-8-4007-2281-3/26/04
https://doi.org/10.1145/3772363.3799138

CCS Concepts

• Human-centered computing → Human computer interaction (HCI); **• Hardware →** *Emerging interfaces.*

Keywords

e-textile; rapid prototyping; fabric; breadboard; weaving; felting; machine-sewing; crochet; knit; fabrication; hybrid craft; physical computing; women; girls; inclusive; STEM

ACM Reference Format:
Salma Ibrahim, Pouya M Khorsandi, Janevra Pier, Jannah Sultan, and Sara Nabil. 2026. Demonstrating Fabric-Based Breadboards as Women-Centered Prototyping Tools for E-Textile LED Circuits. In *Extended Abstracts of the 2026 CHI Conference on Human Factors in Computing Systems (CHI EA '26), April 13–17, 2026, Barcelona, Spain.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3772363.3799138

1 Introduction

E-textile is an expanding area of wearable computing in HCI, where fabrics are embedded with electronic components to create interactive garments [24, 51, 58, 59] and everyday things [24, 32, 41], yet a persistent challenge lies in supporting rapid and flexible prototyping [22, 29, 31, 36]. While solderless breadboards play a central role in traditional electronics for experimentation, testing, and debugging, comparable tools in e-textiles remain limited [22, 44], particularly for makers from non-privileged demographics [19, 50] who must navigate challenges of material compatibility, visual hierarchy, and aesthetics [44, 53]. Existing e-textile prototyping solutions [22, 37, 42] often depend on non-textile-native components [22] or impose rigid structures that conflict with the softness, flexibility, and drape of fabric [34, 37].

HCI literature positions textile crafts as a pathway to broaden participation and foster gender inclusivity in computing [35], yet prior work has identified limitations in the hardware design of commercial e-textile kits from an inclusive design perspective [47]. In response, we use textile-native materials and connections that align with established textile craft practices (e.g., stitching, weaving, embroidery), leveraging familiar tools, tacit skills, and the inherent qualities of fabric, rather than forcing textiles to accommodate standard electronic components such as rigid tools and breadboards [44]. To address this gap, we adopt a Research through Design (RtD) approach to develop FabricBoards as fully fabric-based prototyping boards for e-textile LED circuits that draw inspiration from prior breadboard explorations [22, 37, 42, 60] while reframing electronics prototyping as a craft-native and material-driven practice.

2 Background

Prior HCI work has extensively investigated breadboards as tools for rapid prototyping, spanning software tools for ideation and simulation [38, 39], to physical and hybrid reinterpretations that expose connections, support visual debugging, or adopt unconventional materials and form factors [4, 14, 33, 43, 54]. Educational designs such as EdBoard [57] and BitBlox [11] aim to reduce the opacity of traditional solderless breadboards by exposing internal connections or modularizing circuitry, addressing challenges also noted in ThreadBoard [22]; however, most breadboards remain rigid and plastic-based, making them poorly suited to the soft nature of textiles [6, 22]. E-textile construction kits, such as the LilyPad Arduino [7] and subsequent toolkits [5, 26, 27, 29], have enabled accessible entry points for integrating electronics into fabric, while prior work like TeeBoard [42] and ThreadBoard [22] attempt to support rapid prototyping via snaps or magnets, though often at the cost of flexibility, reusability, or seamless fabric integration [53]. Much of this work has centered able-bodied, often male users [19, 50] or children [47], with limited inclusion of women and disabled makers [19], despite broader calls to support gender equity, aesthetic expression, and individualism in making [50] and rare efforts to engage women in e-textile practices [30]. In parallel, research on hybrid textile crafts has explored hand-stitched [40, 56], machine-sewn [16, 25], and other textile modalities including embroidery [28], crocheting [21], knitting [36], felting [15], and weaving [1], yet rarely in the context of breadboards as a design space. Responding to Posch's call for tools that "*bring e-textile artefacts into being*" within a fragmented toolkit landscape [44], this work situates fabric breadboards at the intersection of unconventional breadboards, inclusive e-textile tools, and hybrid textile crafts.

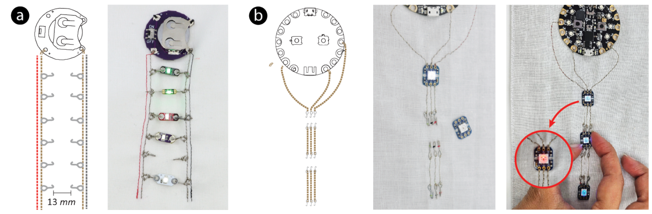

Figure 2: Machine-sewn FabricBoards: (a) FB1 with a battery and hooked LEDs, and (b) FB2 supports RGB LEDs through a microcontroller.

3 Fabrication Methods

In our full paper [23], we adopted a Research through Design (RtD) approach [46, 62] and an iterative design process to explore different fabrication methods. This process resulted in a collection of fabric-based breadboards suitable for women, craft practitioners, diverse audience, and beginners to e-textile prototyping.

3.1 Machine-Sewing with Hooks

Inspired by recent research [16, 25], we explored machine-sewing as an accessible craft-based fabrication method. Our first demo, FB1 (Figure 2a), includes a switchable coin cell battery holder connected to a set of conductive hooks with colour-coded seams (red for power and black for ground) via machine-sewn conductive traces. We used accessible fabric-friendly materials, with a neat finish, offering quick connections in a creative way with high visual clarity, and require no customization of electronic components. In the second demo, FB2 (Figure 2b), we integrate a sewable microcontroller (Adafruit Circuit Playground Express) and RGB addressable LEDs (NeoPixels), commonly used in e-textile projects [3, 52, 55], using hook 'terminals'.

3.2 Quilting: FishBoard and ButterflyBoard

Drawing inspiration from quilting techniques, we extended machine-sewn FabricBoards and designed expressive forms and textures to create two quilted boards: the FishBoard and the ButterflyBoard, shown in Figure 3. Constructed like quilts, each board consists of three layers: a top appliquéd fabric layer using scrap materials, a middle insulating batting layer, and a backing fabric. The use of scrap and recycled materials in this approach contributes to the growing body of HCI research on sustainable textiles [17, 61]. Decorative and functional stitching was used to secure the layers and integrate pairs of conductive seams with hooks and eyes, along with a switchable battery stitched to the back.

3.3 Layering: GridBoard

This technique draws on 'fabric layering' practices, where a semi-transparent overlay is combined with a functional base layer to create a composite textile with both visual appeal (in the overlay) and structural complexity or functional utility (in the underlay). Many e-textile applications require 2D layouts to illuminate specific shapes or visual elements [2, 6, 10, 63]. Inspired by this need, we demo the GridBoard as a horizontal expansion of the circuit layout, featuring a 13×6 grid (Figure 4a). To complement this structure

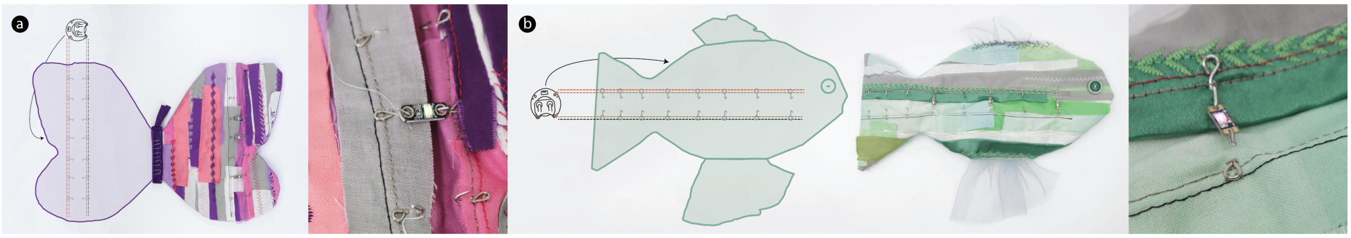

Figure 3: Quilted FabricBoards. Front view with circuit diagram and LED close-up of: (a) ButterflyBoard and (b) FishBoard.

and support creative flexibility, we designed themed overlays such as 'Peas in a Pod' (Figure 4b–c) and 'Starfish' (Figure 4d–e), which conceal the circuit layout and guide complex LED placement. These overlays allow makers to prototype, plan, and test 2D designs.

3.4 FeltBoard

We used needle felting as a fabrication method [15] for creating a textile breadboard, using 100% Merino wool (carded and combed) for the base layered on a 9" × 12" white 100% polyester Tailor craft felt sheet for stability. For the connection paths, we used Merinox conductive fibre. Two parallel paths were felted to serve as power and ground, with red fibre added to mark the power line, as seen in Figure 5a. Short circuits can occur due to the nature of the material as felted conductive fibres are prone to friction with felting needles and tend to interlock, catch, and bridge unintentionally. These issues can be mitigated by twisting the conductive fibres before felting, holding the fibre bundle in hand (rather than placing it on the felt), and keeping the felted sheet on the sponge while working, rather than lifting or shifting it. With these precautions, we achieved reliable results on layouts with aesthetic richness (Figure 5b).

3.5 CrochetBoard

To explore hand crochet as a fabrication method, we used a 2*mm* crochet hook to crochet a FabricBoard of three pairs of 10*cm* long connection paths with single crochet stitches, each using a different combination of conductive strands, see Figure 5c–d. Samples 1 and 3 were quick and easy to connect to, while Sample 2 (using conductive fancy yarn [24]) was unreliable due to the conductive thread being embedded and difficult to access. Sample 1 offered the most reliable and convenient connection due to a larger conductive surface area, though it consumed more conductive thread than Sample 3. On the crochetBoard, both sewing pins and earring studs work well with sewable components such as LEDs, sensors, and battery holders.

3.6 KnitBoard

For knitted FabricBoards, we used both hand-knitting and machine-knitting techniques. For hand-knitting, we used 4*mm* needles and thick polyester yarn, creating two conductive connection paths over a length of 10*cm* with a garter stitch (Figure 5e). Sample 1, utilizing a hand-spun conductive fibre (50-50 blue Merino wool), proved unreliable due to inconsistent surface exposure of the conductive fibres. Sample 2 combined non-conductive red yarn with conductive thread, which was difficult to knit and similarly unreliable. These limitations prompted us to explore machine-knitting for tighter, more consistent results (see Figure 5f). We designed edge-to-edge connection paths, which would be more suitable than inlay techniques for functional breadboard layouts, using a size 6 front-bed stitch on a Kniterate machine using with Madeira HC12 conductive thread. Using the plating technique refined our fabrication method and improved conductivity by bringing the conductive yarn directly to the fabric's surface.

3.7 WovenBoard

The WovenBoard demo (Figure 5g,h) was made using a computational Jacquard loom. Using AdaCAD [13], we designed a weaving draft that mimics a breadboard layout, which included four vertical conductive columns and two horizontal double-layer weft inlay traces, repeated five times and varied by weaving structure (tabby, twill, satin, shaded satin) and conductive material (Madeira HC12, HC40, or textured sperged yarn [24]). The vertical paths used an alternating conductive thread and colour-coded supplementary warp (red for power, black for ground). After weaving, the fabric ends were finished with a decorative fringe, allowing the four vertical conductive paths to serve as attachment points for power and ground. Electrical performance was strong across the ten inlay paths with supplementary warp paths (Sample 3) showing a higher resistance due to partial insulation from the shuttle weft. Despite this, the vertical power and ground paths supported up to 8 LEDs using a 3V coin cell battery, secured with release knots.

3.8 EmbroideredBoard

We applied established methods for digitally-embroidered circuits [32, 45] to design a cotton fabric breadboard featuring three pairs of connection paths (Figure 5i) outlined with a running stitch to colour-code power and ground. We used Madeira HC40 conductive thread and tested three 10*cm* samples with different stitches. Sample 3 (horizontal step stitch) outperformed both satin stitches of Samples 1 and 2 in terms of electrical conductivity, while also using less conductive material and, thus, generating less e-waste. We further expanded the aesthetic possibilities of embroidery, freeing paths from the grid layout of straight lines into creative curved shapes in the *SnailBoard* (Figure 5j). Embroidered stitches demonstrated superior structural integrity, appearing tighter, more uniform, and mechanically stable than the looser knit, compressible crochet, or lower-density woven paths.

Figure 4: (a) GridBoard with "Peas in a Pod" and "Starfish" (b, d) designs on fabric overlays placed on top of the GridBoard (c, e).

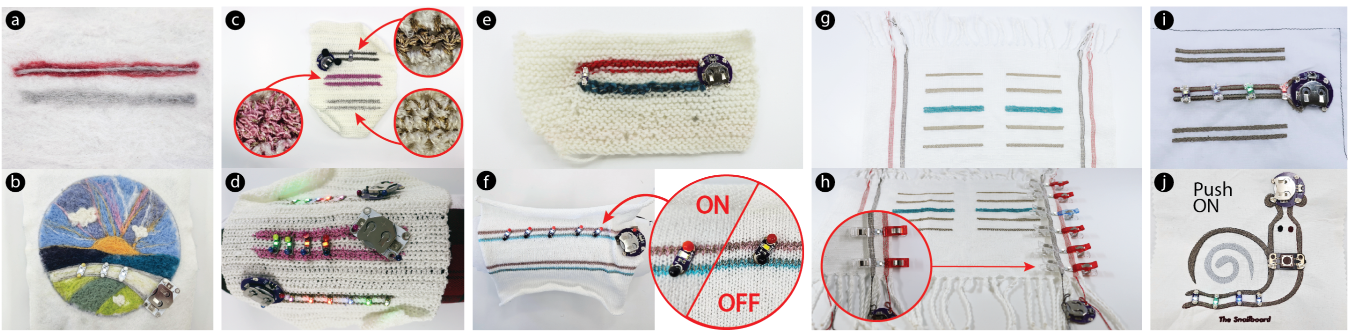

Figure 5: FabricBoard Demos: a) FeltBoard; b) with aesthetically rich design possibilities; c) CrochetBoard; d) with LEDs in a circuit connected using sewing pins; e) KnitBoard; f) with machine-knitting; g) WovenBoard resembling the solderless breadboard layout; h) an LED circuit connected to it using sewing clips; i) EmbroideredBoard; j) supporting creative shapes.

4 Discussion

Building on the Computational Making Framework [49], our work argues for rethinking breadboards as textile-native, materially expressive, and inclusive prototyping tools rather than neutral technical substrates. Prior HCI research has shown that aesthetics, creativity, constructing, and visual clarity are central yet often undervalued dimensions of computational making, particularly in tools historically shaped by male-dominated electronics cultures [50]. Fabric-based breadboards foreground aesthetics as a core design consideration, challenging the visual clutter and intimidation associated with jumper wires and alligator clips, and aligning with long-standing evidence that craft-oriented materials can broaden participation in computing [35]. The flexibility and drapability of textiles enable new creative configurations beyond rigid grid layouts, supporting in-situ, curved, and soft-surface prototyping that is difficult to achieve with traditional methods such as alligator clips [9] or stitched conductive traces [16], while extending prior work on e-textile ideation toward prototyping and testing [29].

Emphasizing ease of construction and replication, fabric-based breadboards leverage off-the-shelf sewable components and accessible craft techniques, avoiding the need for custom-modified hardware common in earlier work [22, 42], and supporting modular reconfiguration. Visual clarity is embedded directly into the material through textile techniques such as colour-coding and structural patterning, extending earlier alternative breadboards [22, 37, 42, 60] and reducing cognitive load during circuit assembly. From a materiality perspective, this work expands explorations of unconventional breadboards beyond plastic, garments, or leather [22, 37, 42] to include diverse textile crafts, aligning with research that positions materials as active contributors to meaning-making and design reasoning [18, 20, 48]. Finally, we argue that inclusivity and sustainability (that are absent from the original Computational Making Framework [49]) are essential dimensions for future prototyping tools that support embodied and tactile accessibility [44, 56], resonating with inclusive e-textile design practices [8, 12], and enabling more sustainable prototyping by reducing reliance on disposable conductive materials and alligator wires [1, 17, 31, 61].

5 Conclusion

This work demonstrates FabricBoards as a design exploration of fabric-based breadboards that reimagine e-textile prototyping through a Research through Design approach. Rather than proposing a single optimized solution, FabricBoards foreground materiality as a central design concern, showing how textile-native materials and construction methods shape interaction, accessibility, and expressiveness in circuit prototyping. Through iterative experimentation across a range of textile crafts (including machine sewing, crochet, knitting, weaving, felting, and digital embroidery) we demonstrate how different textile structures afford distinct forms of connectivity, flexibility and visual clarity revealing trade-offs inherent to each textile craft. By grounding electronic tools in Hybrid Craft research, this work expands the design space of e-textile prototyping tools and argues for inclusive and textile-native alternatives that better align with the practices and constraints of textile-based electronics.

Acknowledgments

This project was funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant (2021-04135). The iStudio equipment was funded by the Canada Foundation for Innovation - John R. Evans Leaders Fund (CFI-JELF: 41215), Ontario Research Fund, and the NSERC RTI (Research Tools and Instruments) Grant (2021-00079).

References

[1] Ahmed Awad, Salma Ibrahim, and Sara Nabil. 2025. WovenCircuits: A 3-Step Fabrication Process for Weaving Electric Circuit Layouts in Everyday Artefacts. In *Proceedings of the 2025 ACM Designing Interactive Systems Conference (DIS '25)*. Association for Computing Machinery, New York, NY, USA, 2428–2444. https://doi.org/10.1145/3715336.3735696

[2] Fiona Bell, Alice Hong, Andreea Danielescu, Aditi Maheshwari, Ben Greenspan, Hiroshi Ishii, Laura Devendorf, and Mirela Alistar. 2021. Self-deStaining Textiles: Designing Interactive Systems with Fabric, Stains and Light. 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 631, 12 pages. https://doi.org/10.1145/3411764.3445155

[3] Mary Ellen Berglund, Esther Foo, Md. Tahmidul Islam Molla, Smitha Muthya Sudheendra, Crystal Compton, and Lucy E. Dunne. 2018. MAKE IT BLUE: a controllable, color-changing dynamic costume. In *Proceedings of the 2018 ACM International Symposium on Wearable Computers* (Singapore, Singapore) *(ISWC '18)*. Association for Computing Machinery, New York, NY, USA, 236–241. https://doi.org/10.1145/3267242.3267304

[4] Anke Brocker, Simon Voelker, Tony Zelun Zhang, Mathis Müller, and Jan Borchers. 2019. Flowboard: A Visual Flow-Based Programming Environment for Embedded Coding. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–4. https://doi.org/10.1145/3290607.3313247

[5] Leah Buechley. 2006. A Construction Kit for Electronic Textiles. In *2006 10th IEEE International Symposium on Wearable Computers*. IEEE, Montreux, Switzerland, 83–90. https://doi.org/10.1109/ISWC.2006.286348

[6] 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

[7] 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

[8] 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

[9] Leah Buechley and Kanjun Qiu. 2013. *Sew Electric*. HLT Press, USA.

[10] Sylvia H. Cheng, Kibum Kim, and Roel Vertegaal. 2011. TagURit: a proximity-based game of tag using lumalive e-textile displays. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI EA '11)*. Association for Computing Machinery, New York, NY, USA, 1147–1152. https://doi.org/10.1145/1979742.1979707

[11] Kayla DesPortes, Aditya Anupam, Neeti Pathak, and Betsy DiSalvo. 2016. BitBlox: A Redesign of the Breadboard. In *Proceedings of the The 15th International Conference on Interaction Design and Children* (Manchester, United Kingdom) *(IDC '16)*. Association for Computing Machinery, New York, NY, USA, 255–261. https://doi.org/10.1145/2930674.2930708

[12] Laura Devendorf and Daniela K. Rosner. 2017. Beyond Hybrids: Metaphors and Margins in Design. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (Edinburgh, United Kingdom) *(DIS '17)*. Association for Computing Machinery, New York, NY, USA, 995–1000. https://doi.org/10.1145/3064663.3064705

[13] Laura Devendorf, Kathryn Walters, Marianne Fairbanks, Etta Sandry, and Emma R Goodwill. 2023. AdaCAD: Parametric Design as a New Form of Notation for Complex Weaving. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 127, 18 pages. https://doi.org/10.1145/3544548.3581571

[14] Daniel Drew, Julie L. Newcomb, William McGrath, Filip Maksimovic, David Mellis, and Björn Hartmann. 2016. The Toastboard: Ubiquitous Instrumentation and Automated Checking of Breadboarded Circuits. 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, 677–686. https://doi.org/10.1145/2984511.2984566

[15] Eleni Economidou. 2025. This Is How I Felt: Crafting Conductive Wool Artefacts as an Embodied Practice to Regulate Anxiety. In *Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '25)*. Association for Computing Machinery, New York, NY, USA, Article 71, 7 pages. https://doi.org/10.1145/3689050.3706011

[16] Yifan Feng, Shengyuehui Li, Hanlin Zhang, Weihong Tang, Josephine E. McCaffrey, Bea S. Wohl, and Jennifer A. Rode. 2025. SewSimple: An E-textile Prototyping Kit for Computational Making with BBC micro:bit. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25)*. Association for Computing Machinery, New York, NY, USA, Article 474, 9 pages. https://doi.org/10.1145/3706599.3720262

[17] Sarah Fletcher, Bennett Graff, Eunjin Hong, and Vishaka Nirmal. 2025. WEFT Furniture. In *Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '25)*. Association for Computing Machinery, New York, NY, USA, Article 117, 5 pages. https://doi.org/10.1145/3689050.3707700

[18] Elisa Giaccardi and Elvin Karana. 2015. Foundations of Materials Experience: An Approach for HCI. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 2447–2456. https://doi.org/10.1145/2702123.2702337

[19] Emilie Giles, Janet van der Linden, and Marian Petre. 2018. Weaving Lighthouses and Stitching Stories: Blind and Visually Impaired People Designing 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, 1–12. https://doi.org/10.1145/3173574.3174044

[20] Shad Gross, Jeffrey Bardzell, and Shaowen Bardzell. 2014. Structures, Forms, and Stuff: The Materiality and Medium of Interaction. *Personal and Ubiquitous Computing* 18, 3 (March 2014), 637–649. https://doi.org/10.1007/s00779-013-0689-4

[21] Kaja Seraphina Elisa Hano and Valkyrie Savage. 2024. Hybrid Crochet: Exploring Integrating Digitally-Fabricated and Electronic Materials with Crochet. In *Proceedings of the Eighteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Cork, Ireland) *(TEI '24)*. Association for Computing Machinery, New York, NY, USA, Article 76, 6 pages. https://doi.org/10.1145/3623509.3635257

[22] Chris Hill, Michael Schneider, Ann Eisenberg, and Mark D. Gross. 2021. The ThreadBoard: Designing an E-Textile Rapid Prototyping Board. 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 23, 7 pages. https://doi.org/10.1145/3430524.3440642

[23] Salma Ibrahim, Pouya M. Khorsandi, Janevra Pier, Jannah Sultan, and Sara Nabil. 2026. FabricBoards: Utilizing Craft Techniques for Inclusive Prototyping of E-Textile LED Circuits with Fabric-Based Breadboards. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems* (Barcelona, Spain) *(CHI '26)*. Association for Computing Machinery, New York, NY, USA, 22 pages. https://doi.org/10.1145/3772318.3790342

[24] Salma Ibrahim and Sara Nabil. 2025. E-Serging: Exploring the Use of Overlockers (Sergers) in Creating E-Textile Seams and Interactive Yarns for Garment Making, Embroidery, and Weaving. In *Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '25)*. Association for Computing Machinery, New York, NY, USA, Article 41, 17 pages. https://doi.org/10.1145/3689050.3704428

[25] Salma Ibrahim and Sara Nabil. 2025. E-Sewing: Exploring the Design Space of Machine-Sewing E-Textile Circuits. In *Proceedings of the 2025 ACM Designing Interactive Systems Conference* (Funchal, Portugal) *(DIS '25)*. Association for Computing Machinery, New York, NY, USA, 17 pages. https://doi.org/10.1145/3715336.3735416

[26] Ben Jelen, Anne Freeman, Mina Narayanan, Kate M. Sanders, James Clawson, and Katie A. Siek. 2019. Craftec: Engaging Older Adults in Making through a Craft-Based Toolkit System. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Tempe, Arizona, USA) *(TEI '19)*. Association for Computing Machinery, New York, NY, USA, 577–587. https://doi.org/10.1145/3294109.3295636

[27] Lee Jones and Audrey Girouard. 2022. Learning with Stitch Samplers: Exploring Stitch Samplers as Contextual Instructions for E-textile Tutorials. In *Proceedings of the 2022 ACM Designing Interactive Systems Conference* (Virtual Event, Australia) *(DIS '22)*. Association for Computing Machinery, New York, NY, USA, 949–965. https://doi.org/10.1145/3532106.3533488

[28] Lee Jones and Sara Nabil. 2022. Goldwork Embroidery: Interviews with Practitioners on Working with Metal Threads and Opportunities for E-textile Hybrid Crafts. In *Proceedings of the 14th Conference on Creativity and Cognition* (Venice, Italy) *(C&C '22)*. Association for Computing Machinery, New York, NY, USA,

364–379. https://doi.org/10.1145/3527927.3532809

[29] 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

[30] Lee Jones, Alaa Nousir, Renee (Xinyu) Chen, Anne Liu, Meara Donovan, Eliza Wallace, and Sara Nabil. 2023. Making From Home: Reflections on Crafting Tangible Interfaces for Stay-at-home Living. In *Proceedings of the Seventeenth International Conference on Tangible, Embedded, and Embodied Interaction* (Warsaw, Poland) *(TEI '23)*. Association for Computing Machinery, New York, NY, USA, Article 13, 16 pages. https://doi.org/10.1145/3569009.3572744

[31] 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

[32] Pouya M Khorsandi, Lee Jones, Vandad Davoodnia, Timothy J Lampen, Aliya Conrad, Ali Etemad, and Sara Nabil. 2023. FabriCar: Enriching the User Experience of In-Car Media Interactions with Ubiquitous Vehicle Interiors using E-textile Sensors. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference* (Pittsburgh, PA, USA) *(DIS '23)*. Association for Computing Machinery, New York, NY, USA, 1438–1456. https://doi.org/10.1145/3563657.3595988

[33] Yoonji Kim, Hyein Lee, Ramkrishna Prasad, Seungwoo Je, Youngkyung Choi, Daniel Ashbrook, Ian Oakley, and Andrea Bianchi. 2020. SchemaBoard: Supporting Correct Assembly of Schematic Circuits using Dynamic In-Situ Visualization. In *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology* (Virtual Event, USA) *(UIST '20)*. Association for Computing Machinery, New York, NY, USA, 987–998. https://doi.org/10.1145/3379337.3415887

[34] Donghyeon Ko, Yoonji Kim, Junyi Zhu, Michael Wessely, and Stefanie Mueller. 2023. FlexBoard: A Flexible Breadboard for Interaction Prototyping on Curved and Deformable Surfaces. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 733, 13 pages. https://doi.org/10.1145/3544548.3580748

[35] Ji Sun Lee. 2008. Technology education for woman by d.i.y. technology in closing gender gap. In *CHI '08 Extended Abstracts on Human Factors in Computing Systems* (Florence, Italy) *(CHI EA '08)*. Association for Computing Machinery, New York, NY, USA, 3447–3452. https://doi.org/10.1145/1358628.1358872

[36] Yifan Li, Ryo Takahashi, Wakako Yukita, Kanata Matsutani, Cedric Caremel, Yuhiro Iwamoto, Sunghoon Lee, Tomoyuki Yokota, Takao Someya, and Yoshihiro Kawahara. 2025. Plug-n-play e-knit: prototyping large-area e-textiles using machine-knitted magnetically-repositionable sensor networks. In *Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '25)*. Association for Computing Machinery, New York, NY, USA, Article 56, 7 pages. https://doi.org/10.1145/3689050.3705973

[37] Yujun Lin and Jeyeon Jo. 2024. LeatherBoard: Sustainable On-body Rapid Prototyping with Leather Scraps and Machine Embroidery. In *Extended Abstracts of the 2024 CHI Conference on Human Factors in Computing Systems (CHI EA '24)*. Association for Computing Machinery, New York, NY, USA, Article 221, 7 pages. https://doi.org/10.1145/3613905.3650894

[38] 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

[39] Jo-Yu Lo, Da-Yuan Huang, Tzu-Sheng Kuo, Chen-Kuo Sun, Jun Gong, Teddy Seyed, Xing-Dong Yang, and Bing-Yu Chen. 2019. AutoFritz: Autocomplete for Prototyping Virtual Breadboard Circuits. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3290605.3300633

[40] Emily Lovell and Leah Buechley. 2010. An e-sewing tutorial for DIY learning. In *Proceedings of the 9th International Conference on Interaction Design and Children* (Barcelona, Spain) *(IDC '10)*. Association for Computing Machinery, New York, NY, USA, 230–233. https://doi.org/10.1145/1810543.1810578

[41] 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

[42] Grace Ngai, Stephen C.F. Chan, Joey C.Y. Cheung, and Winnie W.Y. Lau. 2009. The TeeBoard: an education-friendly construction platform for e-textiles and wearable computing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Boston, MA, USA) *(CHI '09)*. Association for Computing Machinery, New York, NY, USA, 249–258. https://doi.org/10.1145/1518701.1518742

[43] Yoichi Ochiai. 2014. Visible Breadboard: System for Dynamic, Programmable, and Tangible Circuit Prototyping with Visible Electricity. In *Proceedings of the 6th International Conference on Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality - Volume 8526*. Springer-Verlag, Berlin, Heidelberg, 73–84. https://doi.org/10.1007/978-3-319-07464-1_7

[44] 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

[45] Thomas Preindl, Cedric Honnet, Andreas Pointner, Roland Aigner, Joseph A. Paradiso, and Michael Haller. 2020. Sonoflex: Embroidered Speakers Without Permanent Magnets. In *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology* (Virtual Event, USA) *(UIST '20)*. Association for Computing Machinery, New York, NY, USA, 675–685. https://doi.org/10.1145/3379337.3415888

[46] Raquel B Robinson, Anya Osborne, Chen Ji, James Collin Fey, Ella Dagan, and Katherine Isbister. 2024. "That's Not Good Science!": An Argument for the Thoughtful Use of Formative Situations in Research Through Design. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI EA '24)*. Association for Computing Machinery, New York, NY, USA, Article 545, 8 pages. https://doi.org/10.1145/3613905.3644063

[47] Jennifer Ann Rode, Louise Barkhuus, and Andri Ioannou. 2024. Exploring Gender, Computational Making and E-Textiles using the BBC Micro:bit. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI EA '24)*. Association for Computing Machinery, New York, NY, USA, Article 554, 9 pages. https://doi.org/10.1145/3613905.3644056

[48] Jennifer A Rode, Yifan Feng, Annapoorni Chandrashekar, Sonia Andreou, and Andri Ioannou. 2024. Spools and Sparks: The Role of Materiality in Computational Making with E-textiles and BBC Micro:bit. In *Proceedings of the Halfway to the Future Symposium* (Santa Cruz, CA, USA) *(HttF '24)*. Association for Computing Machinery, New York, NY, USA, Article 28, 11 pages. https://doi.org/10.1145/3686169.3686182

[49] Jennifer A. Rode, Anne Weibert, Andrea Marshall, Konstantin Aal, Thomas von Rekowski, Houda Elmimouni, and Jennifer Booker. 2015. From computational thinking to computational making. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (Osaka, Japan) *(UbiComp '15)*. Association for Computing Machinery, New York, NY, USA, 239–250. https://doi.org/10.1145/2750858.2804261

[50] David Roedl, Shaowen Bardzell, and Jeffrey Bardzell. 2015. Sustainable Making? Balancing Optimism and Criticism in HCI Discourse. *ACM Trans. Comput.-Hum. Interact.* 22, 3, Article 15 (June 2015), 27 pages. https://doi.org/10.1145/2699742

[51] Olivia G Ruston, Adwait Sharma, and Mike Fraser. 2024. SeamSleeve: Robust Arm Movement Sensing through Powered Stitching. In *Proceedings of the 2024 ACM Designing Interactive Systems Conference* (Copenhagen, Denmark) *(DIS '24)*. Association for Computing Machinery, New York, NY, USA, 1134–1147. https://doi.org/10.1145/3643834.3660726

[52] Natalie Sontopski, Stephan Hildebrandt, Lena Marcella Nischwitz, Klaus Stephan, Albrecht Kurze, Lewis L Chuang, and Arne Berger. 2024. Wheel of Plush: A Co-Design Toolkit for Exploring the Design Space of Smart Soft Toy Materiality. In *Proceedings of the 2024 ACM Designing Interactive Systems Conference* (Copenhagen, Denmark) *(DIS '24)*. Association for Computing Machinery, New York, NY, USA, 2958–2971. https://doi.org/10.1145/3643834.3660744

[53] Jessica Stanley, John A Hunt, Phil Kunovski, and Yang Wei. 2022. A review of connectors and joining technologies for electronic textiles. *Engineering Reports* 4, 6 (2022), e12491. https://doi.org/10.1002/eng2.12491

[54] Lingyun Sun, Deying Pan, Yitao Fan, Yue Yang, Jiaji Li, Yu Chen, Ye Tao, and Guanyun Wang. 2022. JellyBoard: A Flexible Breadboard for Electronic Prototyping. In *Proceedings of the Ninth International Symposium of Chinese CHI* (Online, Hong Kong) *(Chinese CHI '21)*. Association for Computing Machinery, New York, NY, USA, 117–119. https://doi.org/10.1145/3490355.3490369

[55] Eldy S. Lazaro Vasquez and Katia Vega. 2019. Myco-accessories: sustainable wearables with biodegradable materials. In *Proceedings of the 2019 ACM International Symposium on Wearable Computers* (London, United Kingdom) *(ISWC '19)*. Association for Computing Machinery, New York, NY, USA, 306–311. https://doi.org/10.1145/3341163.3346938

[56] Anne Weibert, Andrea Marshall, Konstantin Aal, Kai Schubert, and Jennifer Rode. 2014. Sewing interest in E-textiles: analyzing making from a gendered perspective. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (Vancouver, BC, Canada) *(DIS '14)*. Association for Computing Machinery, New York, NY, USA, 15–24. https://doi.org/10.1145/2598510.2600886

[57] Ruhan Yang, Cody Candler, and Ellen Yi-Luen Do. 2020. EdBoard: an educational breadboard. In *Proceedings of the 2020 ACM Interaction Design and Children Conference: Extended Abstracts* (London, United Kingdom) *(IDC '20)*. Association for Computing Machinery, New York, NY, USA, 193–198. https://doi.org/10.1145/3397617.3397832

[58] Tianhong Catherine Yu, Manru Mary Zhang, Peter He, Chi-Jung Lee, Cassidy Cheesman, Saif Mahmud, Ruidong Zhang, Francois Guimbretiere, and Cheng

Zhang. 2024. SeamPose: Repurposing Seams as Capacitive Sensors in a Shirt for Upper-Body Pose Tracking. In *Proceedings of the 37th Annual ACM Symposium on User Interface Software and Technology* (Pittsburgh, PA, USA) *(UIST '24)*. Association for Computing Machinery, New York, NY, USA, Article 72, 13 pages. https://doi.org/10.1145/3654777.3676341

[59] Tianhong Catherine Yu, Manru Mary Zhang, Luis Miguel Malenab, Chi-Jung Lee, Jacky Hao Jiang, Ruidong Zhang, François Guimbretière, and Cheng Zhang. 2025. SeamFit: Towards Practical Smart Clothing for Automatic Exercise Logging. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 9, 1, Article 24 (March 2025), 22 pages. https://doi.org/10.1145/3712287

[60] Junyi Zhu, Lotta-Gili Blumberg, Yunyi Zhu, Martin Nisser, Ethan Levi Carlson, Xin Wen, Kevin Shum, Jessica Ayeley Quaye, and Stefanie Mueller. 2020. CurveBoards: Integrating Breadboards into Physical Objects to Prototype Function in the Context of Form. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376617

[61] Jingwen Zhu, Lily Winagle, and Hsin-Liu (Cindy) Kao. 2024. EcoThreads: Prototyping Biodegradable E-textiles Through Thread-based Fabrication. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '24)*. Association for Computing Machinery, New York, NY, USA, Article 857, 17 pages. https://doi.org/10.1145/3613904.3642718

[62] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '07)*. Association for Computing Machinery, New York, NY, USA, 493–502. https://doi.org/10.1145/1240624.1240704

[63] Amit Zoran. 2015. Hybrid craft: showcase of physical and digital integration of design and craft skills. In *ACM SIGGRAPH Art Gallery* (Los Angeles, California) *(SIGGRAPH '15)*. Association for Computing Machinery, New York, NY, USA, 384–398. https://doi.org/10.1145/2810185.2810187